The Mid-Atlantic Berry Guide

for Commercial Growers

2013–2014

Produced by The Pennsylvania State University in cooperation with Rutgers University, the University of Delaware, the University of Maryland, Virginia Tech, and West Virginia University.

ACKNOWLEDGMENTS

The Mid-Atlantic Berry Guide is intended to provide information for commercial berry growers within the region. Homeowners may use this publication for background information; however, many of the recommendations contained in this guide assume that the production is on a large scale and that producers have a commercial pesticide applicator's license.

Uses of pesticides listed in this publication were current as of July 1, 2012. However, changes in registration status may occur at any time, so please consult the label before use—the label is the law. If there are differences in use patterns between the pesticide label in your possession and those listed in this guide, follow the instructions on the label. If in doubt, consult your cooperative extension educator.

COORDINATOR

Kathleen Demchak, Senior Extension Associate, Department of Horticulture, Penn State

CONTRIBUTORS

Penn State

Kathleen Demchak, Senior Extension Associate, Department of Horticulture
Timothy E. Elkner, Senior Extension Educator, Penn State Cooperative Extension in Lancaster County
C. John Esslinger, Extension Educator, Penn State Cooperative Extension, Northeast Region
Maryann Frazier, Senior Extension Associate, Department of Entomology
Scott D. Guiser, Senior Extension Educator, Penn State Cooperative Extension in Bucks County
John M. Halbrendt, Associate Professor of Plant Pathology, Department of Plant Pathology
Jayson K. Harper, Professor of Agricultural Economics, Department of Agricultural Economics and Rural Sociology
Grzegorz Krawczyk, Senior Research Associate, Department of Entomology
Kerry M. Richards, Director, Pesticide Management Information Center

Rutgers University, New Jersey Agricultural Experiment Station

Joseph R. Heckman, Extension Specialist, Department of Plant Biology and Pathology
Bradley A. Majek, Extension Specialist, Department of Plant Biology and Pathology
Peter Nitzsche, County Agent, Rutgers Cooperative Extension of Morris County
Peter V. Oudemans, Associate Professor, Department of Plant Biology and Pathology
Gary Pavlis, County Agent, Rutgers Cooperative Extension of Atlantic County
Dean Polk, Statewide Fruit IPM Agent, Department of Agricultural and Resource Management Agents
Cesar Rodriguez-Saona, Assistant Extension Specialist, Department of Entomology
William J. Sciarappa, County Agent, Rutgers Cooperative Extension of Monmouth County
Daniel L. Ward, Assistant Extension Specialist, Department of Plant Biology and Pathology

The University of Delaware

Gordon C. Johnson, Extension Vegetable and Fruit Specialist and Assistant Professor, Department of Plant and Soil Sciences, Carvel Research and Education Center

The University of Maryland

Bryan R. Butler, Senior Agent, University of Maryland Extension in Carroll County
Joseph A. Fiola, Professor and Specialist in Viticulture and Small Fruit, University of Maryland Extension
Willie Lantz, Senior Agent, University of Maryland Extension in Garrett County

USDA-ARS, Beltsville, Maryland

Mark Ehlenfeldt, Research Geneticist, Genetic Improvement of Fruits and Vegetables Laboratory

Virginia Tech

Jeffrey F. Derr, Professor, Hampton Roads Agricultural Research and Extension Center
Charles Johnson, Professor and Extension Plant Pathologist, Southern Piedmont Agricultural Research and Extension Center
Douglas G. Pfeiffer, Professor, Department of Entomology
R. Allen Straw, Area Specialist, Southwest Virginia Agricultural Research and Extension Center
Keith S. Yoder, Professor of Plant Pathology, Alson H. Smith Jr. Agricultural Research and Extension Center

West Virginia University

Alan R. Biggs, Professor of Plant Pathology and Extension Specialist, Kearneysville Tree Fruit Research and Education Center
John W. Jett, Extension Specialist, West Virginia University Extension Service
Lewis W. Jett, Extension Specialist, West Virginia University Extension Service

Additional Contributors

Ed Mashburn, Northumberland, Pennsylvania, former President of The International Ribes Association
Harry Swartz, Five Aces Breeding, LLC

Past Contributors

This guide includes material from authors whose work appeared in earlier extension publications in the region or in earlier editions of this guide. These authors include John Baniecki, Ed Beste, Barbara Bowling, Tony Bratsch, Margaret Brittingham-Brant, Dewey Caron, Anne DeMarsay, Henry Hogmire, Win Hock, Ed Kee, Henry Ngugi, Jeremy Pattison, Sridhar Polavarapu, Pete Probasco, Ed Rajotte, Bob Rouse, Jo Rytter, Elsa Sánchez, Gary San Julian, Pete Shearer, Mike Stanghellini, Paul Steiner, Jim Travis, and Richard Zimmerman. Their contributions and work, which laid the groundwork for this version, are gratefully acknowledged.

Editor

Amanda Kirsten, Ag Communications and Marketing, Penn State

Designer

Nora Serotkin, Ag Communications and Marketing, Penn State

Illustrations and Photos

Illustrations, except Figure 7.2, by Ellen Lovelidge, Penn State. Figure 7.2 courtesy of Virginia Tech.
Blackberry flower and strawberry photos: Kathleen Demchak
Others: istockphoto.com

PENNSTATE

1855

Cooperative Extension
College of Agricultural Sciences

The Mid-Atlantic Berry Guide

CONTENTS

List of Tables and Figures ii

Chapter 1: Preplant Considerations 1

Chapter 2: Soil Management and Nutrition for Berry Crops 7

Chapter 3: Pesticides, Pesticide Safety, and Chemical Fumigation 15

Chapter 4: Weed Management 31

Chapter 5: Wildlife Damage Control in Commercial Plantings 41

Chapter 6: Strawberries 49

Chapter 7: Blueberries 115

Chapter 8: Brambles 171

Chapter 9: Gooseberries and Currants 225

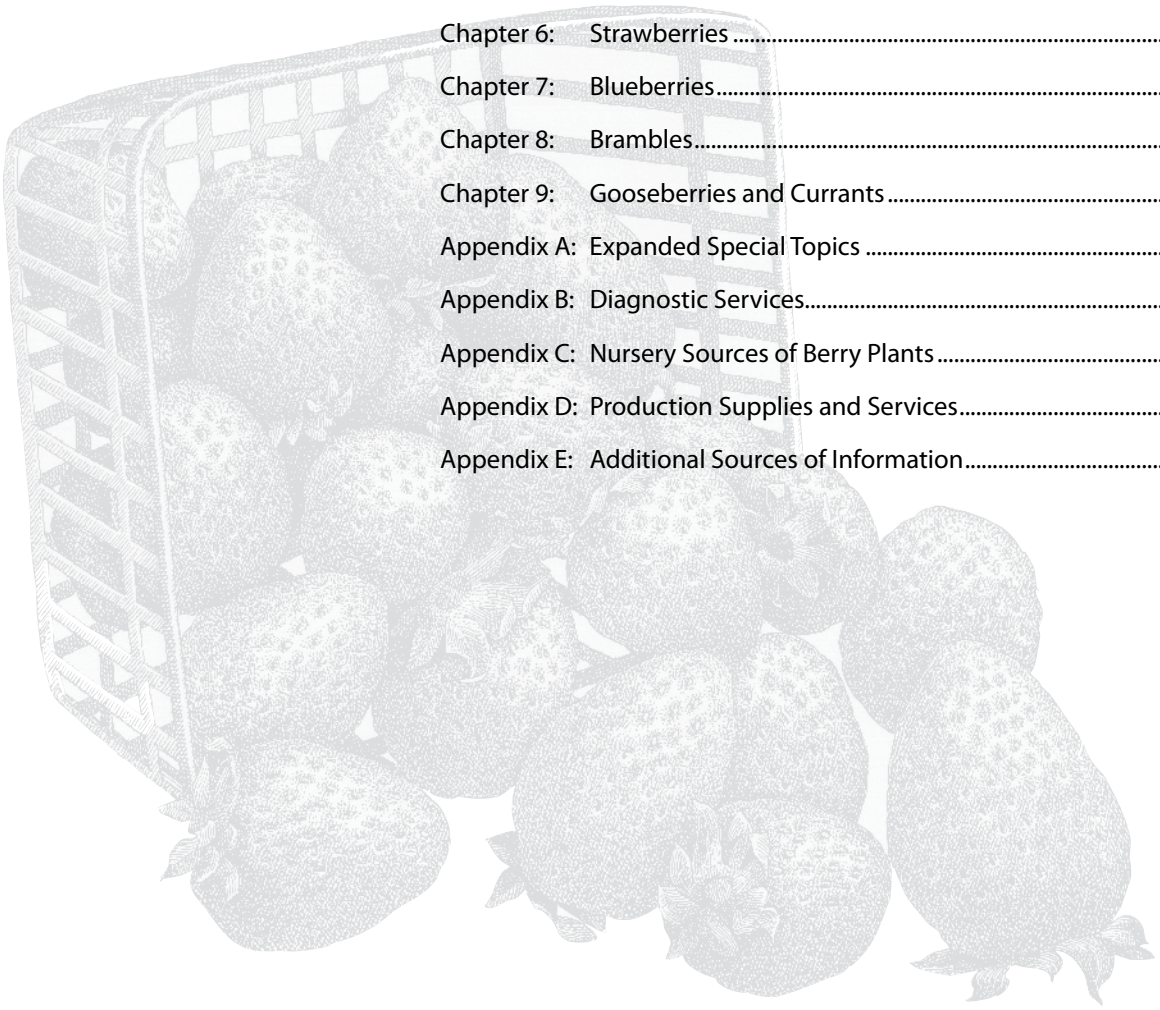
Appendix A: Expanded Special Topics 239

Appendix B: Diagnostic Services 247

Appendix C: Nursery Sources of Berry Plants 259

Appendix D: Production Supplies and Services 263

Appendix E: Additional Sources of Information 269



TABLES AND FIGURES

Chapter 2—Soil Management and Nutrition for Berry Crops.....7

Table 2.1. Pounds of lime with a CCE (calcium carbonate equivalent) of 100 needed per acre to maintain or raise the soil pH to 6.5. 8

Table 2.2. Green manure crops categorized by use, life cycle, and season. 13

Chapter 3—Pesticides, Pesticide Safety, and Chemical Fumigation 15

Table 3.1. Toxicity of pesticides to birds, fish, honey bees, and beneficial predators.....16

Table 3.2. General and restricted-use pesticides labeled for use on strawberries, brambles, blueberries, gooseberries, and currants 23

Table 3.3. Fumigants and spectrums of activity.....27

Chapter 4—Weed Management 31

Table 4.1. Weed susceptibility to herbicides.....34

Table 4.2. Herbicide water solubility and soil adsorption characteristics. 38

Chapter 6—Strawberries.....49

Table 6.1. Number of strawberry plants per acre for different in-row and between-row spacings 52

Table 6.2. Recommended fertilizer amounts for June-bearing matted-row strawberry plantings 53

Table 6.3. June-bearing matted-row strawberry cultivars.....54

Table 6.4. Recommended nutrients for annual plasticulture strawberry plantings.....58

Table 6.5. June-bearing strawberry cultivars for plasticulture production. 61

Table 6.6. Day-neutral strawberry cultivars.....65

Table 6.7. Summary of estimated costs per acre, 2011: year of land preparation for strawberries.....70

Table 6.8. Summary of estimated costs per acre, 2011: planting year for matted-row strawberries. 71

Table 6.9. Summary of estimated costs per acre, 2011: mature planting of matted-row strawberries. 72

Table 6.10. Returns to risk and management for matted-row strawberries, 2011 72

Table 6.11. Summary of estimated costs per acre, 2011: planting year for strawberry plasticulture. 73

Table 6.12. Summary of estimated costs per acre, 2011: mature planting for strawberry plasticulture. 74

Table 6.13. Returns to risk and management for plasticulture strawberries, 2011 .....

Table 6.14. Activity groups and effectiveness of fungicides for strawberry disease control.....87

Table 6.15. Activity groups and effectiveness of insecticides, miticides, and molluscides on strawberry pests.....88

Table 6.16. Pesticides for strawberry disease and insect control. 89
Table 6.17. Additional restrictions on strawberry fungicides and insecticides. 100
Table 6.18. Per-acre rates per application for preemergence (residual) herbicides for common soil types for strawberries 106
Table 6.19. Herbicides for matted-row strawberry weed control 107

Figure 6.1. The strawberry plant. 50
Figure 6.2. Arrangement of strawberry blossoms on fruit truss. 51
Figure 6.3. Common strawberry leaf diseases. 76
Figure 6.4. Tarnished plant bug adult. 79
Figure 6.5. Strawberry sap beetle adult. 79
Figure 6.6. Picnic beetle adult. 80
Figure 6.7. Potato leafhopper adult. 82

Chapter 7—Blueberries 115

Table 7.1. Amount of sulfur required to lower the soil pH. 118
Table 7.2. Number of blueberry plants required per acre at various spacings 118
Table 7.3. Relevant characteristics of various cover crops for row middles. 123
Table 7.4. Seeding rates and requirements for various seasonal and permanent cover crops for row middles. 124
Table 7.5. Postplant nitrogen recommendations for blueberries. 124
Table 7.6. Summary of estimated costs per acre, 2011: year of land preparation for blueberries. 127
Table 7.7. Summary of estimated costs per acre, 2011: planting year for blueberries. 128
Table 7.8. Summary of estimated costs per acre, 2011: year after planting for blueberries 129
Table 7.9. Summary of estimated costs per acre, 2011: mature planting for blueberries. 130
Table 7.10. Returns to risk and management for blueberries, 2011 131
Table 7.11. Activity groups and effectiveness of fungicides for blueberry disease control 141
Table 7.12. Activity groups and effectiveness of insecticides and miticides on blueberry pests 142
Table 7.13. Pesticides for blueberry disease and insect control 143
Table 7.14. Additional restrictions on blueberry pesticides 152
Table 7.15. Crop safety of blueberry herbicides. 156
Table 7.16. Herbicide water solubility and soil adsorption characteristics 157
Table 7.17. Per-acre rates per application for preemergence (residual) herbicides for common soil types for blueberries 158
Table 7.18. Herbicides for blueberry weed control 164

Figure 7.1. Types of buds on blueberry. 125
Figure 7.2. Blueberry bush before and after pruning. 125
Figure 7.3. Blueberry maggot adult. 134
Figure 7.4. Cherry fruitworm adult. 135
Figure 7.5. Cranberry fruitworm adult. 136

Chapter 8—Brambles 171

Table 8.1. Number of bramble plants per acre at different spacings. 178
Table 8.2. Postplant nitrogen recommendations for brambles (lbs N/acre). 179
Table 8.3. Summary of estimated costs per acre, 2011: year of land preparation for summer-bearing red raspberries or thornless blackberries. 186
Table 8.4. Summary of estimated costs per acre, 2011: planting year for summer-bearing red raspberries. 187
Table 8.5. Summary of estimated costs per acre, 2011: year after establishment for summer-bearing red raspberries. 188
Table 8.6. Summary of estimated costs per acre, 2011: mature planting of summer-bearing red raspberries. 189
Table 8.7. Summary of estimated costs per acre, 2011: year of establishment for thornless blackberries. 190
Table 8.8. Summary of estimated costs per acre, 2011: year after establishment for thornless blackberries. 191
Table 8.9. Summary of estimated costs per acre, 2011: mature planting of thornless blackberries. 192
Table 8.10. Returns to risk and management for red raspberries, 2011 193
Table 8.11. Returns to risk and management for blackberries, 2011 193
Table 8.12. Bramble disease control strategies. 206
Table 8.13. Activity groups and effectiveness of fungicides for bramble disease control 207
Table 8.14. Activity groups and effectiveness of insecticides and miticides on bramble pests 207
Table 8.15. Pesticides for bramble disease and insect control. 208
Table 8.16. Additional restrictions on bramble pesticides 213
Table 8.17. Crop safety of bramble herbicides 215
Table 8.18. Bramble herbicide water solubility and soil adsorption characteristics 216
Table 8.19. Per-acre rates per application for preemergence (residual) herbicides for common soil types for raspberries and blackberries 217
Table 8.20. Herbicides for bramble weed control 219

Figure 8.1. Pruning red raspberries. 181
Figure 8.2. Pruning black raspberries. 182
Figure 8.3. Supported hedgerow trellis. 183
Figure 8.4. T or Lincoln trellis. 183

Figure 8.5. V trellis. 183
Figure 8.6. Raspberry crown borer adult. 203
Figure 8.7. Rednecked cane borer adult. 203
Figure 8.8. Raspberry cane borer adult. 203

Chapter 9—Gooseberries and Currants 225

Table 9.1. Pesticides for *Ribes* disease and insect control. 236

Appendix A—Expanded Special Topics 239

Table A.1. Critical temperatures for cold damage of flower buds based on stage of development. 239
Table A.2. Approximate dew points calculated from air temperature and relative humidity values. 240
Table A.3. Recommended temperatures for starting irrigation at various critical temperatures and dew points. 241
Table A.4. Irrigation application rates (inches/hour) for adequate protection of strawberries at various air temperatures, wind speeds, and relative humidity levels. 243
Table A.5. Sample two-year preplant soil conditioning program. 245

CHAPTER 1

Preplant Considerations

CONTENTS

Introduction 1
Economics and Marketing 1
Site Selection 1
Soil Type, Structure, and Drainage 1
Air Drainage 2
Wind Exposure 2
Row Orientation 2
Availability of Irrigation Water 2
Field Borders 2
Crop Rotation 2
Determining Whether Fumigation Is Warranted 3
Sampling for Nematodes 3
Choosing a Source of Plants 4
Organic Production 4

INTRODUCTION

Although berry production can be very profitable, berry crops require intensive management and a significant investment of time and resources. Depending on the crop, berry plantings remain productive for varying lengths of time, from as little as 1 to 2 production years for plasticulture strawberries to up to 50 years for blueberries. Good preplant management decisions will benefit the grower throughout the life of a planting, but, alternatively, the grower may have to endure the consequences of early mistakes for many years. Therefore, a significant amount of planning should be done before planting a berry crop. Consideration should be given to both growing and marketing the crop in order to ensure profitability over the long run.

ECONOMICS AND MARKETING

While most of the information in this production guide is intended to help with producing specific berry crops, growers can stay in business only if their operations are profitable. Within each crop's chapter, enterprise budgets are included that outline expected expenses and potential income based on typical costs, technology, and management for the 2011 crop year. The information contained in these enterprise budgets can be used by agricultural producers, extension specialists, researchers, financial institutions, governmental agencies, and others for making decisions in the food and fiber industry.

Small fruit production has the potential to generate significant income on small acreages and limited-resource farms. This profit potential, however, comes with a considerable amount of risk. Unfortunately, it is not uncommon to lose a crop due to frost or disease. Crop insurance is not available for individual berry crops, but whole-farm revenue protection can be obtained through the use of adjusted gross revenue insurance (either AGR or AGR-Lite). Initial investment is high, and substantial annual cost of production requires you to be able to financially weather annual cash flow demands (and the costs associated with preproductive years in fruit crops). Availability of labor, especially for harvest, is another major consideration.

You must be prepared not only to produce a high-quality crop, but also to be an active and aggressive marketer. Before the plants go in the ground, new and established growers alike should develop a marketing strategy for the planned crop. Even well-established operations will need to adjust to changing costs and markets. The marketing plan should consider who your current and potential customers are or will be and how the berries will be sold (pick-your-own, ready-picked for your own market, or wholesale). Consider the demographics of your area. Are a sufficient number of consumers nearby to purchase your fruit? If not, can they be attracted to your location? How will you let potential customers know about the availability of your product? Do you want to produce and market your fruit as organic? Will you market during the main season for each crop or at off-peak times of the year? It is important to carefully consider these aspects before you choose a planting site and begin making major investments in plants and irrigation systems.

SITE SELECTION

When choosing a suitable site, you need to consider and, in some instances improve, many characteristics. These include soil type, fertility, structure and drainage, previous crops and rotations, air drainage and wind exposure, field access, and surrounding crops and/or field borders. Each of these topics is discussed in greater detail as they apply to individual crops and pests in later chapters; general considerations that apply to all berry crops are briefly discussed below.

SOIL TYPE, STRUCTURE, AND DRAINAGE

Growers may not be able to change the soil type (sand, silt, or clay) on their farms, but they can improve its structure, primarily through practices that improve the organic matter content. Berry crops generally perform best in sandy soils; however, a high organic matter content (minimum of 2 percent; 5 percent preferred) can do much for improving plant growth, even in a heavy clay soil.

Small fruit crops grow best on a site with well-drained soil because of their susceptibility to a number of root rots. On sites where internal soil drainage is marginal, small fruit crops have been grown with better success on raised beds where excess water can drain away from the root zone. Tile drainage can provide some benefits as well. Wet sites should be avoided.

AIR DRAINAGE

Select sites with good air drainage. Air drainage refers to a slow movement of air through the planting site due to differences in air temperature and air density. This is not to be confused with wind exposure, where plantings are exposed to high-velocity winds. Good air drainage reduces the potential for frost damage—a serious problem with strawberries and, less frequently, with blueberries. It also promotes drying and less humidity within the planting, which in turn reduces the potential for problems with foliar and fruit diseases.

WIND EXPOSURE

Constant winds can desiccate plantings, especially over the winter. Additionally, while pollination is aided by wind in small fruit, the stigma, a female flower part, can dry and become unreceptive to pollen quickly in hot, dry winds. Protected sites should be selected, or protection should be provided by planting windbreaks or using other means for moderation. In general, 8 feet of wind protection occurs for each foot of vertical height of the windbreak. If a living windbreak is planted, the plant species used should not readily sucker or produce seed. Options besides windbreaks to minimize damage from wind exposure are floating row covers with plasticulture strawberries; straw (or snow in some locations) for matted-row strawberries; and trellising for brambles to minimize cane breakage.

ROW ORIENTATION

Recommendations are often given to orient rows north to south, or to orient rows with the prevailing wind. In practice, however, these two recommendations often conflict with each other. North-to-south rows intercept sunlight more evenly than east-to-west rows; hence, sunscald is less problematic and fruit ripens more evenly. Rows that run with the wind will dry more quickly than those that block the wind. The best orientation for each site will vary. For example, a grower on a level breezy site with prevailing winds from the west may decide to orient the rows east to west, while a grower on a protected site with little wind may prefer north-to-south rows. There are other aspects to consider as well, such as slope and soil erosion potential, which may override other considerations. On sloping sites, rows should run across the slope.

AVAILABILITY OF IRRIGATION WATER

Berry crops have relatively shallow root systems and, consequently, are sensitive to moisture stress during dry spells. In addition, the need for frost protection with strawberries and blueberries makes overhead irrigation capability highly desirable for consistent year-to-year production. Sites with an ample water supply are much better suited to small fruit production than those without access to water, especially considering the value of the crops and potential income lost due to moisture stress or frost damage.

FIELD BORDERS

Uncultivated land and certain crops bordering small fruit crops can be sources of pests and pathogens. These include strawberry clipper beetles from woodlots and fencerows; plant bugs, spittlebugs, and leafhoppers from various forages; Japanese beetles from sod; and sap beetles from various fruits and vegetables. In addition, viruses and orange rust fungus from wild or abandoned small fruit crops can infect new plantings. While eradicating wild berry plants may not be possible, any measures that can be taken to keep plantings as far from wild plants as possible will be helpful. These problems and their management are discussed in detail in crop-specific chapters.

CROP ROTATION

Which crop(s) precede a berry crop can make the difference between having a healthy planting and having a disaster. Certain crops can encourage a buildup of pathogens to which berry crops are susceptible. Other crops have beneficial effects. Previous annual field crops may have residual herbicide carryover, which can damage new berry plantings.

Problematic Preceding Crops

Certain soilborne pathogens that infect many small fruits can build up in association with other crops. Among the most widespread and commonly troublesome of these problems are plant-parasitic nematodes (microscopic eelworms that parasitize plant roots), especially dagger (*Xiphinema* spp.) and lesion (*Pratylenchus* spp.) nematodes. These nematodes feed on many species of plants including previous small fruit and tree fruit crops, legumes such as clover, alfalfa, and vetch, and weeds. Dagger nematodes vector the tomato ringspot virus (TmRSV) to small fruit crops. All sites should be checked for potentially damaging populations of plant-parasitic nematodes 1 to 2 years before planting, when steps to reduce these pathogens can be more easily taken. If high populations of plant-parasitic nematodes are found, special rotational crops (for dagger nematodes) or soil fumigation are usually required to reduce damaging populations (see Chapter 3 for more information on management options). General information on sampling for nematodes is presented in later sections of Chapter 1; Appendix B contains sampling instructions and information specific to various labs to which samples can be sent.

In addition to nematodes, fields previously planted to tomato, potato, tobacco, eggplant, pepper, cucurbits, and some strawberry, black raspberry, and blackberry cultivars may have well-established populations of the verticillium wilt fungus. Fields previously planted to strawberries may have high populations of the soilborne fungus *Phytophthora fragaria,* which causes red stele or other root-rotting diseases. Fields planted to other fruit may harbor other *Phytophthora* species.

Small fruit crops should not be planted immediately after a heavy sod, as the plants may suffer severe root damage caused by high populations of white grubs (large, fleshy, C-shaped larvae of June beetles and other species of beetles) feeding on the roots. If a sod-covered area must be used, plant corn or a small grain for at least 1 year

before planting strawberries, use the rapeseed rotation with plow down outlined in Appendix A, or treat with a preplant insecticide. In addition to potential problems with high grub populations, grass can become a serious weed problem in strawberry plantings, as can other certain species. Avoid sites heavily infested with sedge, nutgrass, quackgrass, Johnsongrass, and/or thistles, or treat with systemic herbicides before planting. Cover cropping with certain cover crops for 1 to 2 years before planting is also a good way to reduce weed species at a given site.

Finally, raspberries are particularly susceptible to crown gall disease (caused by the bacterium *Agrobacterium tumefaciens)*. Sites with a history of crown gall are best used for other less-sensitive crops such as strawberries, blueberries, and vegetables. Soil fumigation is not generally effective in eliminating a crown gall problem.

Planting in areas where field crops, particularly field corn and soybeans, were previously grown takes advantage of residual fertility and weed control, but beware of possible herbicide carryover that can seriously damage newly set fruit plants. Tissue culture–produced plants are particularly susceptible to any residual herbicide. A bioassay to test for safety can be conducted by germinating seedlings of a susceptible crop in soil from the field to be used (see Appendix A for details on steps to follow).

Desirable Preceding Crops

Small-grain crops such as oats, rye, and wheat are good choices for the year or two before planting, as they increase organic matter while supporting few of the pests that can attack small fruit plantings. Field and sweet corn, due to herbicides that can be used in corn production, can afford an opportunity to control problem weeds in a field, but herbicide carryover can be a problem. If triazine herbicides were used, a bioassay should be done to test for residual herbicide before planting a berry crop (see Appendix A for information on how to do this). Plants in the grass family (small grains and corn) do not become infected with crown gall or TmRSV. Pumpkins and other vine crops have few pests in common with berry crops, with the exception of nematodes and verticillium wilt on susceptible cucurbit cultivars. Sudangrass or sorghum/sudangrass hybrids can do much to increase soil organic matter content. Cover crops and green manures that can be used in rotations are discussed in detail in the following chapter on soil management and nutrition.

DETERMINING WHETHER FUMIGATION IS WARRANTED

In most cases, small fruit crops can be successfully grown without fumigation. Fumigation is not routinely recommended in the Mid-Atlantic region when long crop rotations can be used for disease, insect, and weed management. Long rotations provide opportunities to minimize many problems during the growth cycle of other crops. Beneficial practices such as selecting cultivars with disease resistance and maintaining a high organic matter content can also contribute substantially toward making fumigation unnecessary. However, in some cases, such as when a grower has limited acreage, long rotations are not possible.

When fruit sites are replanted to fruit crops, the plants often show signs of early plant decline or fail to reach their full productive level. Physical and biological reasons cause such poor performance. Small fruit crops are perennial, and populations of soilborne plant pathogens and plant-parasitic nematodes can increase over time in and around the plant root zone. On new sites with low populations of plant pathogens, plants have a window of several years before pathogen populations reach damaging levels as long as clean planting stock is used. On old fruit sites or other sites with high populations of pathogens and plant-parasitic nematodes, however, the roots of newly set fruit plants come under attack early, shortening the productive life of the planting. In addition, soil compaction with resultant decreased internal water drainage adds to the stress on perennial plants over time. This is especially true for many small fruit crops where the root zone is fairly shallow. For this reason, when old sites are replanted, fumigating first is often necessary to destroy the established soil ecosystem, along with its established population of organisms that feed on berry plants. This can mean chemical fumigation or—in the case where dagger nematodes are the only problem—biofumigation using certain green manure crops. Once this is accomplished, newly set plants can establish themselves. Chemical fumigation is discussed in Chapter 3. Some environmentally friendly alternatives to fumigation, and the topic of biofumigation, are discussed in the chapter on soil management and nutrition. When high nematode populations are suspected, test soil for nematodes as described below.

SAMPLING FOR NEMATODES

Nematode assay packets are available from locations listed in Appendix B. Since nematodes are usually not uniformly distributed in a field, you should follow a carefully prescribed sampling procedure to obtain root and soil samples representative of the area surveyed. Samples can be taken anytime, as long as the soil is moist and the temperature is above 40°F. If there has been a prolonged dry spell, or if the soil has been saturated with water for an extended period, wait until normal soil moisture conditions return before sampling. To take samples, follow these steps.

If the area to be sampled is fairly uniform and not too large (less than one acre), one composite sample will suffice. If the area is larger, divide the site into smaller sections of approximately equal size and take composite samples from each block. Keep in mind that the smaller the area sampled, the more accurately the sample will represent the site.

In each field to be assayed, take a sample from each area that has a common cropping history and that will be planted with a single crop. For example, if a one-acre field is to be planted with strawberries and if half the field was in pumpkins last season and the rest was fallow, collect a sample from each area.

If the soil in the area to be sampled is variable, such as being composed of a heavy clay soil in one portion and a sandy soil in another, take one composite sample from each soil type.

Preferably using a 1-by-12-inch sampling tube (or a trowel, small shovel, or similar tool if a sampling tube is unavailable), take at least 20 cores of soil from each sampling area. Samples should be taken to a depth of 8 to 10 inches.

Soil samples should be taken from the area where the feeder roots are found. Therefore, if a crop is present, take samples from within the rows and avoid the row middles.

Do not sample from dead or nearly dead plants. Nematodes feed on live roots and may migrate away from dying plants. Therefore, when sampling problem areas, take samples from adjacent plants that either appear healthy or show early symptoms of stress.

Handling Nematode Samples

Samples must be properly handled and shipped to ensure that the nematodes remain alive until they are processed in the laboratory. Make certain to include all the information requested on the nematode assay form that you receive with the assay packet. This information is needed for identifying the sample and helping to interpret assay data. If you collect more than one sample, you must assign a field number to each area sampled and place that number in the appropriate area of the form. Each plastic bag should be sealed tightly by tying it with a twist tie. A separate assay packet must be used for each composite sample.

Keep samples out of direct sunlight to avoid overheating. Samples may also be damaged by heat if they are stored in the trunk of a car or other hot location. Use a Styrofoam cooler to keep samples cool. Heat kills nematodes, and dead nematodes are unsuitable for identification. When the assay forms are completely filled out and the plastic bags are sealed, place the samples in a suitable container and send or bring them promptly to your closest nematode diagnostic lab (see Appendix B for addresses). Delivery within 1 to 2 days is imperative.

If results from the nematode test indicate that control is warranted, one option is to use biofumigation with a green manure crop as described in Chapter 2. A step-by-step description of a more involved two-year biofumigation protocol is found in Appendix A: Expanded Special Topics. A second option is to use chemical fumigation. The latter may be warranted especially when soilborne diseases or weeds are a problem as well.

CHOOSING A SOURCE OF PLANTS

The most important decisions affecting the profitability of fruit operations are made before planting. The quality of the plants purchased is important. Plants labeled or sold as "registered" stock, available from nurseries in a few states, are grown from tested virus-free parent plants in isolation under supervision from each state's Department of Agriculture. When available, these plants are best for any long-term investment. Plants sold as "certified" are good, but they are not the same as registered stock. Certified stock is grown under state supervision and is inspected and found to be free of most diseases and insects, but the plants may still harbor some viruses, diseases, or insects. Plants propagated from your own fields or other unsupervised sources, even when they appear healthy, are a risky choice because they may be symptomless carriers of viruses, pathogenic fungi, insects, and bacteria. Given the cost of establishing the planting and potential profit that can come from a healthy planting, choosing a certain plant source because it is the cheapest option is often a poor way to try to save money. Nursery sources for small fruit plants are listed in Appendix C.

ORGANIC PRODUCTION

Organic produce is currently the fastest-growing market segment in produce sales. If produce is to be grown organically, many factors need to be considered long before planting begins.
Initial investment in organic production is high due to certification costs and increased time and labor for management; however, returns can be on average 10 to 20 percent higher than on conventionally produced products, provided that a premium market can be identified.

The U.S. Department of Agriculture (USDA) regulates the term "organic." To become certified organic, growers must follow production and handling practices contained in the National Organic Standards (NOS) and must be certified by a USDA-accredited certifying agency. Growers whose annual gross income from organic products is $5,000 or less can be exempted from certification. In this case growers must continue to use production and handling practices in accordance with the NOS, and some restrictions regarding labeling and combination with other organic products apply. Certified organic production is typically preceded by a three-year transition phase during which prohibited materials cannot be used. If prohibited materials have not been applied to an area, the transition phase may be less than three years.

Consider the following questions before initiating organic production:

1. Does a market for organic berries exist in your area?
2. Are adequate resources and materials available to produce an organic crop, particularly in the area of pest and fertility management?
3. Are you willing to devote more time to monitoring pests?
4. Are you willing to devote more time to managing soil fertility?
5. Are you willing to devote more time to record keeping?

If you answered "yes" to all of the above, organic production may be for you.

Organic, sustainable, and conventional small fruit growers use many of the same management practices. However, for organic growers some management practices may differ in following the new production and handling requirements contained in the NOS (the standard can be viewed at **www.ams.usda.gov/AMSv1.0/nop**). Also, the importance of cultural controls is amplified in organic production, and maintenance of soil fertility requires more planning compared to conventional production. This topic is discussed more fully in the next chapter.

Growers beginning the transition from nonorganic to organic production may wish to consider a pretransition phase if pest pressures are high in the planting area. A pretransition phase is a cross between organic and nonorganic production. During this phase, conventional pesticides are used along with

organic tactics to reduce pest pressures. Once pest pressures are reduced, organic pest-management measures are used exclusively.

Growers may market berries from wild plantings as organic, providing prohibited products (see **www.ams.usda.gov/AMSv1.0/nop**) have not been applied to the planting in the three years prior to harvesting. Also, the berries must be harvested so that the environment is not harmed and the planting will grow and produce berries in subsequent years. Consult local and state regulations concerning gathering berries from property that is not privately owned.

CHAPTER 2

Soil Management and Nutrition for Berry Crops

CONTENTS

Introduction 7
Meeting the Crop's Nutrient Requirements 7
Soil Testing 7
Soil pH and Adjustment 7
Use of Inorganic Fertilizers 8
Adding Nutrients with Composts and Manures 9
Value of Organic Matter 11
Biofumigation: Managing Dagger Nematodes with Green Manures 13
Which Rapeseed Varieties to Plant 13
Keeping Your Nutrient Program on Track: Plant Tissue Analysis 13
Nutrient Management Plans 14

INTRODUCTION

Maintaining a productive soil is fundamental to growing a healthy crop. Soil fertility programs should optimize nutrient availability with long-term management in mind. The first step to understanding your soil is to conduct a soil test. From this test, key factors such as soil pH, phosphorus, potassium, and micronutrient levels can be determined, as well as organic matter content. Early adjustments in nutrients and organic matter levels are critical to success and are made through the application of liming materials, fertilizers, composts, animal manure, and/or growth of a green manure crop. It is much more effective, and often safer for the plants, to incorporate most granular or powdered materials, with the exception of nitrogen fertilizers, into the root zone prior to planting rather than applying them to the surface after planting. Throughout the life of the planting, soil nutrient levels should be adjusted using the information obtained from tissue tests and subsequent soil tests.

MEETING THE CROP'S NUTRIENT REQUIREMENTS

SOIL TESTING

A soil sample should be obtained and analyzed at least a year prior to planting blueberries and at least 6 months prior to planting other berry crops. If a green manure crop will be grown prior to planting the berry crop, a preliminary sample can be submitted to obtain fertilizer recommendations for the green manure crop, with a later sample submitted for the berry crop. Making adjustments according to the soil test before planting brings initial soil nitrogen, phosphorus, potassium, calcium, and magnesium to appropriate levels. In particular, applications of phosphorus (phosphate or P_2O_5) and potassium (potash or K_2O) and the adjustment of pH are needed to optimize the growth of plants. A soil test is the only way to accurately determine the pH level and lime or sulfur requirement. In sandy soils, or on sites where strawberries will be planted, also check boron levels. Samples should be representative of the planting site, consisting of combined subsamples from the entire area. Distinct geographical areas or known soil type variations within the site should be sampled separately. Sample to a depth of at least 8 inches and be careful not to expose your soil sample to cardboard glue, as some glues may contain boron and can contaminate the sample, resulting in inaccurate results. After plant establishment, tissue testing in conjunction with soil testing is recommended as the primary means of guiding nutrient adjustments.

General information on nutrient application is presented below, with information provided on both inorganic fertilizer application and application of nutrients through the use of composts and manures. Additional information specific to individual crops (such as with plasticulture strawberries and blueberries) is presented under "Nutrition" in individual crop chapters.

SOIL PH AND ADJUSTMENT

The pH level of soil can affect the availability and uptake of mineral nutrients. Strawberries, raspberries, and Ribes (gooseberries and currants) prefer a soil pH of 6.0 to 6.5, while blueberries perform best in soil with a pH of 4.5 to 5.0.

Raising the Soil pH: Liming

The amount of lime required to adjust the soil pH is based not only on the original pH of the soil, but also on the buffering capacity of the soil and the target pH for each crop. This buffering capacity is higher in soils with higher amounts of clay and organic matter, so different soils will require different amounts of lime to produce the same pH change. Therefore, conducting a soil test is the most accurate way to determine the lime requirement of a given soil. However, in the event that a soil sample is not submitted, ballpark amounts of lime required for raising the soil pH to 6.5 are given in Table 2.1.

If magnesium levels are already sufficient, calcitic lime should be used to raise the pH. However, when magnesium is low, dolomitic limestone can be used. Growers commonly assume that dolomitic limestone is the best material to use in either case, providing extra magnesium as a bonus in addition to adjusting the pH. However, potassium deficiency commonly occurs with small

fruit crops in the Mid-Atlantic region—even on soils with adequate potassium—which is usually caused by competition between magnesium and potassium ions for uptake. Applying dolomitic lime when magnesium is already sufficient in the soil aggravates this situation. Excessive liming, regardless of source, can increase the soil pH beyond what is recommended and result in suboptimal plant growth and development. This is partly because the availability of many nutrients is limited at high pH levels. For example, overliming (and excessive soil phosphorus levels) can tie up zinc, making it unavailable to the plant. If soil tests indicate that more than 4,000 pounds (2 tons) per acre of lime are needed, apply half of the total requirement in each of two successive years before planting rather than in large amounts in a single season. Lime does not move well through the soil profile, so the soil must be worked thoroughly to ensure even distribution in the root zone.

Lowering the Soil pH: Adding Sulfur

Typically, the pH needs to be lowered only when a crop such as blueberries is being grown. However, occasionally, the pH also needs to be lowered when overliming has taken place. Sulfur is the material most commonly used, either in the pure form of a powder (ground sulfur, also called elemental sulfur) or as a salt such as iron sulfate. A table of sulfur amounts needed to lower the pH to various levels is contained in the blueberry chapter. If iron sulfate is used to lower the soil pH, more material will be needed to have an equivalent effect (see Chapter 7 for further details). Ammonium sulfate, when used as a nitrogen source, is also effective in maintaining and sometimes decreasing a low soil pH. Aluminum sulfate is frequently sold but should be avoided for large pH changes due to potential aluminum toxicity.

The amount of time required to lower the soil pH varies with the acidifying material used. The reaction of elemental sulfur (also known as ground or powdered sulfur) with the soil is dependent on soil microorganisms, which are not active until soil temperatures warm in the spring. Thus, elemental sulfur applied in the fall may have little effect in lowering the soil pH until the following year. Reactions with sulfate forms such as iron sulfate do not require soil microorganisms for acidifying effects to take place. Additional details on the processes and effects of soil acidification are presented in Chapter 7.

USE OF INORGANIC FERTILIZERS

Nitrogen, phosphorus, potassium, calcium, and magnesium are the elements required in the highest quantities in small fruit plantings and need to be added most frequently. Manganese, iron, copper, and zinc, among others, are taken up in much smaller quantities and, unless a tissue test indicates low levels, do not need to be added. In certain situations, boron, which is easily leached from the soil, should be monitored and added routinely.

Nitrogen is the primary element required for vegetative growth. Soil nitrogen tests have not correlated well with plant growth. This is because soil nitrogen is present in several different forms, which are in constant states of flux, and only a small proportion is in forms available to the plants at any given time. Nitrogen requirements after planting are best determined by tissue analysis. Also, plant vigor provides many clues to nitrogen levels. If plants are not growing as vigorously as they should be and are an even light green, nitrogen deficiency should be suspected. As with liming, excessive nitrogen fertilization can lead to production problems, including greater susceptibility to diseases and winter-kill.

Phosphorus is especially important during the early establishment years. Because its mobility in the soil profile is limited, phosphorus should be worked well into the rooting zone prior to planting. Surface applications later in the life of the planting generally have little impact and are either bound to the surface or washed away by heavy rains. Excess phosphorus application can result in deficiencies of micronutrients, especially zinc, in small fruit crops and also contributes to eutrophication of waterways.

Potassium moves into the fruit in relatively large quantities during ripening and, therefore, is readily lost through harvesting and by leaching through the soil beyond the root zone. Additional potassium amendments are often part of a fertility maintenance program. Potassium uptake can be negatively affected by high calcium and, especially, magnesium levels. Consequently, an excess of any one of these elements can cause the others to appear deficient.

Soil calcium levels are generally sufficient for berry crops within the region, as long as the soil pH is in the correct range. Adjustments of pH through the use of lime provide additional calcium beyond that already present in the soil. Calcium deficiencies—when they do occur—are often more likely due to dry soil conditions or an uneven moisture supply, especially when plants are growing rapidly, rather than a true calcium deficiency in the soil. Calcium deficiency symptoms on strawberry leaves (appearing as a tipburn), for example, most frequently appear during dry spells in the spring. This problem can be made worse by high relative humidity. This is because calcium moves into the plant with moisture flow, and when water isn't moving evenly into the plant, calcium uptake is negatively affected. In the unusual situation where

Table 2.1. Pounds of lime with a CCE (calcium carbonate equivalent) of 100 needed per acre to maintain or raise the soil pH to 6.5.

	Soil Texture				
Initial Soil pH	Loamy Sand	Sandy Loam	Loam	Silt Loam	Clay Loam
4.1–4.4	4,500	5,400	9,800	11,600	23,300
4.5–4.8	3,600	4,500	8,100	9,800	18,800
4.9–5.2	2,700	3,600	6,300	8,100	15,200
5.3–5.6	1,800	2,700	4,500	6,300	12,500
5.7–6.0	900	1,800	3,600	4,500	8,100
6.1–6.4	500	900	1,800	3,600	5,400
Above 6.5	0	0	0	0	2,700

calcium needs to be added without raising the soil pH, gypsum (calcium sulfate) can be used.

Magnesium levels are generally sufficient in the soil for strawberry and bramble production within the Mid-Atlantic region. However, magnesium is frequently deficient for blueberries in "upland soils" where soil calcium levels are often too high for optimum blueberry production. In situations where magnesium needs to be added and the soil pH is sufficient or shouldn't be raised, Epsom salts (magnesium sulfate) or Mag-Ox can be used.

Boron levels should be above 1½ pounds per acre (¾ ppm in the soil) in sandy soils for any berry crop, or in any soil planted to strawberries. Ten pounds of boron per acre (5 ppm in the soil) is toxic to most fruit plants. If boron is deficient, mix boron with your fertilizer, and soil incorporate the mixture before planting. There is a very narrow range between boron deficiency and boron toxicity, so when applying boron, be sure that the rate applied is accurate across the entire field. If boron deficiency is suspected after planting and a tissue test confirms the diagnosis, correct the deficiency with either a Solubor foliar spray at bloom or a topdressing to the soil in the fall. A foliar spray is preferred, as the likelihood of inaccurate application is less. Very small amounts (4/5 pound of actual boron (B) per acre to the soil, or 1/3 pound per acre to the foliage) are sufficient to correct most deficiencies. Maintain healthy root growth through the summer to facilitate boron uptake. Note, too, that boron is less available to plants at soil pH levels above 6.0 to 6.5. Under marginally deficient conditions, foliar applications of phosphorus can precipitate boron in the tissues, causing a deficiency, which in turn can result in significant crop loss.

Additional Considerations for Organic Growers

In organic production, maintenance of soil fertility is primarily managed by reliance on nutrient cycling (i.e., slow nutrient release from plant, animal, and mineral sources). However, commercial "fertilizers" derived from natural sources that meet the requirements of the NOS are also available for use. These products typically release nutrients more slowly as compared to synthetic fertilizers. To ensure that plants receive adequate nutrients, apply products with organic nutrient sources 2 to 4 weeks prior to the time nutrients are needed by the plants.

ADDING NUTRIENTS WITH COMPOSTS AND MANURES

Composts and raw manures can be an important part of nutrient management for small fruit crops. In addition to adding nutrients to the soil, they can improve long-term soil health. Composts and manures can be best utilized when used in combination with other nutrient management strategies including green manures, fertilizers, and crop rotations to keep nutrients balanced. Before adding compost or manure to fields, check state regulations because some states have implemented or are in the process of implementing nutrient management legislation to address nutrient pollution problems. Depending on the state in which you reside and your type of farming operation, you may be required to develop and follow a nutrient management plan. Timing the application of organic nutrients is different from that of adding chemical fertilizers because nutrients are generally slowly made available to plants, and timing must be adjusted to account for decomposition and the subsequent release of nutrients. Applying compost or manure too late can result in vigorous plant growth late in the season, which can delay hardening off of the plant and lead to winter injury.

Compost

The nutrient content of compost varies depending on source materials and composting protocols used. As a result, compost should be tested to determine the amount of nutrients it contains, as failure to do so may result in under- or overapplication of certain nutrients. When a nutrient is overapplied, imbalances that are frequently difficult to correct result. Various university and private laboratories offer a compost analysis. The types of tests available and costs vary considerably with each laboratory and are subject to change. See Appendix B for contact information of laboratories in the region.

Finished compost typically contains 0.5 to 2.5 percent total nitrogen. Most of the nitrogen is in an organic or slow-release form. As a general rule, about 10 percent of the organic nitrogen in the compost will be available to the plant per year. Phosphorus in composts, like nitrogen, is largely in a form not available for plant use. As phosphorus is changed to a form useable by plants, some of it binds to soil particles and is again unavailable for plant use. Because of this, compost generally contains very little phosphorus for plant use, and phosphorus from other sources is typically needed to meet plant requirements. The plant-unavailable phosphorus forms can, however, tie up micronutrients. Potassium in compost is readily available for plant use, but it is water soluble and can leach out of compost piles. Placing a cover over a compost pile can help reduce the amount on potassium lost to leaching. In addition to determining the nutrient content of compost, its pH should be determined, particularly if it is intended for use in blueberry production, as the pH is usually between 6.5 and 7.5.

When using compost, applying it based on crop needs rather than on a depth basis is best for long-term soil health. Studies have shown that this is especially the case when growing in high tunnels, which exclude rain. The rain assists in the breakdown of compost but also leaches some nutrients and salts. Applying compost on a depth basis in high tunnels (or other production systems to a lesser extent) can increase soil nutrient and soluble salts to well above optimum levels, thereby compromising yields. Compost can be applied based on the amount of nitrogen, phosphorus, or potassium needs of the crop, of which nitrogen is often most limiting.

To calculate how much compost to apply based on the nitrogen needs of a crop, first determine the amount of organic and ammonium nitrogen contained in the compost and convert these values to pounds per ton (see the example below). Generally, these values are given in units of pounds per ton, milligrams per kilogram (which is equivalent to parts per million), or as a percentage. Multiply milligrams per kilogram by 0.002 to convert to pounds

per ton. If these values are given as a percentage, multiply the numeral of the percentage by 20 to convert to pounds per ton.

Next, determine how much nitrogen will be available from the compost in the first year after application by multiplying the organic nitrogen by a mineralization rate and adding that to the amount of ammonium. Compost must be decomposed for organic nitrogen to be converted to plant available nitrogen. The mineralization rate accounts for this conversion. Mineralization rates can range from 10 to 40 percent. The range is wide because many factors affect mineralization rates, including soil moisture, the population of soil microbes decomposing the compost, soil temperature, compost particle size, the makeup of the compost, depth of incorporation of the compost, and so forth. A conservative mineralization estimate is 10 percent. However, using 10 percent can result in excess nitrogen in the soil relative to plant demand, which can result in the plant sacrificing fruit production for vegetative growth, among other problems, so a 20 percent mineralization rate is probably a good starting point. When a higher rate of mineralization is expected—for example, if growing in a hot climate, when using certain plastic mulches (soil temperatures may be higher), or when using drip irrigation (soil moisture may be more uniform)—consider using an even higher mineralization rate.

The final step is to determine the amount of compost to apply by dividing the amount of nitrogen needed by the amount of nitrogen available in the compost. Remember to subtract nitrogen added from other sources (e.g., green manures or fertilizers) from the nitrogen needed.

Example: A compost has 1.1 percent organic nitrogen and 451.6 mg/kg ammonium nitrogen on a wet-weight basis, and a planting needs 30 pounds of nitrogen per acre.

- Step 1: Convert the organic and ammonium nitrogen levels to pounds per ton.

  Convert the percent organic nitrogen to pounds per ton by multiplying 1.1 by 20 = 22 pounds of organic nitrogen contained per ton of compost.

  Convert 451.6 mg/kg ammonium N to lbs per ton by multiplying by 0.002 = 0.9 pounds ammonium per ton.
- Step 2: Determine how much nitrogen will be made available to the plant by multiplying 22 pounds of total nitrogen per ton by a 20 percent mineralization rate = 4.4 pounds of available nitrogen per ton of compost. Add to that the amount of ammonium available; 4.4 + 0.9 = 5.3 pounds per ton available nitrogen in the compost.
- Step 3: Determine how much compost to apply. Thirty pounds of nitrogen needed per acre divided by 5.3 pounds of nitrogen available per ton = 5.7 tons of compost needed per acre.

Accepted values of plant availability of phosphorus and potassium from compost are not established, but keep in mind that little phosphorus is readily available to plants, while much of the potassium is in plant-available forms and is probably available within the first year.

Additional Considerations for Organic Growers

According to the NOS, compost can be applied as necessary, provided the compost meets the C:N ratio and temperature requirements and has not been treated with prohibited substances. When using compost, it must have a C:N ratio between 25:1 and 40:1. In addition, when using an in-vessel or static aerated pile system for composting, the pile must reach and remain at a temperature between 131°F and 170°F for a minimum of 3 days. If using a windrow system for composting, the pile temperature must be maintained between 131°F and 170°F for a minimum of 15 days and turned a minimum of five times during that time. A compost log should be used to document that the composting procedure meets protocol. If the compost used is purchased, it must also have been produced in adherence with these requirements.

Raw Manures

Tables listing the nutrient content of different manures are available for use. Nutrient content varies depending on several factors including the feed the source animal was provided, presence of bedding in the manure, and manure handling procedures. Also, nutrient availability decreases as the manure ages. As with composts, manures should be tested for nutrient content to avoid over- or underapplying various nutrients. Manure is typically applied based on the nitrogen needs of the crop. Fact sheets are available through cooperative extension with detailed calculations for determining application rates for manures.

Nitrogen contained in manures is in the form of ammonia or ammonium, which can be quickly lost through volatilization to the atmosphere. To avoid this nitrogen loss, raw manures should be soil incorporated when possible. Soil incorporating manures can be a challenge for small fruit crops because the plants are perennial and have shallow root systems that can be damaged during incorporation. Applying raw manures to the small fruit crop can also damage the plants because of potentially high nitrogen and salt levels. Additionally, raw manures can be contaminated with microorganisms that cause human disease, which can be transferred to fruit. Applying manure well in advance of fruit production (e.g., in the fall) or as mandated for organic growers (see section below) is recommended. Manures often have high weed seed levels, which complicate production. It has been documented on vegetable crops that as manures decompose they can release compounds, which, when taken up, can lead to off-flavors and odors, though this has not been investigated with small fruit crops. For these reasons, raw manures are better suited for incorporation during soil preparation prior to planting rather than after the crop has been planted. Composted manures are a better option for application after the crop has been planted.

Using sewage sludge is not recommended. Individual state regulations may require a permit for application, and state guidelines for application must be strictly followed. However, the use of sewage sludge is permitted by federal and some state regulations for production of certain crops. If opting to use sewage sludge, carefully follow

established guidelines and consult your local county extension educator. Some labs offer a soil amendment test to assist growers in making sound management decisions when considering use of alternative soil amendments such as sewage sludge (see Appendix B for a list of laboratories). This test includes analyses for standard nutrients plus potential metal and heavy metal contaminants. In addition, the facility producing the sludge may have test results available to those obtaining sludge.

Additional Considerations for Organic Growers

According to the NOS, raw animal manures can be used whenever needed on fields planted with crops not intended for human consumption, such as on green manures or cover crops. When raw manures are used on fields that are planted in crops for human consumption with the edible part of the crop not in contact with the soil (e.g., trellised brambles, highbush blueberries, gooseberries, currants), the raw manure must be soil incorporated a minimum of 90 days before harvest. When raw manures are applied to fields with a crop for human consumption and the edible part of the crop is in contact with the soil (e.g., strawberries), the manure must be soil incorporated a minimum of 120 days before harvest. The use of sewage sludge is prohibited in certified organic production.

VALUE OF ORGANIC MATTER

Organic matter does much to improve the structure of the soil, sometimes referred to as "soil tilth." It also binds excess nutrients and releases them slowly as it decomposes. Organic matter therefore tends to buffer the effects of inorganic fertilizer application, smoothing peaks and dips in availability. Organic matter that is high in nutrients relative to the amount of carbon it contains (e.g., composted chicken manure) almost immediately begins releasing some nutrients and continues to release additional nutrients as the material decomposes. Organic matter high in carbon relative to the amount of nutrients (e.g., sawdust) can tie up nutrients, especially when fresh. Eventually, as the material decomposes, these "tied up" nutrients are released. In addition to increasing the nutrient-holding capacity of the soil, organic matter also increases the water- and air-holding capacity. Soil organic matter can be increased through the on-site growth and incorporation of green manure crops or through the addition of organic matter produced elsewhere in the form of composts or manures.

Green Manure Crops

Seeding a cover crop (green manure) on a site the year before planting is an excellent way to improve the soil organic matter content, add nitrogen to the soil, scavenge soil nutrients, and/or manage plant-parasitic nematodes (discussed further in the next section). At or before flowering, the green manure is chopped and incorporated (i.e., turned under), by plowing, disking, or rototilling, where it breaks down and adds organic matter.

For spring-planted small fruit crops, green manures are usually incorporated in the late fall or early spring. Green manures with low nitrogen content (most grains and dry grasses) should be plowed under in the fall. This allows adequate time for them to break down and prevents soil nitrogen tie-up. Green manures in the legume (clovers and vetches) family contain more nitrogen than other green manures and can be turned under in early spring, a month or so before small fruit crops are planted.

Selecting a Green Manure Crop

Which green manure crop is best for your particular situation can be decided by: (1) determining the weed and nematode populations, as well as organic matter and nutrient status of the planting area; (2) identifying the primary purpose of the green manure; (3) determining the time of year and length of time the green manure will be grown; and (4) giving consideration to factors specific to your operation. By following these steps, you can select a green manure crop that best suits your needs. Finding a green manure that meets all goals for improving soil can be difficult; you will most likely have to make trade-offs.

(1) Determining the weed and nematode populations and organic matter and nutrient status of the planting area. The first step in selecting a green manure is to become familiar with the current condition of the planting area. Gather information on weed density and types by visually inspecting the field. Since the majority of small fruit crops are grown in perennial systems, perennial weeds tend to be a larger concern than annual weeds. Soil samples can be collected to determine the planting site soil's nematode populations and organic matter and nutrient content. Results from nematode tests will reveal the types and abundance of nematodes present. Dagger and lesion nematodes negatively affect small fruit production. If dagger nematodes are present, they can be managed using rapeseed green manure crops or nematicides. Lesion nematodes are currently managed with nematicides. Results from the soil analysis will reveal the percentage organic matter (keep in mind that this test needs to be specifically requested from most labs), the soil pH, nutrient levels in the soil, and crop needs for added nitrogen, phosphate, and potash. Soils for growing berry crops should contain a minimum of 2 percent organic matter with 5 percent preferred. Results of this assessment of the current condition of the planting area will be used to decide on the primary purpose of the green manure.

(2) Identifying the primary purpose of a green manure. Many green manure crops are available for meeting site-specific soil-improvement goals. Green manures can be used to provide nitrogen, increase the organic matter content, suppress weeds, scavenge nutrients in the soil, and/or manage plant-parasitic nematodes. It is likely that more than one goal will be identified for a site. Goals will need to be prioritized, and some may need to be addressed by other means, as one green manure generally cannot fulfill all needs.

Providing nitrogen. If, based on your assessment of prior growth on the site or expected subsequent crop needs, nitrogen is of primary concern, legumes are the best choice. They are able to establish relationships with soilborne "nitrogen-fixing" bacteria that remove nitrogen from the atmosphere and change it into a form that the plant can use. As a result, the tissues of leguminous crops have a lot of nitrogen relative to the amount of carbon, which results in their rapid decomposition when incorporated into the soil. This results in

a relatively quick release of nitrogen, but the amount of organic matter retained in the soil is limited over the long term. Each leguminous crop differs in the amount of nitrogen added to the soil. Information is available on amount of nitrogen added by various cover crops (see Appendix E).

Increasing organic matter. On sites with an organic matter content below 2 percent, increasing the soil organic matter content should be a priority. When growing a green manure to increase the organic matter content in the soil, nonleguminous crops or mixtures of grasses and leguminous crops are good options. The best crops for this purpose are generally those with large above-ground plant canopies and include annual ryegrass, cereal rye, triticale, sorghum/sudangrass, and hairy vetch. These green manures can suppress weeds through direct competition.

Suppressing weeds. On sites with high weed densities, the primary purpose of a green manure would be to suppress weeds. Green manures that establish quickly and have large above-ground canopies are the best options for this goal. Buckwheat, in particular, is especially valuable for this purpose due to its ability to establish quickly. In general, green manures that suppress weeds are also more effective for increasing the soil organic matter content (see preceding paragraph).

Scavenging nutrients. The primary purpose of growing green manure may be to efficiently use nutrients by recycling excess nutrients from deep in the soil, or to "scavenge" nutrients remaining in the soil after the previous crop is harvested, thereby preventing these nutrients from leaching out of the root zone. These nutrients will then be made available to subsequent crops as the green manure breaks down. For this purpose, select green manures with large, deep root systems that develop quickly. Options include small grains, cereal rye, triticale, rapeseed, annual ryegrass, oil seed radish, mustard, and some leguminous crops.

Managing dagger nematodes. If dagger nematodes have been a problem on your site in the past, and/or a nematode test indicates the presence of high populations, green manures can be used for management. As an alternative to chemical fumigation, a variety of novel rotations and green manures for nematode management have been evaluated. This work has shown that some plants can naturally reduce populations of dagger nematodes and improve soil structure. Based on these results, using selected rapeseed cultivars can help manage dagger nematodes; however, the treatment is not very effective against other nematode populations. Specific suggestions and additional information on this subject is discussed below and in Appendix A.

(3) Determining the time of year and length of time the green manure will be grown. Once the primary purpose for growing the green manure is identified, the next step is to identify the time of year and length of time the green manure will be grown. Ideally, the planting area should be devoted to soil improvement, including using green manures, for the year prior to planting small fruit. However, this may not be an option on some farms. Another opportunity for planting green manures is between cash crops, in the late fall and/or early spring. For fall-planted green manures, cool-season crops including vetches, peas, annual and perennial clovers, wheat, ryegrass, rye, winter rapeseed, or barley are good choices. However, if the small fruit crop is to be planted in the spring, the green manure crop may need to be incorporated before it reaches mature size in order to allow sufficient time for it to decompose before planting. For green manures planted in the late spring or summer, warm-season crops including sorghum/sudangrass, cowpeas, or buckwheat should be grown. Consider growing multiple green manures in both the cool and warm seasons.

(4) Other considerations. Here are some final questions to consider when selecting a green manure. What equipment do you have available for managing the green manure? Will you be able to manage a crop with a large canopy with the equipment that you have available? How much are you willing to pay for cover crop seed, and what type of seed is available? (Suppliers of cover crop seed are listed in Appendix D.) What crop will you be growing next? If blueberries, you should choose a green manure that grows well in soils with a pH similar to blueberry plants (4.5 to 5.0)—for example, buckwheat.

Once these factors have been considered, a green manure crop can be chosen. Table 2.2 categorizes several green manures by use, life cycle, and season.

Growing Green Manure Crops

Most green manures perform best under the same general range of soil nutrients and conditions as required by small fruit crops, but submitting an initial soil sample specifically for the green manure crop is useful. Small grains or hardy sod grasses take large amounts of nitrogen from the soil but release it back slowly as they break down. Based on soil test results before planting the green manure, add 40 to 50 pounds of nitrogen per acre and adjust the soil pH, potassium, and phosphorus. These practices help establish the green manure and promote more rapid breakdown when it is incorporated, preventing nitrogen drag (a lack of available N) when small fruit crops are planted.

Since preplant green manures are not intended to become permanently established, suppliers usually recommend minimum seeding rates to produce an acceptable stand. If a dense and fast-growing cover is needed for weed management, higher seeding rates of green manures such as buckwheat, rye, annual ryegrass, or sudangrass are recommended.

Many other sources are available to further detail the benefits and cultural requirements of various green manure crops. For sources of further information on green manures and cover crops, see Appendix E.

Adding Organic Matter from Sources other than Green Manure Crops

Sources of organic matter such as composts or animal manures can also be added to increase organic matter content. As a general rule of thumb, 10 tons of manure per acre is considered a reasonable rate for improving organic matter content. If berry plants will be planted before the material has time to decompose, using composts is preferred over using fresh materials. See considerations discussed above concerning using these materials for nutrient addition.

Table 2.2. Green manure crops categorized by use, life cycle, and season.

Nitrogen Building	Long-Term Organic Matter Building and Weed Management	Nutrient Scavenging
PERENNIALS		
Legumes generally are planted from late April to early May or from late July to early August. Nonlegumes are generally planted from early April to early June.*		
Alfalfa Alsike, ladino, white clover, sweet clover Red clover	Alfalfa Perennial ryegrass Red clover	Perennial ryegrass
WARM-SEASON ANNUALS		
Generally planted from late May to mid-July.		
	Buckwheat Japanese millet Sorghum/sudangrass Sudangrass	Buckwheat Sorghum/sudangrass
COOL-SEASON ANNUALS		
Generally planted from late April to early May or from August to early September.		
Hairy vetch	Annual ryegrass Hairy vetch Rapeseed Spring oats Winter rye	Annual field brome Annual ryegrass

* Planting dates are only intended as general guides for groups of crops. Specific crops will vary in ideal planting time. See Appendix E for additional sources of information on growing cover crops.

BIOFUMIGATION: MANAGING DAGGER NEMATODES WITH GREEN MANURES

A green manure crop of rapeseed can be used for nematode management. Experiments have shown that after the crop is soil incorporated, decomposing rapeseed releases nematicidal compounds. Work on rapeseed has shown that two years of rotation is desirable (see Appendix A for a detailed procedure), but getting the same benefit may be possible by growing two crops of rapeseed within one year. The following timetable is suggested for producing two rotations of rapeseed within one year:

- Prepare seedbed and plant rapeseed by late April or early May. (Plant only recommended winter rapeseed cultivars. See below.)
- Incorporate (i.e., turn under) green rapeseed by early September. Prepare seedbed and plant second crop by mid-September.
- Turn under the second crop in late spring after soil temperatures reach 45°F or higher.
- Ideal conditions for incorporating rapeseed are similar to those required for obtaining the maximum benefit from fumigation (i.e., the soil temperature should be above 45°F and moist).
- Alternatively, planting dates may be reversed so that the first planting is in the fall followed by a second crop planted in the spring. This would end the rotation cycle in fall of the following year.

WHICH RAPESEED VARIETIES TO PLANT

Some rapeseed cultivars are more effective at suppressing nematode populations than others, and some cultivars do not overwinter or bloom too early in summer to be useful. The winter cultivars Dwarf Essex and Humus work well for both spring and fall planting dates. When planted in the spring, these varieties do not bloom but instead grow vigorously and help crowd out weeds. Here are some tips for planting rapeseed:

- Rapeseed requires a firm, smooth seedbed that is free of weeds, heavy residue, and large clods.
- Seed may be drilled or broadcast. Avoid planting too deep! A seeding depth of 3/8 inch is good; if broadcast, a cultipacker may be used.
- A seeding rate of 7 to 8 pounds per acre works well.
- Rapeseed is sensitive to broadleaf herbicide carryover.
- Fall-planted rapeseed should have 8 to 10 true leaves and a 5- to 6-inch tap root with a 3/8-inch-diameter root neck before the ground freezes.
- Sulfur is necessary for rapeseed to produce nematicidal compounds. Although agricultural soil is not usually deficient in sulfur, soil testing to assess the availability of this element may be beneficial.

KEEPING YOUR NUTRIENT PROGRAM ON TRACK: PLANT TISSUE ANALYSIS

After the crop is established, plant tissue analysis is recommended to guide adjustments to your nutrient program. Tissue analysis (also called leaf analysis) is an excellent means of monitoring plant nutrient levels. Brambles, strawberries, and blueberries can all benefit from the proper use and interpretation of leaf analysis. While soil tests reveal the quantity of certain nutrients in the soil, leaf analyses show what the plants have successfully absorbed. If you suspect nutritional problems in a planting, it is a good idea to test both leaves and soil so that quantities can be correlated. In some cases where a plant deficiency is difficult to correct, a soil test in addition to a tissue analysis can sometimes reveal the underlying cause for the problem (e.g., when deficient tissue potassium occurs as a result of high soil magnesium levels).

While tissue analysis is essential for the planting where nutritional deficiencies are suspected, it is also beneficial for plantings where no nutrient deficiency is obvious because tissue analysis detects nutrient deficiencies (especially of minor nutrients) before symptoms appear on plants and affect plant health or yield.

Tissue analysis kits can be obtained through your county extension office for samples sent to university laboratories. Several commercial laboratories also conduct nutrient analyses (see Appendix B). Follow the general instructions on the kit, unless they conflict with the specific small fruit instructions below. Be sure to complete the information sheet in the kit.

Standard values for interpreting results are only established for certain times of the year and certain plant parts. Some elements become more concentrated, while others become more dilute in certain plant parts over the course of a growing season, or they may fluctuate widely at certain times of the year. For these reasons, samples for berry crops should only be collected when specified (see exception below), as samples collected at other times may produce nearly meaningless results. For matted-row strawberries, sample the first fully expanded leaves after renovation, about July 15 to August 1. For plasticulture strawberries, sample the first fully expanded leaves in spring after plants have resumed growth but before early fruit set for first harvest-year plantings, or after renovation for carry-over plantings. In summer-bearing brambles, the most recently fully expanded leaves should be sampled on nonfruiting canes between August 1 and 20. With primocane-bearing brambles, the most recently fully expanded leaves should be sampled when flower buds are emerging. Blueberry leaves (most recently fully expanded) should be sampled during late July or early August.

An exception to the rule of only sampling at certain times exists. When plants that are performing poorly can be compared to healthy plants of the same cultivar, age, and otherwise same growing conditions, samples can be collected at almost any time of the year, and results of these samples can be compared to each other. This is especially useful if you suspect that soil conditions are causing localized nutrient deficiencies. In this case, obtain separate samples from both poor and good plants of most recently fully expanded leaves and submit them for separate analysis.

Select a minimum of 30 leaves (strawberries and brambles) or 60 leaves (blueberries) for each analysis. All leaves within each kit should be from the same cultivar, although they should be taken from several plants. Detach the leaves from the plant and remove the petioles. Place leaves in a dry paper bag and label immediately.

Critical values for tissue analysis results for each berry crop and recommendations for changes in nutrient programs based on these results are presented in Appendix B.

Petiole sap testers (Cardy meters) are sometimes used to determine nitrate-nitrogen and potassium levels in the petioles of strawberry plants. These results may be useful as a rough guide for determining the nitrogen and potassium status of plants, but they should not be used as the sole source of information for guiding nutrient programs.

NUTRIENT MANAGEMENT PLANS

The requirement of having nutrient management plans varies from state to state within the region. Nutrient management plans are intended to protect water resources through minimizing nutrient runoff and, hence, water contamination from fertilizers and manures. The intended benefactor of nutrient management legislation is the environment, but effective nutrient management planning also increases productivity and profitability. As of this printing, Maryland is the only state within the Mid-Atlantic region that requires all horticultural crop producers to have nutrient management plans. Delaware also requires nutrient management plans for those who apply nutrients to more than 10 acres of land. Some states require training for nutrient applicators. Because requirements in this area are changing, growers should consult their local extension educator or soil and water conservation district office for information on current state regulations.

CHAPTER 3

Pesticides, Pesticide Safety, and Chemical Fumigation

CONTENTS

Effect of Pesticides on Nontarget Organisms ... 15
Crop Groupings—How Crops Are Listed on the Label ... 15
Pesticide Activity Groups and Resistance Management ... 15
Spray Application ... 15
Herbicide Equipment ... 17
Fungicide and Insecticide Equipment ... 17
Spray Water pH ... 17
Pesticide Safety ... 17
General Guidelines for Pesticide Safety ... 17
Pesticide Toxicity ... 18
Symptoms of Pesticide Poisoning ... 19
Responding to Pesticide Poisoning Symptoms ... 19
First Aid for Pesticide Poisoning ... 19
Safe Storage of Pesticides ... 20
Safe Disposal of Pesticides ... 21
Current Status of Restricted-Use Pesticides ... 21
Worker Protection Standard for Agricultural Pesticides ... 21
Chemical Fumigation ... 22
Soil Fumigation Chemicals ... 22
New Regulations Concerning Fumigation ... 22
Site Preparation for Chemical Fumigation and Treatment Guidelines ... 26

EFFECT OF PESTICIDES ON NONTARGET ORGANISMS

Growers often ask whether certain pesticides are harmful to beneficial insects or other nontarget organisms. A simple but logical rule of thumb is that if a broad range of pests are listed on the label, it is likely the pesticide will also affect nontarget organisms of the same type (insects, mites, or fungi). Wide-spectrum insecticides affect a biological process common to many species of insects, so these pesticides are often toxic to nontarget species as well. This is the case with both synthetic and organic insecticides, though organic insecticides usually break down to nonlethal products quickly—a trait that certain synthetic pesticides also have. However, even pesticides that break down quickly are often toxic to nontarget species when exposure is direct. Conversely, if an insecticide is selectively effective only on certain species or family(ies) of insects, it is more likely to be safe for beneficials and pollinators. Table 3.1 lists relative toxicity of pesticides to several common beneficial insects, bees, birds, and fish.

CROP GROUPINGS—HOW CROPS ARE LISTED ON THE LABEL

In the past, individual crops on which pesticides could be used had to be specifically listed on a label in order for use on that crop to be legal. This resulted in few chemical control options for certain crops, including many berry crops. Changes in regulations have now made it possible for crops to be covered under various categories on labels, known as crop groups. Pesticides can now be used on various crops in a crop group or subgroup as long as they are designated correctly, even if the individual crop is not specifically mentioned on the label. Use of crop group designations is not mandatory, so on some labels, most frequently older ones, specific crops rather than crop groups are mentioned. In these cases, individual crops need to be listed on the label for a pesticide to be legally used on the crop.

The berry crops discussed in this guide all fall under Crop Group 13-07, the Berry and Small Fruit group. Thus, if a pesticide is labeled for this entire group, it can be used on any berry or small fruit crop. Subgroups that may appear on a label include subgroup 13-07A: the caneberry subgroup, subgroup 13-07B: the bushberry subgroup, and 13-07G: the low-growing berry subgroup. The caneberry subgroup includes raspberries, blackberries, and any hybrids of the two (boysenberries, tayberries, etc.). The bushberry subgroup includes highbush and lowbush blueberries, gooseberry, currants, jostaberries, plus many others. The low-growing berry subgroup includes strawberries, as well as lowbush blueberries. Any crop may also appear individually on a label, as frequently occurs with strawberries. Modifications will continue to be made if necessary.

PESTICIDE ACTIVITY GROUPS AND RESISTANCE MANAGEMENT

When pesticides that affect a certain biological process of a pest are used repeatedly, strains of the pest develop that can tolerate the pesticide's use. Various pesticides may target the same processes, so pesticides that have similar mode(s) or target site(s) of action are grouped into "activity groups." To delay the buildup of resistance to a particular activity group, pesticides from different activity groups should be rotated in subsequent applications or tank-mixed when compatible. In order to help growers identify which activity groups pesticides belong to, the activity groups into which various pesticides fall are listed on some pesticides' packaging. However, this type of labeling is voluntary, so not all packages bear this information. Activity groups of pesticides labeled for each crop are also provided in the tables in chapters on individual crops.

SPRAY APPLICATION

There is no substitute for choosing the correct equipment and calibrating it correctly. Problems from over- or under-application range from crop phytotoxicity and unnecessary environmental contamination to a lack of pest control. A poorly calibrated sprayer also wastes pesticides by applying too much or too little material, both of which are costly. Close attention to detail in choosing the right equipment and in the calibration

Table 3.1. Toxicity of pesticides to birds, fish, honey bees, and beneficial predators.

	Toxicity[a] to:							
				Mite Predators				
Pesticide	Birds	Fish	Honey Bees	*N. fallacis*	*Stethorus* Adults	*Stethorus* Larvae	Ladybugs	Lacewings
INSECTICIDES								
Actara (thiamethoxam)	ST	N	H	N	H	H	M	M
Admire (imidacloprid)	M	M	H	M	S	—	ST–M	ST
Altacor, Coragen (chlorantraniliprole)	N	N–ST[b]	N	N	N	N	N	N
Asana (esfenvalerate)	ST	H	H	H	H	H	H	H
Assail (acetamiprid)	N	N	M	N	M	M	M	M
Athena (bifenthrin + avermectic)	S	H	H	H	H	—	—	—
Avaunt (indoxacarb)	M	H	ST-H[c]	N	M	M	M	ST
Aza-Direct (azadirachtin)	—	H	ST	ST	ST	ST	ST	ST
Brigade, Capture (bifentrhin)	N–ST	H	H	H	H	—	H	H
Confirm (tebufenozide)	ST	M	M	N	N	N	N	N
Courier (buprofezin)	N	N	N	—	—	—	—	—
Danitol (fenpropathrin)	S	H	H	H	H	H	H	H
Delegate (spinetoram)	N	M	M	M	ST	ST	ST	ST
Diazinon (diazinon)	H	H	H	ST	ST	ST	M	M
Dibrom (naled)	M	H	H	H	—	—	H	H
Dipel, other Bt products (Bt)	N	N	N	N	N	N	N	N
Entrust,Success, Spintor (spinosad)	ST	M	M	ST	N	N	N	N
Esteem (pyriproxyfen)	N	H	N	N	M	H	H	H
Guthion, for use only in NJ (azinphos-methyl)	H	H	H	N	ST	ST	M	M
Hero(zeta-cypermethrin + bifenthrin)	ST	H	H	H	H	—	—	—
Imidan (phosmet)	M	H	H	N	ST	ST	M	M
Intrepid (methoxyfenozide)	N	MT	N	N	N	N	N	N
Lannate (methomyl)	H	M	H	H	M	M	H	H
Lorsban (chlorpyrifos)	H	H	H	N	ST	ST	M	ST
Malathion (malathion)	M	H	H[d]	N	ST	ST	M	ST
M-Pede (insecticidal soap)	N	N	N	M	ST	M	ST	ST
Mustang Max (zeta-cypermethrin)	ST	H	H	H	M	H	H	H
Platinum (thiamethoxam)	ST	N	H	N	H	H	H	M
Provado (imidacloprid)	M	M	H	M	M	M	M	M
Pyganic (pyrethrins)	N	H	ST	H	—	—	M	ST
Radiant (spinetoram)	N	M	M	M	ST	ST	ST	ST
Rimon (novaluron)	—	—	H	N	N	H	H	H
Sevin XLR (carbaryl)	N	H	H[d]	M	H	H	H	M
Surround (kaolin clay)	—	—	—	M	M	M	M	—
Thionex (endosulfan)	M–H	H	M[d]	ST	M	M	M	M
Voliam Flexi (thiamethoxam + chlorantraniliprole)	ST	ST	H	N	M	M	M	M
MITICIDES								
Acramite (bifenazate)	N	H	ST	M	N	N	N	N
AgriMek, Abba, Temprano (abamectin)	N	M	H[d]	M	M	M	ST	ST
Kanemite (acequinocyl)	N	H[b]	N	ST	ST	ST	—	—
Oberon (spiromesifen)	N	ST	N	M	—	—	ST	ST
Portal (fenpyroximate)	N	H	N	ST	M	M	—	—
Savey (hexythiazox)	N	H	N	ST	N	N	N	N
Vendex (fenbutatin oxide)	N	H	N	M	ST	ST	ST	ST
Zeal (etoxazole)	ST	H	N	M	N	N	—	—

a. N = practically nontoxic (for bees, apply anytime); ST = slight toxicity (for bees, apply in evening after bees have stopped foraging until early morning before they start foraging); M = moderately toxic (for bees, apply in evening after bees have stopped foraging); H = highly toxic (for bees, do not apply to blooming plants); — = insufficient data.

b. Altacor, Coragen, and Kanemite are toxic to invertebrate aquatic organisms such as oysters.

c. Avaunt is highly toxic to bees exposed to direct spray, but it is rated as slightly toxic once sprays have dried.

d. Depending on rate and formulation, different products containing abamectin, malathion, endosulfan, or carbaryl as the active ingredient have different lengths of time of toxicity to honey bees.

NOTE: Information on toxicity to birds, fish, and honey bees was drawn from numerous sources such as Material Safety Data Sheets, EPA rulings, and EXTOXNET PIPs. Information on toxicity to beneficial predators is largely drawn from that contained in Penn State's *Tree Fruit Production Guide,* which draws on other sources as well. For additional information on this subject and additional sources of information used in this table, see Appendix E. When scientifically substantiated differences existed in ratings among data sources or species tested, the more conservative ratings were chosen.

and adjustments required for maximum performance and efficiency are important.

HERBICIDE EQUIPMENT

See discussion in Chapter 4: Weed Management.

FUNGICIDE AND INSECTICIDE EQUIPMENT

In general, foliar sprays are applied to strawberries using a horizontal boom-type sprayer. Airblast sprayers are used in some strawberry operations, but penetration of the foliar canopy decreases markedly with distance from the sprayer so that coverage in the crowns and of the fruit is sometimes poor. For bramble crops and highbush blueberries on small plantings of less than 1 to 2 acres, a high-pressure (200 to 300 psi), hand-held spray gun is both practical and economical. Hydraulic sprayers with vertical booms fitted with hollow-cone nozzles work well for plantings of 1 to 3 acres, but for larger plantings airblast sprayers are generally the most efficient. Only airblast sprayers can be used effectively for low-volume, concentrated applications. High-pressure or airblast spraying equipment can also be used to deliver high-volume, diluted spray mixtures to the point of runoff.

Horizontal boom sprayers used for fungicide and insecticide sprays are usually fitted with hollow-cone nozzles spaced 20 inches apart and adjusted to a height where the spray patterns of adjacent nozzles overlap slightly. On vertical-boom and airblast sprayers, the spray stream should overshoot the tops of the plants slightly, and adjacent nozzle spray patterns must converge before they reach the foliar canopy. One or two solid-cone nozzles (center hole in nozzle whirl plate) can be added to vertical-boom sprayers to increase spray penetration where foliar canopies are dense, but be careful that the narrower pattern produced by these does not limit overall coverage. Solid-cone nozzles are not recommended for airblast sprayers. Airblast sprayers equipped with air-shear-type nozzles are designed specifically for low-volume applications of less than 50 gallons per acre. Exceeding this rate overloads the nozzles and can result in poor coverage. For airblast sprayers using standard, hollow-cone type nozzles, delivery rates of 30 to 200 gallons of water per acre will provide good coverage in most plantings. Note that regardless of the sprayer type, if the spray volume used results in wetting the foliage to the drip point, the concentration of the spray mixture in the sprayer tank should never exceed the pounds-per-100-gallon recommendation on the product label. Do not operate horizontal-boom sprayers at more than 3 mph, airblast sprayers at more than 2½ mph, and vertical-boom sprayers at more than 2 mph. On strawberries, apply fungicides and insecticides at an operating pressure of 200 to 300 psi for the delivery of at least 100 gallons of diluted pesticide mixture per acre. This is done to ensure thorough coverage of all foliage and fruit and the penetration of spray droplets through the foliar canopy to the crowns. Operate vertical-boom sprayers at 200 to 400 psi for good penetration of the foliar canopy and adequate breakup of spray droplets. Operating pressures for airblast equipment vary with the type of nozzle used; follow the manufacturer's recommendations.

Regardless of the spraying method used, spray coverage within the treated crop should be checked several times during the course of the season as the foliar canopy changes. This is best done with water-sensitive paper spray targets that can be hung on hooks in the canopy structure or stapled directly to leaves. These spray targets are relatively inexpensive and are available from sources listed in Appendix D.

SPRAY WATER PH

For maximum effectiveness, the pH of the spray water should be in the 6.5 to 7.0 range. Although extremely acidic water is uncommon in this area, the limestone and surface runoff in parts of the region can make spray water alkaline. In general, alkaline spray water should not be used with many pesticides, primarily carbamates and organophosphates, because it promotes the hydrolysis or destruction of the pesticides. This is particularly important where low-volume sprays are used on larger acreages since emptying the spray tank may take several hours. See Appendix D for suppliers of pH-testing equipment. Where the pH of the spray water needs to be adjusted, special spray water buffering agents are available from most pesticide suppliers.

PESTICIDE SAFETY

Many growers practice IPM, in which pesticides play a vital role. Applicators must realize their legal obligations when using pesticides. Furthermore, applicators who implement pesticide safety practices and take proper precautions will greatly reduce the possibility of accidents.

GENERAL GUIDELINES FOR PESTICIDE SAFETY

Always read the label!

When pesticides are necessary it is important to make sure many factors are considered when selecting the specific chemical to use. Before using any pesticide product, always read the label, as it is a legal document. The label provides information on which pests can be controlled, on which crops the pesticide product can be used, and the recommended rates and times of application. Using a pesticide in a way that is not allowed by the label is a violation of both federal and state laws. Correct use of pesticides is essential to protect human, animal, and plant health as well as to protect the environment. It is also critical to help ensure pest control without damaging crops. For example, in some cases when rates that are higher than recommended by the label are used, crop injury occurs. Proper use will ensure that chemical residues on crops and livestock do not exceed legal limits (tolerances).

- Before using any pesticide, READ THE LABEL.
- Become familiar with current federal and state pesticide laws and regulations.
- Follow all safety precautions on the label.
- Wear protective clothing and use protective equipment (both are referred to as personal protective equipment, PPE) according to instructions on the pesticide label.
- Minimum clothing requirements are long pants, long-sleeved shirt, socks, and shoes. In addition, the applicator should wear chemically resistant

gloves (nitrile, butyl, or neoprene) and unlined rubber boots.

- Be careful when handling pesticide materials to avoid spilling on skin or clothing.
- Never eat, drink, smoke, or use tobacco products while applying pesticides.
- When selecting pesticides, consider type of formulation and the application equipment required.
- Avoid drift to nontarget areas, which may endanger other plants or animals. Dusts drift more than sprays and airblast sprayers create more drift than boom sprayers.
- For record-keeping requirements, record the date, time, location, amount of each pesticide used, and any other required information within 24 hours of the application. In addition, if workers/handlers are employed that are covered under the Worker Protection Standard (WPS), this information must be documented at the completion of the application. It must also be available at a central location where employees have unrestricted access to the information.
- Bathe or shower in hot, soapy water after applying pesticides.
- Wash clothing worn while applying pesticides separately from other laundry, in hot, soapy water. Contaminated clothing must be handled with the same precautions as the pesticide itself.

PESTICIDE TOXICITY

For all pesticides to be effective against the pests they are intended to control, they must be biologically active, or toxic. Because pesticides are toxic, they are also potentially hazardous to humans and animals. Any pesticide can be poisonous or toxic if absorbed in excessive amounts. Pesticides can cause skin or eye damage (topical effects) and can also induce allergic responses. However, if used according to label directions and with the proper personal protective equipment (PPE), pesticides can be used safely. For this reason, people who use pesticides or regularly come in contact with them must understand the relative toxicity and the potential health effects of the products they use. The risk of exposure to pesticides can be illustrated with the following simple equation:

Hazard of Pesticide Use = Toxicity x Actual Exposure

Toxicity is a measure of a pesticide's ability to cause injury, which is a property of the chemical itself. Pesticide toxicity is determined by exposing test animals to different dosages of the concentrated active ingredient. Tests are also done with each different formulation of the product (for example, liquids, dusts, and granulars). By understanding the difference in toxicity levels of pesticides, a user can minimize the potential hazard by selecting the pesticide with the lowest toxicity that will control the pest.

Applicators may have little or no control over the availability of low-toxicity products or the toxicity of specific formulated products. However, exposure can be significantly reduced or nearly eliminated by using the correct PPE. For example, over 90 percent of all pesticide exposure comes from dermal exposure, primarily to the hands and forearms. By wearing chemically resistant gloves, this exposure can be reduced by at least 90 percent. Therefore, by wearing the correct PPE, the hazard of pesticide use can be reduced significantly for the applicator.

Acute Toxicity and Acute Effects

Acute toxicity of a pesticide refers to the chemical's ability to cause injury to a person or animal from a single exposure, generally of short duration. The four routes of exposure are dermal (skin), inhalation (lungs), oral (mouth), and ocular (eyes). Acute toxicity is determined by examining the dermal toxicity, inhalation toxicity, and oral toxicity of test animals. In addition, the potential for eye and skin irritation are also examined.

Acute toxicity is usually expressed as LD_{50} (lethal dose 50) or LD_{50} (lethal concentration 50) values. This is the amount or concentration of a toxicant required to kill 50 percent of a test population of animals under a standard set of conditions. The most common practice is for the toxicity of pesticides to be referred to by their LD_{50} values. The LD_{50} of a pesticide is recorded in milligrams of pesticide per kilogram of body weight of the test animal (mg/kg), or in parts per million (ppm). LC_{50} values of pesticides are recorded in milligrams of pesticide per volume of air or water (ppm). To put these units into perspective, 1 ppm is analogous to 1 inch in 16 miles or 1 minute in 2 years.

The LD_{50} and LC_{50} values are useful in comparing the toxicity of different active ingredients as well as different formulations of the same active ingredient. The lower the LD_{50} value of a pesticide, the less it takes to kill 50 percent of the test population, and therefore the greater the acute toxicity of the chemical. Pesticides with higher LD_{50} values are considered the least acutely toxic to humans when used according to the directions on the product label.

The LD_{50} and LC_{50} values are found in the products' Material Safety Data Sheets (MSDS), which are available from the supplier or product manufacturer when pesticide products are purchased. Most are also available from various online sources, including the manufacturer's website or through various search engines as listed on the Pesticide Education Program's website at **extension.psu.edu/pesticide-education-applicators-labels=and=msdss.** For many reasons, especially in an emergency situation, maintaining a file with copies of the label and MSDS for each pesticide product used is highly recommended.

Signal Words

The LD_{50} of the chemical is the basis for assigning pesticides to a toxicity category and determining the appropriate signal word for the product label. Pesticides that are classified as "highly toxic," on the basis of either oral, dermal, or inhalation toxicity, must have the signal words **DANGER** and **POISON** (in red letters) and a graphic of a skull and crossbones prominently displayed on the package label. **PELIGRO**, the Spanish word for danger, must also appear on the label of highly toxic chemicals. Acute oral LD_{50} values for pesticide products in this group range from a trace amount to 50 mg/kg. An exposure of a few drops of a highly toxic material taken orally could be fatal to a 150-pound person. Some pesticide products are labeled with the signal word **DANGER** without

the skull and crossbones symbol. A **DANGER** signal word in this instance does not provide information about the LD_{50} value of the chemical. Instead, this signal word means that potentially damaging skin or eye effects (due to the product's irritant or corrosive properties) are more severe than the acute toxicity (LD_{50}) of the product would indicate.

Pesticide products considered "moderately toxic" must have the signal words **WARNING** and **AVISO** (Spanish) displayed on the label. Acute oral LD_{50} values range from 50 to 500 mg/kg. An exposure of 1 teaspoon to 1 ounce could be fatal to a 150-pound person.

Pesticide products classified as either "slightly toxic" or "relatively nontoxic" are required to have the signal word **CAUTION** on the pesticide label. Acute oral LD_{50} values are greater than 500 mg/kg.

Chronic Toxicity and Chronic Effects

Any harmful effects that occur from repeated small doses over a period of time are called chronic effects. The chronic toxicity of a pesticide is determined by observing symptoms in test animals that result from long-term exposure to the concentrated active ingredient.

Some of the potential chronic effects from exposure to certain pesticides include birth defects (teratogenesis); fetal toxicity (fetotoxic effects); production of tumors (oncogenesis), either benign (noncancerous) or malignant (cancerous/carcinogenesis); genetic changes (mutagenesis); blood disorders (hemotoxic effects); nerve disorders (neurotoxic effects); and reproductive effects. The chronic toxicity of a pesticide is more difficult to determine through laboratory analysis than is acute toxicity. However, the product's MSDS also contains information regarding chronic symptoms of pesticide exposure based on laboratory animal test results.

SYMPTOMS OF PESTICIDE POISONING

The symptoms of pesticide poisoning can range from a mild skin irritation to coma or even death. Different classes or families of chemicals cause different types of symptoms. Individuals also vary in their sensitivity to different levels of these chemicals. Some people may show no reaction to an exposure that may cause severe illness in others. Because of potential health concerns, pesticide users and handlers must recognize the common signs and symptoms of pesticide poisoning.

The effects, or symptoms, of pesticide poisoning can be broadly defined as either topical or systemic. Topical effects generally develop at the site of pesticide contact and are a result of either the pesticide's irritant properties (from either the active and/or inert ingredient) or an allergic response by the person exposed. Dermatitis, or inflammation of the skin, is accepted as the most commonly reported topical effect associated with pesticide exposure. Symptoms of dermatitis range from reddening of the skin to rashes and/or blisters. Some individuals exhibit allergic reactions when using pesticides or when these materials are applied in or around their homes or places of work. Symptoms of allergic reactions range from reddening and itching of the skin and eyes to respiratory discomfort that often resembles an asthmatic condition.

Systemic effects are quite different from topical effects. They often occur away from the original point of contact, as a result of the pesticide being absorbed into and distributed throughout the body. Systemic effects often include nausea, vomiting, fatigue, headache, and intestinal disorders.

Seeking prompt medical attention and providing information about the potential of a pesticide exposure causing the symptoms is important. However, the development of certain symptoms is not always the result of exposure to a pesticide. For example, common illnesses such as the flu, heat exhaustion or heat stroke, pneumonia, asthma, respiratory and intestinal infections, and even a hangover can cause symptoms similar to pesticide exposure. Carefully consider all possible causes of your symptoms and provide medical personnel with all of the information they need to make an informed diagnosis.

RESPONDING TO PESTICIDE POISONING SYMPTOMS

Be alert for the early symptoms of pesticide poisoning. Responding immediately and appropriately when pesticide exposure is suspected will help minimize the effects of exposure and, in extreme cases, may save a life. If you are having symptoms but are unsure whether they are pesticide related, at least notify someone in case your symptoms become worse. If you are not feeling well and suspect it may be due to a pesticide exposure, call the National Poison Center at 1-800-222-1222 for guidance on the proper response to your symptoms. This number will direct your call to the nearest poison center, which is staffed on a 24-hour basis.

If safe to do so, take the pesticide container to the telephone. However, if the pesticide container is contaminated, write down the EPA registration number, product name and percentage of active ingredients, and take that information to the phone. The product label provides medical personnel information such as active ingredients, an antidote, and an emergency contact number for the manufacturer of the product. If you must go to the hospital or doctor's office, take the entire container, including the label, with you. In order to avoid inhaling fumes or spilling the contents, make sure the container is tightly sealed and never put it in the enclosed passenger section of a vehicle. If the Material Safety Data Sheet (MSDS) is available, also take this with you because it frequently contains additional information for medical personnel to determine treatment options.

In addition to posting emergency numbers or having them readily available by a telephone, keep these numbers in all service vehicles involved in transporting pesticides. Additional pesticide information can also be obtained by contacting the National Pesticide Information Center (NPIC) located at Oregon State University at 1-800-858-7378. The NPIC provides a variety of unbiased information about pesticides to anyone in the United States.

FIRST AID FOR PESTICIDE POISONING

Reviewed by J. Ward Donavon, medical director of PinnacleHealth Toxicology Center, Harrisburg Hospital

Immediate and appropriate action, such as providing basic first aid, may be necessary to prevent serious injury to a victim of pesticide poisoning. The situation can be a life-or-death matter.

Providing immediate care is important; however, it is more important to provide the correct assistance and protect yourself in the process. The product label should be one of the first sources of information in a pesticide exposure emergency, in addition to calling 911 and the National Poison Center (1-800-222-1222). First aid is only the "first response" and is not a substitute for professional medical help.

Basic First Aid Instructions

- Most important, be sure to protect yourself by wearing appropriate protective clothing and equipment if there is a likelihood of being directly exposed to a pesticide while administering first aid or removing the victim from an enclosed area.
- Have current labels and MSDSs available.
- Have emergency response telephone numbers readily available.
- Assemble a first aid kit with necessary supplies.
- Always have a source of clean water available. In an extreme emergency, even water from a farm pond, irrigation system, or watering trough could be used to dilute the pesticide.
- If oral or dermal exposure has occurred, the first objective is usually to dilute the pesticide and prevent absorption.
- If inhalation exposure occurs, first protect yourself, and then get the victim to fresh air immediately.
- Never give anything orally to an unconscious person.
- Become familiar with the proper techniques of artificial respiration; it may be necessary if a person's breathing has stopped or become impaired.

Specific First Aid Instructions

If the victim IS NOT breathing:

FIRST—Evaluate the surroundings of the victim. Protect yourself from pesticide exposure prior to and while giving assistance.

SECOND—Administer artificial respiration and call 911.

THIRD—Call the National Poison Center (1-800-222-1222).

FOURTH—Decontaminate the victim immediately; wash thoroughly and quickly. Speed is essential.

If the victim IS breathing:

FIRST—Evaluate the surroundings of the victim. Protect yourself from pesticide exposure prior to and while giving assistance.

SECOND—Decontaminate the victim immediately; wash thoroughly and quickly. Speed is essential.

THIRD—Call 911 if the victim has ill effects from the exposure.

FOURTH—Call the National Poison Center (1-800-222-1222).

If the pesticide has been spilled on the skin or clothing, remove any contaminated clothing immediately and thoroughly wash the skin with soap and water. Avoid harsh scrubbing, as this enhances pesticide absorption. Rinse the affected area with water, wash again, and rinse. Gently dry the affected area and wrap it in a loose cloth or blanket, if necessary. If chemical burns of the skin have occurred, cover the area loosely with a clean, soft cloth. Avoid the use of ointments, greases, powders, and other medications unless instructed by medical personnel.

Heavily contaminated clothing should be disposed of properly. If clothing is not heavily soiled, wash all contaminated clothing separately from any other laundry, in hot water, at a high water level, and with a heavy duty liquid detergent. Run the washer through a complete cycle with detergent and no clothes to remove pesticide residue from the washer drum before the next load of laundry. Store washed protective clothing separately from other clothes. Also, do not store protective clothing and equipment in pesticide storage areas.

If the pesticide has entered into the eyes, hold the eyelid open and immediately begin gently washing the eye with clean running water, so that the water flows away from the nose. If contact lenses are worn, remove and discard the contacts before beginning this process. Do not use chemicals or drugs in the eye wash water. Continue washing for 15 minutes. If only one eye is involved, avoid contaminating the other one. Flush under the eyelids with water to remove debris. Cover the eye with a clean piece of cloth and seek medical attention immediately.

If the pesticide has been inhaled, get the victim to fresh air immediately. However, do not attempt to rescue someone who is in an enclosed area unless you are wearing appropriate protective equipment. Have the victim lie down and loosen their clothing. Call 911. Keep the victim warm and quiet. If the victim is convulsing, watch their breathing and protect their head. Keep the chin up to keep air passages free for breathing. If breathing stops, administer artificial respiration. Call the National Poison Center (1-800-222-1222) after the victim is stabilized for further advice.

If the pesticide has been swallowed, contact the National Poison Center (1-800-222-1222) and provide them with the EPA registration number, product name, and approximate amount of material that was ingested. Call 911 immediately if the victim has symptoms from the exposure. If the pesticide has entered the mouth but has not been swallowed, rinse the mouth with large amounts of water. Inducing vomiting is rarely advised for any poisoning, including pesticide poisonings. Check the product label to demine the appropriate immediate action.

If a petroleum product (kerosene, gasoline, oil, lighter fluid, EC pesticides) **has been swallowed,** call the National Poison Center (1-800-222-1222) and 911 immediately for further instruction.

If a corrosive poison (a strong acid or alkali) **has been swallowed,** dilute with water or milk immediately. Consult the National Poison Center (1-800-222-1222) and 911 immediately. The victim may experience severe pain and have extensive mouth and throat burns. Fortunately, most commonly used pesticides are not corrosive, but some cleaners, disinfectants, and germicides fall into this category.

SAFE STORAGE OF PESTICIDES

- Read the label for specific storage instructions and precautions.
- Store pesticides in a clean, cool, dry, and well-ventilated building. Always lock the area to prevent entry by chil-

dren and untrained persons. Mark the storage facility with an appropriate warning sign.

- Maintain proper temperature control. For example, if emulsion-type materials freeze, the emulsion may be destroyed, resulting in loss of effectiveness and possible serious plant injury.
- To avoid the danger of cross-contamination, do not store herbicides with other pesticides.
- Keep dry materials above liquid materials.
- Do not store pesticides where food, water, feed, seeds, fertilizers, or personal protective clothing and equipment (such as respirators) can become contaminated.
- Store pesticides in their original containers. Never store pesticides in any food or drink containers.
- Do not remove the labels. Keep lids tightly closed.
- Check containers frequently for leaks.
- Clean up spilled chemicals promptly and properly. Dispose of broken or damaged containers and any pesticide waste in an approved and safe manner as directed on the product label.
- Keep an inventory of all chemicals. Mark each container with the year of purchase.
- Inform your local fire department of any chemicals (including fertilizers) stored in large quantity.

SAFE DISPOSAL OF PESTICIDES

- Read the pesticide label for specific disposal instructions.
- Avoid disposal problems by purchasing only the amount of material needed for one growing season. Do not stockpile.
- Use proper personal protective clothing and equipment when you dispose of pesticide wastes and containers.
- Mix only the amount of pesticide required for a particular application. If you mix too much, use the surplus by applying the material at the recommended rate to one of the crops listed on the label.
- Do not dump pesticides or pesticide rinsates on the ground or pour them down sinks, toilets, or other drains, including storm sewers.
- Pressure rinse or triple rinse empty pesticide containers with water. Pour the rinse water into the spray tank, making sure to drain the container for 30 seconds each time.
- After rinsing metal, plastic, or glass containers, puncture, break, crush, or in some way to render unusable. Where possible, recycle plastic containers through a Plastic Pesticide Container Recycling Program; in some states these are sponsored by the state's Department of Agriculture. Contact your state pesticide regulatory agency or extension office for further information. Otherwise disposal in a sanitary landfill is desirable if conducted in accordance with local regulations.
- If stated on the label and permitted by local ordinances, combustible containers can be burned. However, do not burn pesticide containers near residential areas or where the smoke can contact humans. Avoid exposure to the smoke; it may contain toxic vapors. Bury the ashes since they also may be toxic.
- Send large metal drums to a reconditioning company.
- Before disposing of pesticide concentrates, check with your state pesticide regulatory agency, which may provide disposal options for unwanted and outdated pesticide concentrates free of charge. For example, in Pennsylvania this can be accomplished by participating in the CHEMSWEEP program sponsored by the Department of Agriculture.
- Do not reuse empty pesticide containers for any purpose.
- Clean up thoroughly after handling and disposing of pesticides.

CURRENT STATUS OF RESTRICTED-USE PESTICIDES IN PENNSYLVANIA

Under the authority of the amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), applicators who apply restricted-use pesticides (RUPs) in the production of an agricultural crop must be certified as a private applicator or must work under the direct supervision of a certified applicator. Furthermore, only certified applicators can purchase restricted-use pesticides. The pesticide dealer is required by law to record the name, address, and certification number of the purchaser of RUPs, as well as the identity of the product, amount sold, and date of purchase. Either photo identification or two other acceptable forms of identification are required to be presented to the dealer when RUPs are delivered. Commercial and public pesticide applicators must be certified to use both general and restricted-use pesticide products.

RUPs include all pesticide products designated as restricted-use by the U.S. Environmental Protection Agency; however, for use to be legal, products must also be registered by the state. In addition, states may choose to assign restricted-use status to other products if it is deemed in the interest of the public health and welfare. States may also refuse to register a pesticide for use if they choose. If a pesticide is restricted-use, this status will be clearly marked on the label.

WORKER PROTECTION STANDARD FOR AGRICULTURAL PESTICIDES

In 1992, the U.S. Environmental Protection Agency (EPA) revised its Worker Protection Standard (WPS), which addresses the protection of agricultural workers from pesticide exposure (40 CFR Part 170). The WPS includes requirements designed to reduce the risks of illness or injury to agricultural workers and pesticide handlers from occupational or accidental exposure to pesticides in the production of agricultural plants on farms and in nurseries, greenhouses, and forests.

The WPS expands the scope of prior worker protection regulations to identify two types of agricultural employees:

- **Pesticide handlers**—those who handle agricultural pesticides (mix, load, apply, clean or repair contaminated equipment, act as flaggers, etc.), and
- **Agricultural workers**—those who perform tasks related to the cultiva-

tion and harvesting of plants on farms or in greenhouses, nurseries, or forests where pesticides are used.

The WPS holds growers/employers responsible for compliance. The regulations expand requirements for the employer to make sure that employees are provided with the following:

- Warnings about pesticide applications
- Clean and properly maintained personal protective equipment (PPE), which employers must ensure is worn
- Restrictions on reentry by personnel to treated areas (all pesticides used on farms and in forests, nurseries, and greenhouses have specific restricted-entry intervals (REIs) that are listed on the label under the "Agricultural Use Requirements" section)
- Decontamination facilities
- Pesticide safety training and information
- Notification of pesticide applications and information about the pesticide(s) used
- Maintained contact with handlers when applying highly toxic pesticides
- Emergency assistance when required
- A pesticide safety poster placed in an area where it can be seen easily by all workers and handlers
- Information about pesticide label safety for pesticide handlers and early entry workers
- A centrally located listing of recent pesticide applications made on the premises within the past 30 days

Under WPS, labels now include statements specifying personal protective equipment, restricted-entry intervals (REIs), and (on some pesticide labels) a requirement to provide both oral warnings and posting of treated areas. EPA developed these regulations with the non-English-speaking worker specifically in mind. Safety warnings, information, and training must be given in "a manner the worker can understand."

The Pesticide Safety Fact Sheet "EPA Worker Protection Standard for Agricultural Pesticides" from the Penn State Pesticide Education Program describes these requirements in some detail. It is available from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802; phone 814-865-6713, or online at **extension.psu.edu/pesticide=education/applicators/fact-sheets**.

CHEMICAL FUMIGATION

Chemical fumigation is utilized to varying degrees within the Mid-Atlantic region depending on location and berry crop grown. Soil fumigants are highly toxic chemicals that are introduced into soil as liquids but quickly volatilize upon release to move through the air spaces in treated soil. Fumigants are used most frequently for strawberry production where growers intend to maximize yield every year, especially in locations where practicing crop rotation is difficult or where disease, nematode, and/or annual weed pressure may be high. Chemical fumigation temporarily reduces the populations of disease pathogens, nematodes, and weed pests, giving the crop to be planted a "head start." This benefit from fumigating soil usually lasts for only one or two growing seasons since soil pathogens and pests can begin increasing in treated soil almost as soon as the crop is planted. The cost of these chemical applications can range from about $400 to $900 per acre. Costs for soil fumigation by custom applicators may often be double. Despite the drawbacks to soil fumigation, these treatments are extremely effective and can quickly return old sites to their full productive potential.

SOIL FUMIGATION CHEMICALS

Soil fumigants containing chloropicrin possess similarly high effectiveness against diseases caused by soilborne pathogens. Methyl bromide, 1,3-dichloropropene, or iodomethane are most effective against nematodes, followed by dimethyl disulfide, metam sodium, and chloropicrin. However, 1,3-dichloropropene does not provide disease or weed control benefits. Chloropicrin does not contribute to weed control. Metam sodium products, while controlling most weeds, provide very limited nutsedge control. Most soil fumigants can be applied using standard, chisel-type applicators. Some products, depending on formulation, can also be applied through drip irrigation. Metam sodium products are sometimes applied via overhead irrigation. The recommended application rates for soil fumigants are given in Table 3.3. A plastic tarp is used with most soil fumigant applications to limit escape of the material from treated soil. Soil fumigant application rates may often be reduced when new highly retentive tarp types are used, such as VIF (virtually impermeable film) or TIC (totally impermeable film). Use of VIF is increasingly required with some soil fumigants, such as methyl bromide.

All soil fumigants have specific, and often different, handling properties, special safety precautions, application rates adjusted for soil type, and aeration times following treatment. This information is explained in detail on the extensive product labels. Literature covering these topics may also be available from your pesticide dealer. Read all of these materials carefully. Be aware that most custom applicators will insist on proper site preparation prior to their arrival and may require payment for a minimum area.

NEW REGULATIONS CONCERNING FUMIGATION

Fumigants are very biologically active and produce gases that can readily move off site, so they can also be very dangerous to people and other organisms in the surrounding environment. *Labels for soil fumigants containing chloropicrin, dazomet, metam potassium, metam sodium, and methyl bromide were extensively revised in 2011* to require additional steps of fumigant applicators (called risk mitigation measures) to safeguard the general public, the applicators and handlers, and the environment. These requirements are discussed on current fumigant labels. *Reading and understanding the new soil fumigant labels is critically important. Additional revisions to these new soil fumigant labels are being developed, further increasing the importance for growers to study the labels and visit EPA's website.* Key changes already in effect include the following:

- All chemical fumigants are now "restricted use." Previously, metam sodium, metam potassium, and dazomet were considered general use materials.
- Soil fumigant applicators must write a fumigant management plan (FMP)

Table 3.2. General (G) and restricted-use (R) pesticides labeled for use on strawberries (sb), brambles (br), blueberries (bl), gooseberries, and currants.

Pesticides are legal for use in PA, WV, MD, DE, NJ, and VA, except in the following cases:
- *Stinger herbicide (clopyralid) may be used on strawberries only in New Jersey, Maryland, Pennsylvania, and Virginia.*
- *Guthion use is no longer allowed as of September 30, 2012.*
- *Endosulfan (Thionex) use is being phased out.*
- *Karmex is labeled for blueberries only in New Jersey and Maryland.*

			Preharvest Interval (Days)					
Trade Name	Chemical Name	Use Status	Strawberries	Raspberries	Other Brambles	Blueberries	Gooseberries, Currants	REI (hr = hours, d = days)
HERBICIDES								
Aim	carfentrazone-ethyl	G	0	15	15	0	0	12 hr
Amine 4, Formula 40	2,4-D	R (NJ), G	not spec.[a]	—	—	—	—	48 hr
Callisto	mesotrione	G	—	prebloom	prebloom	prebloom	—	12 hr
Casoron	dichlobenil	G	—	not spec.[a]	not spec.[a]	not spec. [a]	not spec.[a]	12 hr/24 hr[b]
Chateau	flumioxazin	G	not spec.[a]	—	—	7[a]	—	12 hr
Dacthal	DCPA	G	prebloom	—	—	—	—	12 hr
Devrinol	napropamide	G	prebloom	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a,c]	24 hr
Fusilade[d]	fluazifop-P-butyl	G	—	365	365	365	365	12 hr
Gallery[d]	isoxaben	G	—	365	365	365	365	12 hr
Gramoxone Inteon	paraquat	R	21	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a]	24 hr
Greenmatch	d-limonene	G	prefruit[e]	prefruit[e]	prefruit[e]	prefruit[e]	prefruit[e]	4 hr
Karmex, NJ and MD	diuron	G	—	—	—	not spec.[a]	—	12 hr
Kerb	pronamide	R	—	—	—	not spec.[a]	—	24 hr
Poast	sethoxydim	G	7	45	45	30	—	12 hr
Princep	simazine	G	—	prefruit	prefruit	prefruit	—	12 hr
Prowl H_2O	pendimethalin	G	35	—	—	—	—	24 hr
Rage	carfentrazone + glyphosate	R	—	15	15	14	14	12 hr
Rely	glufosinate	G	—	—	—	14	14	12 hr
Roundup, Touchdown	glyphosate	G	14	14	14	14	14	4 hr, 12 hr[f]
Sandea	halsulfuron-methyl	G	—	—	—	14	—	12 hr
Scythe	pelargonic acid	G	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a,c]	12 hr
Select Max	clethodim	G	4	7	7	14	14	24 hr
Sinbar	terbacil	G	110	70	70	not spec.[a]	—	12 hr
Snapshot	trifluralin + isoxaben	G	—	365	365	365	365	12 hr
Solicam	norflurazon	G	—	60	60	60	—	12 hr
Spartan	sulfentrazone	G	preplant	—	—	—	—	12 hr
Stinger[g]	clopyralid	G	30	—	—	—	—	12 hr
Surflan	oryzalin	G	—	not spec.[a]	not spec.[a]	not spec.[a,h]	not spec.[a]	24 hr
Touchdown	glyphosate	G	—	14	14	14	14	12 hr
Ultra Blazer	acifluorfen	G	60	—	—	—	—	48 hr
Velpar	hexazinone	G	—	—	—	90, 450[i]	—	48 hr
FUNGICIDES/BACTERICIDES								
Abound	azoxystrobin	G	0	0	0	0	0	4 hr
Aliette	fosetyl-Al	G	0.5	60	60	0.5	—	12 hr
Bravo	chlorothalonil	G	—	—	—	42	—	12 hr
Cabrio	pyraclostrobin	G	0	0	0	—	0	12 hr
Captan	captan	G	0	3	3	0	—	24 hr sb/1–4 d br and bl[j]
Captevate	captan + fenhexamid	G	0	3	—	0	—	24 hr sb/48 hr br and bl
Elevate	fenhexamid	G	0	0	0	0	0	12 hr
Evito	fluoxastrobin	G	1	—	—	—[k]	—	12 hr
Flint	trifloxystrobin	G	0	—	—	—	—	12 hr
Indar	fenbuconazole	G	—	—	—	30	—	12 hr
Kocide	copper hydroxide	G	0	0	0	0	0	24 hr

CONTINUED

Table 3.2. General (G) and restricted-use (R) pesticides labeled for use on strawberries (sb), brambles (br), blueberries (bl), gooseberries, and currants, continued.

			Preharvest Interval (Days)					
Trade Name	Chemical Name	Use Status	Strawberries	Raspberries	Other Brambles	Blueberries	Gooseberries, Currants	REI (hr = hours, d = days)
Lime Sulfur	calcium polysulfide	G	—	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a]	48 hr
Omega	fluazinam	G	—	—	—	30	30	48 hr, 3 d[l]
Orbit	propiconazole	G	0	30	30	30	30	12 hr
Phostrol, others	phosphorous acid	G	not spec.[a]	not spec.[a]	not spec.[a]	not spec.[a]	—	4 hr
Ph-D	polyoxin D zinc salt	G	0	—	—	—	—	4 hr
Pristine	pyraclostrobin + boscalid	G	0	0	0	0	0	12 hr
Procure	triflumizole	G	1	—	—	—	—	12 hr
Quash	metconazole	G	—	—	—	7	7	12 hr
Quilt Xcel	azoxystrobin + propiconazole	G	0	30	30	30	30	12 hr
Quintec	quinoxyfen	G	1	—	—	—	—	12 hr
Rally	myclobutanil	G	0	0	0	—	0	24 hr
Ridomil Gold SL	mefenoxam	G	0	45	45	0	0	48 hr
Rovral	iprodione	G	prebloom	0	0	—[m]	0	24 hr
Scala	pyrimethanil	G	1	—	—	—	—	12 hr
Switch	cyprodinil + fludioxinil	G	0	0	0	0	0	12 hr
Tanos	famoxadone + cymoxanil	G	—	0	0	—	—	12 hr
Thiram	thiram	G	3	—	—	—	—	24 hr
Tilt	propiconazole	G	0	30	30	30	30	12 hr
Topsin M	thiophanate-methyl	G	1	—	—	—	—	24 hr
Ziram	ziram	G	—	—	—	not spec.[a,n], 14	—	48 hr
INSECTICIDES/MOLLUSCIDES								
Actara	thiamethoxam	G	3	3	3	3	3	12 hr
Altacor	chlorantraniliprole	G	1	3	3	1	1	4 hr
Athena	bifenthrin + avermectin B1	R	3	—	—	—	—	12 hr
Admire Pro	imidacloprid	G	14 (soil) 5 (foliar)	7 (soil) 3 (foliar)	7 (soil) 3 (foliar)	7 (soil) 3 (foliar)	7 (soil) 3 (foliar)	12 hr
Asana XL	esfenvalerate	R	—	7	7	14	—	12 hr
Assail	acetamiprid	G	1	1	1	1	1	12 hr
Avaunt	indoxacarb	G	—	—	—	7	7	12 hr
Aza-Direct	azadirachtin	G	0	0	0	0	0	4 hr
Brigade	bifenthrin	R	0	3	3	1	1	12 hr
Confirm	tebufenozide	G	—	14	14	14	14	4 hr
Coragen	chlorantraniliprole	G	1	—	—	—	—	4 hr
Courier	buprofezin	G	3	—	—	—	—	12 hr
Danitol	fenpropathrin	R	2	3	3	3	3, 21[o]	24 hr
Deadline	metaldehyde	G	not spec.[p]	not spec.[p]	not spec.[p]	not spec.[p]	—	12 hr
Delegate	spinetoram	G	—	1	1	3	3	4 hr
Diazinon	diazinon	R	5	—	—	7	—	3 d sb, 5 d bl
Dibrom	naled	R[q]	1	—	—	—	—	48 hr
Dipel, others	Bt	G	0[r]	0[r]	0[r]	0[r]	0[r]	4 hr
Entrust	spinosad	G	1	1	1	3	3	4 hr
Esteem	pyriproxyfen	G	2	—	—	7	7	12 hr
Hero	zeta-cypermethrin + bifenthrin	R	—	3	3	1	—	12 hr
Imidan	phosmet	R (NJ), G	—	—	—	3	—	24 hr
Intrepid	methoxyfenozide	G	3	—	—	7	7	4 hr
Lannate	methomyl	R	—	—	—	3	—	48 hr

CONTINUED

Table 3.2. General (G) and restricted-use (R) pesticides labeled for use on strawberries (sb), brambles (br), blueberries (bl), gooseberries, and currants, continued.

			Preharvest Interval (Days)					
Trade Name	Chemical Name	Use Status	Strawberries	Raspberries	Other Brambles	Blueberries	Gooseberries, Currants	REI (hr = hours, d = days)
Lorsban	chlorpyrifos	R, G[q]	prebloom	—	—	—	—	24 hr
Malathion	malathion	G	3	1	1	1	3, 1[s]	12 hr
M-Pede	insecticidal soap	G	0	0	0	0	0	12 hr
Mustang	cypermethrin	R	—	1	1	1	1	12 hr
Mustang Max	zeta-cypermethrin	R	—	1	1	1	1	12 hr
Platinum	thiamethoxam	G	50	—	—	75	75	12 hr
Provado	imidacloprid	G	7	3	3	3	3	12 hr
Pyganic	pyrethrins	G	0	0	0	0	0	12 hr
Radiant	spinetoram	G	1	—	—	—	—	4 hr
Rimon	novaluron	G	1	—	—	8	8	12 hr
Sevin	carbaryl	G	7	7	7	7	7	12 hr
Sluggo	iron phosphate	G	0	0	0	0	0	0 hr
Spintor/Success	spinosad	G	1	1	1	3	3	4 hr
Surround	kaolin clay	G	0	0	0	0	0	4 hr
Synapse	flubendiamide	G	1	—	—	—	—	12 hr
Thionex 50WP(see heading)	endosulfan	R	12[t]	—	—	—	—	15, 12, or 22 d[u]
Voliam Flexi	thiamethoxam + chlorantraniliprole	G	3	—	—	—	—	12 hr
MITICIDES								
Acramite	bifenazate	G	1	1	1	—	—	12 hr
Agri-Mek	abamectin	R	3	—	—	—	—	12 hr
Kanemite	acequinocyl	G	1	—	—	—	—	12 hr
Oberon	spiromesifen	G	3	—	—	—	—	12 hr
Portal	fenpyroximate	G	1	—	—	—	—	12 hr
Savey	hexythiazox	G	3	3	3	—	—	12 hr
Temprano	abamectin	R	3	—	—	—	—	12 hr
Vendex	fenbutatin oxide	R	1	—	—	—	—	48 hr
Zeal	etoxazole	G	1	0	0	—	—	12 hr

— = not labeled for use on the crop.

a. "Not spec." indicates that a specific preharvest or reentry interval is not specified in terms of days or hours; however, use may be limited to certain times of the year or crop development stages.
b. The REI is 12 hours for granular formulations of Casoron but 24 hours for the CS formulation in horticultural operations.
c. Currants are the only *Ribes* crop on which Devrinol and Scythe can legally be used.
d. Fusilade and Gallery are for use only on nonbearing plantings.
e. For spot treatments with Greenmatch, the PHI is 7 days.
f. Different formulations containing the same active ingredient have different reentry intervals.
g. MD, NJ, PA, and VA have Special Local Needs (Section 24C) labels for the use of Stinger on strawberries.
h. Not for use in lowbush blueberries.
i. Velpar has a 90-day PHI for highbush blueberries and a 450-day PHI for lowbush blueberries.
j. Various formulations of captan have different REIs ranging from 24 hours to 4 days.
k. Evito is labeled for use on lowbush blueberries with a 1-day PHI.
l. Different REIs are listed for different activities.
m. Certain formulations of the active ingredient iprodione are labeled for use on blueberries but are not included in other tables in this guide due to issues with phytotoxicity.
n. The general Ziram label states that applications should be made no later than 3 weeks after full bloom, but NJ's 24C label specifies a 14-day PHI.
o. The PHI for Danitol is 3 days for gooseberries and 21 days for currants.
p. No preharvest interval is specified. Deadline is not to come in direct contact with the crop.
q. Dibrom was previously general use. Lorsban may be restricted or general use depending on the formulation.
r. Individual state regulations may vary.
s. The PHI is 3 days for gooseberries and 1 day or 3 days for currants, depending on the formulation.
t. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, on blueberries after July 31, 2015, or on perennial (matted-row) strawberries after July 31, 2016. The PHI is 12 days for perennial strawberries. For blueberries, Thionex should be applied 8 weeks after harvest is complete.
u. The REI is 15 days for lowbush blueberries, 12 days for perennial strawberries, and 22 days for highbush blueberries.

that outlines how the application will be made and describes plans to address problems should any arise. Custom applicators must provide growers with a copy of the FMP, which must be maintained for a period of two years.

- Practices previously recommended to improve efficacy and reduce off-gassing are now requirements, such as proper calibration, soil tillage before application, fumigating when soil temperature and moisture levels are within the proper ranges, etc.
- Maximum application rates are being reduced in some instances and untarped applications for some materials can no longer be made.
- Respiratory protection requirements for those involved with fumigant application or tarp perforation or removal have been significantly expanded and include medical evaluation and fit-testing for respirator use.
- The 48-hour "reentry interval" following soil fumigant application has been changed into a 5-day "entry restricted period."
- Training programs are being developed by the product registrants for applicators and handlers. In the future, product registrants will also provide training on information that is required to be provided. This includes training of first responders on handling fumigant exposure incidents in areas where fumigation is commonly used and information to the general public on fumigant safety issues.

Additional new label requirements to be enacted soon include the establishment and posting of restricted-entry buffer zones around application sites, among other changes. At this point, growers are encouraged to prepare for changes and provide input on their needs to regulatory agencies as the timeline and details of new requirements are being worked out. Updates and templates of required forms are available on EPA's website at **www.epa.gov /opp00001/reregistration/soil_ fumigants.**

SITE PREPARATION FOR CHEMICAL FUMIGATION AND TREATMENT GUIDELINES

A good soil fumigation job is important in order to extend the productive life of the planting. Soil fumigation treatments should be planned well in advance so that the site can be prepared properly. Several rules apply to most treatments.

1. Prepare the soil by deep plowing followed by disking. The purpose is to loosen the soil throughout what will be the crop rooting zone and to thoroughly incorporate all plant residues. Do this at least 3 weeks in advance of fumigation so that buried plant residues begin decomposing. Remove all woody or bulky accumulations of plant residues and large rocks from the site. These will foul the chisel applicators, decrease the effectiveness of the job, increase the hazard to workers who must clear them, and can cause a custom applicator to legally withdraw from a contract job.
2. If the soil is dry one week prior to treatment, thoroughly wet down the soil to at least 6 inches deep by sprinkler irrigation. Do not attempt to fumigate soil that is too wet or too dry. At the 6- to 8-inch level, a handful of soil should not clump tightly when squeezed, but it should have enough moisture to feel cool in the hand and remain in a loose clump when it is released. Soil that feels warm to the touch or that is crumbly and dusty is too dry. Some moisture in the soil encourages weed seed germination and is necessary for the fumigant to kill nematodes and fungi. Soil that is saturated will limit movement of fumigants through soil so that some of the soil to be treated may not be exposed to the product.
3. Soil temperatures at the time of treatment should be above 40°F at the 5- to 6-inch depth to allow for adequate volatilization of the fumigant but below 80°F to avoid too rapid an escape of the chemical. Optimal soil temperatures vary among different fumigants. Consult the label for the fumigant you are using for its specific temperature requirements.
4. Chisel fumigants in at least 10 to 12 inches deep with the shanks set 8 to 12 inches apart for broadcast treatments over the whole planting site. Because strip or row fumigation only treats a portion of the field, less chemical is used per field acre, and it is useful for annual strawberry production systems. However, this practice is not recommended for perennial systems where treated areas could be recolonized over time.
5. Soil should be sealed as stated on the product label. Leave treated sites undisturbed for at least 5 to 7 days.
6. Aerate treated sites to allow any residual fumigant and ammonia (a temporary side effect of fumigation) to escape before planting. Aeration times vary with the type of material used, soil type, temperature, and moisture level. Check the label for details. At least 14 to 21 days should pass between the application of most soil fumigants and the time a crop is planted. Details are available on the manufacturer's label. A simple lettuce quick test can be done to determine whether planting in fumigated soil is safe. Collect a soil sample from the treated field (do not go below the treated depth). Place the sample in a glass jar with a screw-on lid. Firmly press numerous seeds of a small-seeded vegetable crop (lettuce, radish, etc.) on top of the soil (moisten if necessary) and tighten the lid securely. Repeat the process in another jar with nonfumigated soil to serve as a check. Observe the jars within 1 to 2 days. If the seeds have germinated, planting in the field is safe. If the seeds have not germinated in the fumigated sample and have germinated in the nontreated sample, then the field is not safe to plant. Wait and retest.
7. Fumigation kills most weed seeds, but it can also stimulate the germination of some species, such as Carolina geranium, velvetleaf, and morning glory. Use of chloropicrin has been shown to stimulate yellow and purple nutsedge emergence. Treat these problem weeds with herbicides before they become established.

Table 3.3. Fumigants and spectrums of activity.

All fumigants are now restricted use. This table is intended to provide information on allowable application methods for different fumigants and the purpose each material serves. Additional options for application and/or restrictions may be specified on the product label. Information that allows the applicator to refine, decrease, or increase rates may also be provided on the product label or can be obtained from a qualified fumigation service provider or dealer. When rates vary for different types of applications on the label, rates are presented for an option that would make effective use of the fumigant chosen. This table does not provide details on every allowable option. Information is current as of July 1, 2012.

Common Name	Trade Name	Allowable Application Methods	Rate as Stated on Label* (see also next column)	Conditions Under Which Listed Rate Applies	For Control of:		
					Nematodes	Fungi	Weeds
METAM-SODIUM	Vapam HL	Shank, chisel, etc.; drip irrigation; solid-set irrigation, others listed	37.5–75.0 gal per treated acre	All listed application methods	Yes	Yes	Yes
Comments: Water-soluble liquid that decomposes to a gaseous fumigant. Efficacy affected by soil moisture, temperature, texture, and organic matter content. May be less effective on nematodes than 1,3-D and possibly iodomethane.							
METAM-POTASSIUM	K-Pam HL	Shank, chisel, etc.; drip irrigation; solid-set irrigation, others listed	30–62 gal per treated acre	All listed application methods	Yes	Yes	Yes
Comments: Water-soluble liquid that decomposes to a gaseous fumigant. Efficacy affected by soil moisture, temperature, texture, and organic matter content. May be less effective on nematodes than 1,3-D and possibly iodomethane.							
1,3-DICHLOROPROPENE	Telone II	Shank, chisel, etc. May not be applied through any type of irrigation system	27–35 gal per acre (label states product may be concentrated in the row)	Annual or perennial plantings on mineral soils	Yes	No	No
Comments: Liquid that diffuses as a gas through soil. Effective against nematodes and insects. Rates vary with soil texture; efficacy strongly affected by soil moisture and temperature.							
	Telone EC	May be applied only through a drip system	9–24 gal per acre broadcast equivalent	Annual or perennial plantings on mineral soils	Yes	No	No
Comments: Liquid that diffuses as a gas through soil. Effective against nematodes and insects. Rates vary with soil texture; efficacy strongly affected by soil moisture and temperature. If the material is applied only to beds and not row middles, rates must be reduced proportionately. This can be calculated as follows: product rate x bed width/ row spacing.							
CHLOROPICRIN	NutraPic	Shank, chisel, etc., if tarped; drip irrigation, but not any other type of irrigation; if through drip and not tarped, tape must be at least 5 inches deep	150–350 lb (10.9–25.5 gal) per acre broadcast equivalent	Shank injection if tarped	No	Yes	No
			100–300 lb (7.1–21.9 gal) per acre broadcast equivalent	Through drip system whether tarped or not	No	Yes	No
Comments: May be applied with other materials such as metam-sodium to increase spectrum of control. If the material is applied only to beds and not row middles, rates must be reduced proportionately. This can be calculated as follows: product rate x bed width/row spacing.							
1,3-DICHLOROPROPENE + CHLOROPICRIN	Telone C17	Shank, chisel, etc.; no chemigation allowed	32.4–42.0 gal per acre if tarped (label states product may be concentrated in the row)	If tarped; allowed rates are lower if not tarped	Yes	Yes	No
	Telone C35	Shank, chisel, etc.; no chemigation allowed	39.0–50.0 gal per acre if tarped (label states product may be concentrated in the row)	If tarped; allowed rates are lower if not tarped	Yes	Yes	No
Comments: Liquid that diffuses as a gas through soil. Added chloropicrin increases efficacy against soilborne fungi. Rates vary with soil texture; efficacy strongly affected by soil moisture and temperature.							

CONTINUED

Table 3.3. Fumigants and spectrums of activity, continued.

Common Name	Trade Name	Allowable Application Methods	Rate as Stated on Label* (see also next column)	Conditions Under Which Listed Rate Applies	For Control of:		
					Nematodes	Fungi	Weeds
1,3 DICHLOROPROPENE + CHLOROPICRIN	InLine	May only be applied through a drip system and a tarp must be applied	29.0–38.4 gal per acre broadcast equivalent	Must be tarped	Yes	Yes	No
Comments: Liquid that diffuses as a gas through soil. Added chloropicrin increases efficacy against soilborne fungi. Rates vary with soil texture; efficacy strongly affected by soil moisture and temperature. If the material is applied only to beds and not row middles, rates must be reduced proportionately. This can be calculated as follows: product rate x bed width/row spacing.							
Note: As of March 20, 2012, sales of all Midas formulations were suspended. Product registration was being maintained as of this writing. Information on Midas is retained in this table in the unlikely event that Midas sales resume.							
IODOMETHANE + CHLOROPICRIN (Strawberries only)	Midas 33:67	Shank, chisel, etc., either broadcast or applied to beds; either standard tarps or highly retentive films must be applied	11.6–16.6 gal (175–250 lb) per acre (reduce rates proportionately when applied only to beds)	Rate is applicable only if highly retentive film is used; standard film requires higher rates	Yes	Yes	Yes
	Midas 50:50	Shank, chisel, etc., either broadcast or applied to beds; either standard tarps or highly retentive films must be applied	9.4–12.6 gal (175–250 lb) per acre (reduce rates proportionately when applied only to beds)	Rate is applicable only if highly retentive film is used; standard film requires higher rates	Yes	Yes	Yes
	Midas 98:2	Shank, chisel, etc., either broadcast or applied to beds; either standard tarps or highly retentive films must be applied	5.3–9.3 gal (175–250 lb) per acre (reduce rates proportionately when applied only to beds)	Rate is applicable only if standard film is used; call manufacturer for recommendation if using highly retentive film	Yes	Yes	Yes
	Midas EC Bronze	May only be applied through buried drip tape to already-tarped areas	9.4–12.6 gal (150–200 lb) per acre (reduce rates proportionately when applied only to beds)	Rate is applicable only if highly retentive film is used; standard film requires higher rates	Yes	Yes	Yes
	Midas EC Gold	May only be applied through buried drip tape to already-tarped areas	11.6–13.3 gal (175–200 lb) per acre (reduce rates proportionately when applied only to beds)	Rate is applicable only if highly retentive film is used; standard film requires higher rates	Yes	Yes	Yes
Comments: Liquid that diffuses as a gas through soil. Added chloropicrin increases efficacy against soilborne fungi. Waiting period between soil fumigation and planting increases from 7–14 days to 14–21 days when VIF or higher density tarps are used. If the material is applied only to beds and not row middles, rates must be reduced proportionately. This can be calculated as follows: product rate x bed width/row spacing.							
DIMETHYL DISULPHIDE (Strawberries or blueberries only)	Paladin	Shank, chisel, etc., either broadcast or applied to beds; may be used only under highly retentive films	35.0–51.3 gal (310–455 gal) broadcast per treated acre	Rates within range depend on whether nematodes, diseases, or weeds are the primary target	Yes	Yes	Yes

* Rate would be applied to an acre of land if broadcast. If the material is applied only to beds and not row middles, rates must be reduced proportionately. This can be calculated as follows: product rate x bed width/row spacing.

8. For annual plasticulture strawberries, fumigation must be completed at least 21 days before planting. The optimal planting date varies widely within the region and also depends on plant type used (see Chapter 6: Strawberries). Thus, fumigation may need to be completed as early as early summer in cooler areas of Pennsylvania when using dormant plants or as late as early fall for warmer areas of Virginia when using plug plants. The best timing for fumigation is early fall if planting matted-row strawberries, brambles, or blueberries in the spring, as soil conditions that satisfy the specific temperature and moisture requirements of fumigants are more likely to exist in the fall. The usually wet and often prolonged cool spring conditions in the region often cause delays in fumigation attempts in the spring. If fumigation is done in the fall prior to spring planting, a winter cover crop of small grains or a permanent between-row sod cover can be seeded after aeration.
9. Make sure to plant disease-free crops and use good management practices to avoid reintroducing pathogens.

CHAPTER 4

Weed Management

CONTENTS

Introduction 31
Weed Control Measures 31
Weed Identification 31
Cultural Practices for Weed Management .. 32
Site Selection and Preparation 32
Crop Rotation 32
Mechanical Management 32
Importance of Timing 32
Mulches 33
Alleyway Management 33
Herbicides for Weed Control 33
Terminology 36
Determining the Correct Rate 36
Application Pointers 36
Influence of Soil and Water (Rainfall and Irrigation) on Herbicides 37
Problem Weeds 39

INTRODUCTION

Weeds harm crops by

1. competing for light, water, nutrients, and space;
2. acting as hosts for harmful insects, diseases, and nematodes, and as cover for undesirable animals;
3. reducing air circulation within a planting which can promote certain diseases;
4. reducing quality and/or yield; and
5. impeding harvest.

WEED CONTROL MEASURES

Complete eradication of any weed is difficult or impossible. Established perennial weeds are among the most difficult to kill and often require diverse strategies for successful management. Cultural and chemical means are suited to different situations, and often both are needed.

WEED IDENTIFICATION

Weed identification is the first step in a successful weed control program. In addition, knowledge of the life cycle of problem weeds is extremely valuable, as it allows us to use control measures in ways and at timings that will provide maximum effectiveness. Conversely, using control measures in a more hit-or-miss fashion can waste time and money and, perhaps worst of all, may allow problems with weeds to become worse. Use control measures that are a match with targeted susceptible stages in the weed's life cycle. Weeds can be divided into three groups based on life cycle.

Annuals are weeds that live less than one year. There are summer annuals and winter annuals. Summer annuals germinate in the late spring and early summer, flower and set seed in late summer or early fall, and die when it gets cool. Winter annuals germinate in the fall or early spring, flower and set seed in late spring, and die when it gets hot. Annual weeds are easier to manage than perennial or biennial weeds using cultural strategies because they reproduce only by seeds. For example, timely cultivation or preventing annual weeds from producing seeds can be very effective management strategies.

Biennials are weeds that live longer than one year but less than two full years. Biennials often grow vegetatively during the first year, then flower and die during the second year. There are relatively few biennial weeds in our area. Yellow rocket and bull thistle are two of our more common ones.

Perennials are weeds that live longer than two years, often reproducing vegetatively by horizontal shoots, roots, nutlets, or rhizomes, as well as by seed. They may be herbaceous or woody. Because of their perennial life cycle and ability to reproduce by multiple means, perennial weeds are the most difficult to manage. Perennial production, as for blueberries, raspberries, gooseberries, currants, and jostaberries, tends to favor the establishment of perennial weeds because minimal soil disruption allows plants to grow undisturbed. Strawberries, when grown in a perennial system, also can favor the establishment of perennial weeds. It can be extremely difficult to control perennial weeds once the berry planting is established, so controlling them before planting is the best approach by far.

Weeds also can be divided into three botanical groups. Differences in various characteristics of these three groups affect the effectiveness of weed management measures and how and when they should be used.

Grasses are in a single botanical plant family (Poaceae) and have jointed stems and leaves with parallel veins that are divided into a blade and a sheath that wraps around the stem. The seedhead forms from a flower cluster called a spike which can be further branched into a panicle consisting of many spikelets. Grasses can be annuals or perennials depending on species.

Sedges appear similar to grasses at a glance, but they can be differentiated from grasses by their distinctly triangular stem. Leaves are narrow with parallel veins, but they are not divided into a blade and sheath. The seedhead is in the form of a spike or many-branched spikelets. Sedges can be annuals or perennials. Yellow nutsedge, a perennial sedge, is probably the most well-known weed in this category within the Mid-Atlantic area.

Broadleaf weeds are in a large collection of diverse plant families and have wide leaves. They have seeds that easily

split into two "halves" since they are dicots (will produce seedlings with two cotyledons), as opposed to grass seeds that will remain in one portion when opened. Broadleaf weeds can be annuals, biennials, or perennials.

CULTURAL PRACTICES FOR WEED MANAGEMENT

Advance planning and good cultural practices can reduce many weed problems and improve effectiveness of measure used. All options should be carefully evaluated for suitability on your farm prior to using them.

Site Selection and Preparation

Good site selection is an important weed management strategy. Select a site with minimal weeds. Conduct a weed survey and identify the weeds in the field before planting. Control the weeds in the site prior to planting. It is especially important to get difficult perennial weeds under control before planting. Success may require action for only the year prior to planting or for several years before your crop is established.

Site selection also influences the health of the planting. Vigorous crop plants on a suitable site can outcompete many weeds, but crops established on a site that is marginal may lose the race. Weeds are often better foragers for nutrients and water, and there is always a weed of a different species that can tolerate (or even prefer) poor conditions, whatever they might be.

Green manure crops are valuable for weed suppression. Select green manures that establish quickly and have large, aboveground canopies, such as sudangrass or hairy vetch. For more information on selecting a green manure crop, see Chapter 2: Soil Nutrition and Management for Berry Crops. Once plantings are in, consider sowing areas in the field where bare ground is not desired to a cool-season perennial grass that will not compete vigorously with the crop but will suppress weeds. Where a perennial grass sod is not used, consider sowing a small grain as a winter cover crop to suppress annual weeds.

Crop Rotation

Many difficult perennial weeds such as Canada thistle, bindweed, and yellow nutsedge can be controlled by growing a row crop such as corn or soybeans one or two years prior to the small fruit crop. Herbicides labeled for use in these crops, as well as the intense competition that they provide, can produce excellent control of many perennials. Be sure to double-check replant restrictions for herbicides used on any crop preceding the small fruit crop. Glyphosate-tolerant corn and soybeans in rotation would present no potential herbicide carryover. Metolachlor (Dual, other formulations) can be used in corn and soybeans and provides excellent control of yellow nutsedge. Stinger (clopyralid) can be used in corn and small grains to control Canada thistle. Many other examples of crop/herbicide combinations that will result in perennial weed control exist. In many annual vegetable crops, practicing continuous cultivation can provide a level of weed control that will have benefits in small fruit plantings that follow.

Mechanical Management

Timely cultivation can be used to manage most weeds, though there are a few cautionary notes. It is important to identify the weeds in an area before using tillage. In one trial, repeated tillage was very effective for managing Canada thistle, while in minimally tilled plots, Canada thistle became dominant. However, in some instances, tillage can actually make a weed problem worse by spreading the weed if care isn't taken, as is the case with yellow nutsedge. Another factor to consider when using cultivation is the location of crop roots. Avoid damaging crop roots with cultivation. Strawberry and blueberry roots are especially shallow.

Perennial weeds can be controlled without herbicides, but success requires diligence and an understanding of the weed's reproductive cycle. Primary tillage can be used for suppressing perennial weeds, including Canada thistle and field bindweed. Repeated tillage can be useful for suppressing all weed types (annual, biennial, perennial, grasses, sedges, and broadleaf weeds). Most perennial weeds reproduce vegetatively as well as by seed with vegetative reproductive structures such as nutlets, bulbs, rhizomes, or tubers.

Repeated tillage drags perennial weeds' vegetative reproductive structures to the soil surface and exposes them to drying in midsummer and freezing in winter. However, you must take into account that tillage generally has a negative effect on soil health, including decreasing the organic matter content of the soil.

Weeds with extensively spreading root systems can starve. Emerging shoots use food stored in the roots to grow leaves. The shoot uses food from the root for the first 7 to 10 days after emergence, and begins to send food back to the root after 10 to 14 days. Till the field within 10 days of emergence of the weed to prevent the food supply in the root from being replaced. Continue to repeat the tillage until no regrowth occurs. Be diligent. The control of established perennial weeds using tillage will require months of regular, timely tillage operations. A single missed tillage can nullify months of effort. Cropping options are limited during the tillage period, and the field is exposed to erosion by wind and water during the entire period.

Repeated mowing is another cultural tool for managing weeds. Mowing works by decreasing the competitive ability of weeds and also can prevent weeds from producing seeds when timed correctly. Mowing should take place before weeds set seed, or much of the benefit of mowing will have been lost.

Importance of Timing

Critical Times for Weeds

Mechanical means for managing weeds are almost always more effective when weeds are small. Managing weeds at this time is valuable because they do not have the chance to become established, thus avoiding future problems. With perennial weeds that have vegetative reproductive structures, weed control measures must be taken during the period of the year when these structures are produced.

In no case should weeds be allowed to go to seed. Many weeds can produce 10,000 to more than 100,000 seeds per plant. Most will be "hard" seed that will not germinate for several years. The

weed seeds from one prolific year of weed seed production will take many years to be depleted. Preventing seed production of new and hard-to-control weeds is very important. Also, suppress perennial weeds, regardless of the time of year, to prevent them from establishing.

Critical Times for the Crop

Critical times during the growing season for managing weeds in matted-row strawberries have been studied. A key time for weed management is in the first few months during plant establishment. When weeds were not managed for longer than one month following planting, yield and runner production were lower than when plots were kept weed free during the same time. When weeds were not managed late in the growing season (September), there was little effect on yield and the number of runners compared to when plots were kept weed free during the same time. While this indicates that early season weed management is most critical when establishing a new planting, key times of the year for weed management may vary depending on the weed species typically encountered and on soil moisture levels. In the study, predominant weeds included yellow nutsedge, common groundsel, purslane, and numerous grass species. If, for example, common chickweed was predominant, then late-season weed management may have been equally as important as early season weed management.

With perennial crops as well, the period of establishment is a critical time for weed control, though the period of establishment is years rather than just months for strawberries. Newly planted crops rarely can compete with vigorous weeds, which deprive them of nutrients, water, and sunlight. Crops that suffer greatly from competition with weeds may take years longer to reach full production or may never reach full production at all.

Mulches

Mulches control annual weeds and provide additional horticultural benefits in many fields. When using mulch for weed control, apply the mulch 3 to 4 inches thick when the rows are weed free. Thinner layers of mulch may not smother emerging weeds. All organic mulches break down over time and tie up important nutrients, so the use of mulch may require additional fertilizer. Reapply mulches annually or when needed to maintain weed suppression. Choose mulch products such as sawdust or wood chips. Avoid mulches such as straw that provide a favorable environment for rodents such as field mice and voles that may damage blueberries.

In one study, commercially available planter's paper was found to be effective for suppressing weeds during the establishment year of matted-row strawberries as compared to not using mulch. The plastic used in plasticulture strawberry production can be effective for managing weeds within the strawberry row. Be aware that light-transmitting plastics are not effective for managing weeds without the use of fumigant prior to laying the plastic. In a trial using a semitransparent blue plastic, weeds grew so well that they levitated the plastic, resulting in the strawberry plants being swallowed underneath the plastic. Fabric weed barriers also are a good option for suppressing weeds and are used by a number of black raspberry and blackberry growers. Plastic mulches could be used similarly. Use of plastic mulches and weed barriers in bramble plantings is discussed further in Chapter 8: Brambles.

Whether or not straw mulch is used for winter protection in strawberry fields, straw may be placed in the alleyways of strawberries in the spring in order to offer some weed control. Straw is also commonly used in bramble plantings during the establishment year to suppress weeds. Straw should be removed from these plantings after the first year because it can promote moisture around the roots, which in turn can promote root rots. Applying 4 to 6 inches of an organic mulch (for example, rotted sawdust) at the base of the plants is a common practice in blueberry production. In addition to regulating fluctuating soil moisture, the mulch suppresses weeds.

Alleyway Management

The alleys between rows of plants are well suited to the use of a living mulch for managing weeds. A living mulch is created when a plant is broadcast seeded in the alleyways. When selecting what species to use as a living mulch, choose a plant that will outcompete weeds but will not creep or spread into the row of small fruit plants. Some grass species, such as hard fescue, meet these criteria and have been used successfully as living mulches in bramble and blueberry production. Living mulches may be used between rows of plasticulture strawberries. Living mulches have also been tried between rows of matted-row strawberries in research trials and on grower farms. However, the strawberries were poor competitors with the mulch, and there were other disadvantages such as increased clipper damage. For more information on recommended practices for alleyway management, see the individual crop chapters.

HERBICIDES FOR WEED CONTROL

Table 4.1 lists the effectiveness of various herbicides for common weeds, which may be substituted for each other when such use is allowed according to the label. In some cases, fumigation for weed management may be warranted. Fumigation materials that may be used are covered in Chapter 3, Table 3.3. Especially with perennial weeds, one application of a herbicide may not provide complete management, but regrowth should be limited and competitive ability reduced. Follow-up spot treatments will improve the long-term result of the initial herbicide application, but knowledge of the target weed's life cycle can be even more valuable. Chemical weed management can be effective, economical, and safe when used correctly. It eliminates potential injury from close cultivation or cultivating too deeply and reduces rodent injury by eliminating cover.

Choose herbicides for use in the row that are labeled, have adequate crop safety, and target the weeds in your field. Use the correct amount of residual herbicides for each soil type. These topics are discussed in greater detail in individual crop chapters.

Repeatedly using a single herbicide will lead to an increase in resistant weeds. Use of a single herbicide will also result in control of certain species, which will allow other weed species to

Table 4.1. Weed susceptibility to herbicides.

		PREEMERGENT															POSTEMERGENT TRANSLOCATED						POSTEMERGENT NONTRANSLOCATED		
CROPS LABELED ON[a]	Cultivation	Callisto	Casoron	Chateau	Dacthal	Devrinol	Gallery	Karmex	Kerb	Princep	Prowl	Sandea	Sinbar	Solicam	Surflan	Velpar	2,4-D	Roundup	Stinger	Fusilade	Poast	Select	Rely[b]	Gramoxone	Scythe
	Any crop	(B, Br)	(B, Br)	(S, B)	(S)	(B, Br, S, C)	(B, Br)	(B in NJ & MD)	(B)	(B, Br)	(S)	(B)	(B, Br, S)	(B, Br)	(B, Br, R)	(B)	(S)	(B, Br, R)	(S in MD, NJ, PA & VA)	(Nonbearing B, Br, R)	(B, Br, S)	(S, R)	(B, R)	(B, Br, S, R)	(S, B, Br, C)
ANNUAL AND BIENNIAL WEEDS																									
Broadleaves (sa = summer annual, wa = winter annual, b = biennial)																									
Bedstraw, catchweed (sa, wa)	G[c]	—	G	—	—	—	—	—	P	—	—	—	P	—	F	—	—	—	—	N	N	N	—	P	P
Bittercress (sa, wa)	G	—	G	—	—	G	—	—	P	F	—	—	G	—	P	—	—	G	—	N	N	N	—	G	F
Buckwheat, wild (sa)	G	—	G	—	—	—	—	—	—	G	G	—	G	—	—	—	—	G	G	N	N	N	G	G	F
Carpetweed (sa)	F	G	G	G	P	G	F	G	G	G	G	P	G	G	G	G	G	G	N	N	N	N	—	G	F
Chickweed, common (wa)	G	G	G	G	G	G	G	G	G	G	P	—	G	G	G	G	P	G	N	N	N	N	F–G	G	F
Common cocklebur (sa)	—	F	—	—	—	N	—	—	N	F–G	N	G	G	P	N	G	—	G	G	N	N	N	—	G	—
Common mallow (wa, sa, b)	F	—	G	G	N	N	—	N	—	N	—	—	—	—	N	—	—	G	—	N	N	N	F	P	P
Filaree, redstem (wa,b)	G	—	G	G	—	G	—	F	P	P	—	—	G	G	P	—	—	G	—	N	N	N	F	F	F
Galinsoga, hairy (sa)	G	G	F	—	N	P–F	G	G	P	G	N	G	G	G	N	G	F	G	G	N	N	N	F	G	F
Geranium, wild or cranesbill (b)	G	—	G	—	P	G	—	—	P	—	—	—	G	—	—	—	G	G	P	N	N	N	—	G	F
Groundsel, common (sa, wa)	G	—	G	G	P	G	G	P	P	F	—	—	F	F	P	—	F–G	G	G	N	N	N	—	G	F
Henbit (wa)	G	—	G	G	G	F	G	G	F	G	F	—	F–G	G	F–G	G	F	G	N	N	N	N	F–G	G	F
Horseweed (sa)	F	G	G	G	N	N	—	G	P	P	—	—	F–G	F–G	F	F–G	G	G	G	N	N	N	F–G	P	P
Jimsonweed (sa)	—	F	—	G	—	N	G	G	N	G	P	G	—	F	N	G	—	G	P	N	N	N	—	G	—
Knotweed, prostrate (sa)	F	—	G	G	G	F–G	—	F–G	F	G	P	—	G	G	G	—	F	G	—	N	N	N	—	N	N
Lambsquarters (sa)	G	G	G	G	G	F–G	G	G	G	G	F–G	F	G	F	G	G	G	G	P	N	N	N	G	G	F
Morning glory spp. (sa)	—	F	G	F	N	N	G	G	—	G	P	F	N	F	N	G	G	F	N	N	N	N	F	F–G	F
Mustard, wild (wa)	G	G	G	G	N	F	G	G	F	G	P	G	G	G	F	G	G	G	N	N	N	N	F–G	F	F
Nightshade, black (sa)	G	G	G	G	N	P	G	G	F	G	P	P	G	G	P	—	G	G	P	N	N	N	G	G	F
Pepperweed, Virginia (sa)	G	—	G	—	—	F	—	—	P	G	—	—	—	F–G	F–G	—	G	G	N	N	N	N	—	—	—
Pigweeds (sa)	G	F	G	G	F	G	G	G	G	G	P	P–F	P	G	G	G	G	G	P	N	N	N	G	G	F
Pineappleweed (sa, wa)	G	—	G	G	P	G	G	G	P	G	F–G	—	G	G	P	—	G	G	G	N	N	N	F	G[d]	F
Prickly lettuce (sa, wa, b)	G	—	G	G	—	G	—	G	P	G	—	—	G	P	F	—	P	G	G	N	N	N	G	G	F
Purslane (sa)	F	—	G	G	G	G	G	G	G	G	F–G	G	G	G	G	G	G	G	P	N	N	N	F–G	G	F
Ragweed (sa)	F	P	G	G	N	F	G	G	P	G	N	F	G	G	P	G	G	F	G	N	N	N	G	G	F
Shepherds purse (wa)	G	G	G	G	P	F	G	G	P	G	P	G	G	F	F	G	G	G	N	N	N	N	F–G	G	F
Smartweed, Pennsylvania (sa)	G	F–G	G	G	N	P	G	F–G	F	G	F	N	G	G	P–F	G	F	G	P	N	N	N	G	F	F
Sowthistle, annual (sa)	G	—	—	G	—	G	—	P–F	P	F	—	—	G	F	P	—	—	G	—	N	N	N	—	G	F
Tansy ragwort (sa)	F	—	G	—	—	P	—	—	P	—	—	—	P	—	P	—	—	G	—	N	N	N	—	G[d]	F
Thistle, bull (b)	G	—	G	—	N	N	—	—	P	G	—	—	F	—	F		F–G	G	—	N	N	N	F	P	P
Velvetleaf (sa)	G	G	G	G	N	N	G	F–G	P	G	G	G	G	F	P	G	G	G	P	N	N	N	G	G	F
Wild or field pansy (wa, sa)	G	—	—	G	G	N	—	—	—	P	—	—	G[e]	—	P	—	P	P	N	N	N	N	—	P	P
Yellow rocket (wa, b)	G	—	G	P	N	N	—	—	—	N	N	—	N	F	N	—	P–F	G	P	N	N	N	—	P	P
Grasses and Sedges (sa = summer annual, wa = winter annual, b = biennial)																									
Barnyardgrass (sa)	G	N	G	F	F	G	N	G	G	F	G	N	F	G	G	G	N	G	N	G	G	G	G	G	F
Bluegrass, annual (wa)	G	P	G	P	F	G	G	G	F	G	P	N	F	G	G	G	N	G	N	—	P	F	G	G	F
Bromegrass, annual (wa)	G	P	G	P	—	G	G	F	G	F	—	N	—	G	G	G	N	G	N	G	G	G	—	G	—
Cheat (wa)	G	—	G	—	—	G	—	—	G	G	—	N	G	F–G	G	—	N	G	N	G	G	G	—	—	—

CONTINUED

Table 4.1. Weed susceptibility to herbicides, continued.

		PREEMERGENT															POSTEMERGENT TRANSLOCATED						POSTEMERGENT NONTRANSLOCATED		
CROPS LABELED ON[a]	Cultivation	Callisto	Casoron	Chateau	Dacthal	Devrinol	Gallery	Karmex	Kerb	Princep	Prowl	Sandea	Sinbar	Solicam	Surflan	Velpar	2,4-D	Roundup	Stinger	Fusilade	Poast	Select	Rely[b]	Gramoxone	Scythe
	Any crop	(B, Br)	(B, Br)	(S, B)	(S)	(B, Br, S, C)	(B, Br)	(B in NJ & MD)	(B)	(B, Br)	(S)	(B)	(B, Br, S)	(B, Br)	(B, Br, R)	(B)	(S)	(B, Br, R)	(S in MD, NJ, PA & VA)	(Nonbearing B, Br, R)	(B, Br, S)	(S, R)	(B, R)	(B, Br, S, R)	(S, B, Br, C)
Crabgrass, large (sa)	G	F	G	F	G	G	N	F–G	G	F–G	G	N	F	G	G	G	N	G	N	G	G	G	G	G	F
Fall panicum (sa)	G	N	F	F	F	G	N	G	G	F–	G	N	G	G	G	G	N	G	N	G	G	G	G	G	F
Foxtail (sa)	G	P	F	F	G	G	N	G	G	G	G	N	F	G	G	G	N	G	N	G	G	G	G	G	F
Goosegrass (sa)	G	N	F	F	F	G	N	F–G	G	G	G	N	F	G	G	G	N	G	N	G	G	G	G	G	F
Annual sedge (sa)	—	F	G	P	—	P–F	N	F–G	N	F–G	—	G	—	F–G	N	G	—	F	—	N	N	N	—	G	—
PERENNIAL WEEDS																									
Broadleaves																									
Aster, white flower	F[c]	P	G	F	N	N	P	P	—	N	N	—	N	N	N	F–G	N	G	G	N	N	N	F	P	P
Chickweed, mouseear	—	—	—	G	—	—	—	G	—	G	—	—	—	G	G	—	—	—	—	—	—	—	—	—	—
Chicory	F	—	G	—	N	N	—	—	—	P–F	—	—	G	N	N	—	G	G	G	N	N	N	F	P	P
Clovers	F	—	—	—	N	P	—	—	P	P	—	—	P	—	P	—	P	P	G	N	N	N	P	P	P
Dandelion, common	F	—	G	G	N	G	G	G	P	G	F	—	G	G	N	—	G	G	F	N	N	N	F	P	P
Dandelion, false	P	—	G	—	—	P	—	—	P		—	—	P	G	P	—	—	G	—	N	N	N	F	P	P
Docks	P	—	G	N	N	N	—	—	—	N	F	—	F	N	N	—	G	F	F	N	N	N	P	P	P
Field bindweed	P	P	F–P	F	—	P	P	P	P	P	—	—	P	P	P	F	—	F	P	N	N	N	P	P	P
Field horsetail	P	—	G	—	—	P	—	—	P	P	—	—	P	P	P	—	—	P	—	N	N	N	P	P	P
Goldenrod	F	P	F–G	P	N	N	P	P	—	N	—	—	P–F	N	N	F	P–F	G	G	N	N	N	F	P	P
Ground ivy	F	—	G	—	N	N	—	—	—	N	—	—	N	N	N	—	P–F	G	—	N	N	N	F	P	P
Hemp dogbane	F	P	N	P	N	N	P	P	—	N	—	—	N	N	N	F	P–F	F	—	N	N	N	F	P	P
Milkweed	P	—	—	—	N	N	—	—	—	N	—	—	N	—	N	—	P–F	G	N	N	N	N	F	P	P
Mugwort	F	—	G	—	N	N	—	—	—	N	—	—	P	N	N	—	P	F	G	N	N	N	P	P	P
Mulberry	—	P	P	P	—	N	N	N	N	N	—	P	—	N	—	P	—	G	—	N	N	N	—	P	—
Plantain	G	—	G	N	N	N	—	—	P	G	P	—	F	P	N	—	G	G	N	N	N	N	F	P	P
Poison ivy	—	P	P	P	N	N	N	N	N	N	—	P	N	P	N	P	—	G	—	N	N	N	—	P	—
Sorrel, red	F	P	G	F	F	N	P	P	—	N		—	P	N	N	F	P	G	F	N	N	N	F	P	P
Thistle, Canada	P	P	G	P	N	F	P	P	P	N	P	P	N	P	N	F	P	G	G	N	N	N	F	P	P
Virginia creeper	—	P	P	P	N	N	N	N	N	N	—	P	N	P	N	P	F	G	—	N	N	N	—	P	—
Yarrow, common	F	—	—	—	N	N	—	—	—	—	—	—	N	N	N	—	F	G	—	N	N	N	F	P	P
Yellow woodsorrel	G	—	G	—	F	P	G	—	—	F	—	—	G	F	F	—	F	G	N	N	N	N	F	P	P
Wild carrot	F	—	G	—	N	N	—	—	—	N	—	—	F	F	N	—	P–F	G	—	N	N	N	F	P	P
Wild strawberry	F	—	G	—	N	N	—	—	—	N	—	—	N	P	N	—	P–F	G	—	N	N	N	F	P	P
Grasses and Sedges																									
Bermudagrass	P	N	N	N	N	N	N	N	—	N	—	N	F	P	N	P	N	G	N	F–G	F–G	—	F	P	P
Bentgrass	G	—	—	—	—	—	—	—	F	G	—	N	—	—	G	—	—	—	N	G	F	F	—	P	P
Fescues	—	—	G	—	N	N	—	—	—	P	—	N	F	F	N	—	N	G	N	P–F	P–F	G	F	F	P
Johnsongrass (seedlings)	G	N	F	F	—	G	N	N	—	N	G–F	N	—	F	F–G	—	N	G	N	G	G	G	G	G	F
Johnsongrass (rhizomes)	P	—	—	N	N	N	—	—	—	P	N	N	P	P	N	—	N	G	N	G	G	G	F	G	P
Orchardgrass	—	—	G	N	N	N	—	—	G	P–F	N	N	G	F	N	—	N	G	N	G	G	F–G[d]	F	G[d]	F
Quackgrass	P	N	G	N	N	N	N	P	G	P–F	N	N	P	P	N	F	N	G	N	G	G	F	F	P	P
Velvetgrass	P	—	—	—	—	P			G	P	—	N	G	—	—		—	G	N	—	F	G	F	G	F
Yellow nutsedge	P	P	F	P	N	N	P	P	N	N	P	F–G	P	F	N	F	N	F	N	N	N	N	P	P	P

a. S = strawberries; Br = brambles; B = blueberries; R = *Ribes*; C = currants.

b. Rely is partially translocated.

c. G = good; F = fair; P = poor; N = no control; — = insufficient data.

d. Seedling state only.

e. Sinbar does not control pansy postemergence.

take over. Use herbicide combinations, herbicide rotations, and sequential or spot treatments in a well-managed weed control program to eliminate or minimize problems. The recommended herbicides in this guide have been evaluated for crop safety and effectiveness. Information on all varieties is incomplete. Use herbicides with care on new varieties.

Terminology

Residual

Residual herbicides remain in the soil and kill weeds through their roots for several weeks or up to several months. Most frequently, they are effective only on germinating seeds, so they must be applied before weeds germinate. Some, however, have "kickback" activity on small weeds. Weeds begin to compete with most crops within 2 to 4 weeks of planting without application of a residual herbicide. If weeds are present, a postemergence herbicide can be combined with a residual herbicide to burn down weeds and then provide control of new weeds that may germinate. Residual herbicides can be used to control both grasses and broadleaves.

Incorporated

Incorporated herbicides are mechanically mixed with the soil. This application method is not well suited to crops with shallow roots such as strawberries and blueberries. It is difficult or impossible to incorporate herbicides near the crown of the blueberry plant, and shallow roots may be pruned by the incorporation equipment.

Preemergence

Preemergence herbicides are applied to the soil surface. Rainfall or overhead irrigation before weeds emerge is needed to move the herbicide into the soil. Use a preemergence herbicide in combination with a postemergence herbicide if weeds have emerged, unless the preemergence herbicide also is effective postemergence.

Postemergence

Postemergence herbicides kill weeds through their leaves. Carefully apply those that are nonselective to the weeds without allowing the herbicides to contact the crop plants. The best time to apply postemergence herbicides is when weeds are growing rapidly. Do not treat weeds that are dormant or under stress, as the herbicide will be absorbed to a lesser extent. Most herbicides that enter the plant through the leaves need a minimum rain-free period of at least 1 to 8 hours after application for maximum effectiveness. Postemergence herbicides may be selective or nonselective. They may work only where they contact the weed, or they may translocate and work systemically throughout the plant.

Selective postemergence herbicides kill only certain susceptible weeds. Poast, Select, and Fusilade DX are examples that kill only grasses and will not have any effect on broadleaf weeds or harm broadleaf plants. 2,4-D selectively controls many broadleaved weeds at certain times in strawberries.

Nonselective postemergence herbicides kill or injure any treated plant. They may be contact or translocated. Contact herbicides work only where they are placed. Thorough spray coverage is essential for good results. Roots of established annual weeds and perennial weeds often survive. Gramoxone Inteon and Scythe are examples of nonselective contact herbicides. Translocated herbicides move systemically in the weed after treatment. Application at the proper growth stage will often result in injury to or destruction of the roots as well as tops of established annuals and perennial weeds. Results of translocated herbicides may not be evident for several days or weeks. Roundup and other glyphosate products are examples of nonselective translocated herbicides.

Determining the Correct Rate

Improperly applied herbicides or herbicides applied above recommended rates may cause damage to crop plants.

Residual herbicide rates must be matched with soil type and percentage of organic matter to obtain good weed management and crop safety. Determine type and percentage of organic matter for each soil on the farm with a separate soil test for each soil. Rates for different soil types and percentage organic matter are listed for labeled herbicides within individual crop chapters.

Be aware that most herbicide labels are written for "typical agricultural soils" and that many common blueberry fields are not "typical." Most coarse-textured soils, such as loamy sands and sandy loams, are low in organic matter—often less than 2 percent. Medium-textured soils, such as loams, may have 2 to 4 percent organic matter. Soils with a high clay content have varying levels of organic matter but always have a high CEC. See the section below on soil properties for further details. Many traditional "black" blueberry soils may be classified as loamy sands, but they may have organic matter contents over 8 percent. Have your soil analyzed for percent organic matter. This is a separate test that must be requested from most soils laboratories. If your soil has an organic matter content higher than the choices listed on the herbicide label for your soil texture, choosing the correct rate may be difficult. Consult your local Cooperative Extension service for assistance in determining the correct herbicide rate to use on your soil if needed.

Application Pointers

Herbicide application should be accomplished with a "conventional" fixed-boom sprayer calibrated to accurately deliver the intended gallonage of water per acre using flat fan nozzles at 30 to 40 psi, unless otherwise stated. Herbicide rate recommendations are made on a broadcast basis (amount of herbicide applied per sprayed acre, or 43,560 sq ft).

Good agitation is needed for uniform distribution of the chemical in the spray solution. It is most important when wettable powder, flowable, or water-dispersible granules/dry flowable formulations are sprayed. Good agitation can be achieved mechanically with paddles or hydraulically with spray material from a bypass line. Do not use the pressure regulator bypass for agitation. If hydraulic agitation is used, be sure the pump has the capacity to spray and agitate at the same time. Tank shape also affects agitation. Corners and edges in tanks increase the agitation requirement. The boom should be modified to reach under the crop canopy. The outside nozzle may be of the offset type to reach into the middle of the row.

Nozzle tips may be made from many materials. Plastic and brass tips wear more rapidly and should be replaced annually. Use only stainless steel or tungsten carbide nozzles with wettable

powder, flowable, or water-dispersible granules/dry flowable formulations. These products are abrasive and wear other tips too quickly. Flat fan nozzle tips are designed for herbicide application. Most herbicides should be applied with a TeeJet 8002 to 8004 nozzle or equivalent. Most herbicides can be applied effectively with flat fan nozzles applying between 15 and 50 gallons of water per acre. Flood jet nozzles are economical to use but do not provide the uniform coverage obtained with flat fan nozzles. Nozzles that are designed to reduce drift are available.

Influence of Soil and Water (Rainfall and Irrigation) on Herbicides

Most weed control programs rely on nonresidual postemergence (knockdown) herbicides and residual preemergence herbicides to manage weeds. Applications are typically sprayed once a year in the spring, or twice a year (in late fall and late spring). Residual herbicides applied at these times are relied on to minimize weed growth through the summer months and harvest.

After application to the soil surface, most residual herbicides must be moved into the soil by rainfall or overhead irrigation to be effective. The amount of rain or overhead irrigation needed depends on weeds targeted, soil properties, and the chemical properties of the herbicide.

Many weeds, such as pigweed species, produce huge numbers of tiny seeds. Small seeds must germinate at or very near the surface of the soil. Other weeds, such as morninglory seeds or yellow nutsedge tubers, can germinate or sprout from deeper in the soil. Early in the season, herbicides must be moved farther into the soil to affect weeds that germinate or sprout from deeper in the soil. Later in the season, shallow-germinating weeds may become established and escape control if the herbicide has moved too deep into the soil to be available during weed emergence and establishment.

Soil Properties

Soil can have a strong influence on weed growth and residual herbicide effectiveness. The soil characteristics that influence herbicide effectiveness include texture, percent organic matter, and pH. Soil maps list soil texture. Soil tests that employ the "feel" method may be inaccurate. A mechanical analysis of your soil will determine the amounts of sand, silt, and clay in the mineral portion of the soil. Have soil texture determined by mechanical analysis one time. The texture will not change unless soil is lost by erosion or other means. Sand particles are the largest, silt is medium in size, and clay particles are the smallest. Soils with a large percentage of sand particles are considered to be coarse in texture and are called sand, loamy sand, or sandy loam. Soils with a moderate amount of each size soil particle are considered to be medium in texture and are called loams. Soils with a large percentage of clay particles are considered to be fine in texture and are called clay loam or clay.

Soil particles are negatively (-) charged. The negative charge of soil particles attracts positively (+) charged fertilizer molecules such as H_2PO_4+, K^+, Ca^{++}, Mg^{++}, and many herbicides. The attraction of the positive charge to the negative charge of the soil particles slows leaching. Other fertilizer molecules, such as NO3- and a few herbicides, have a negative charge. Negatively (-) charged molecules are not bound to the soil and are more subject to leaching, especially if they are highly soluble in water. Since substances that are positively charged are called cations, the measure of a soil's ability to hold onto cations is called the cation exchange capacity (CEC). Sand is the largest particle in size and has the lowest CEC value, less than 1. Silt is intermediate in size and has an intermediate CEC value, near 5. Clays are the smallest soil particles and have the highest CEC value of the mineral component of soil—near 35—depending on the type of clay.

Organic matter makes up only a small part of most soils, usually between 0.5 and 5.0 percent in soils across the northeastern United States, but it has the highest CEC value, near 200. Traditional "black" blueberry soils may have organic matter contents well over 5 percent. Even small changes in the percent organic matter in soils, especially sandy soils, can have a strong influence on herbicide performance. That is the reason small changes in percent organic matter may require herbicide rate changes. Rate tables may have several columns with different herbicide rates for different levels of organic matter in each soil type.

Soil pH also affects the performance of some herbicides by influencing the degree of attraction to soil particles. The pH of soils suited to blueberry production is lower than the recommended soil pH levels for other small fruit crops, which range between 6.0 and 6.5, and vegetable crops, which range between 6.0 and 7.0. Low pH (below 6.0) or high pH (above 7.0) may affect the availability of certain herbicides by changing the positive charge of the molecule. Effectiveness may be reduced and/or herbicide carryover may be increased if the herbicide is more tightly bound to the soil. The risk of crop injury may increase if a herbicide is less tightly bound to the soil and more available. Herbicides that are affected by pH may have "Do Not Use" warnings on the label if the soil pH is above or below a value that increases the risk of crop injury, herbicide carryover, or poor weed control.

Chemical Properties of the Herbicide

The solubility, or the ease with which an herbicide dissolves in water, affects the rate of movement through the soil (Table 4.2). A herbicide that is more soluble in water may be activated by less rainfall or irrigation but may not provide the length of control that could be obtained with a less soluble herbicide, especially in a coarse-textured soil low in organic matter.

In addition, most residual herbicides can become bound to soil particles. When attached, or bound to the soil, these individual molecules of herbicide are not available to the weeds or the crop.

Herbicides can be held onto by the soil to varying degrees (see Table 4.2). The degree of binding is influenced by the chemistry of the herbicide and the CEC of the soil. Lower herbicide rates are needed to prevent crop damage in soils with a low CEC. Plant nutrients, such as NO_3^-, and herbicides with a negative charge are not held by the soil, leach more rapidly, and are less affected by soil texture than those with a positive charge.

Nonresidual postemergence herbicides have no activity after application

for one of two reasons. Some herbicides are too tightly bound to the soil to be available to plants after application. Care must be exercised in soilless growing environments, where surprising residual activity can be observed from these herbicides. Other herbicides are highly soluble in water and are not bound to soil particles. Residual activity from these herbicides can be observed in the soil, but it often lasts only a few days. They are rapidly leached out of the zone of weed seed germination and degraded by soil microorganisms.

Glyphosate products—including Roundup products, Touchdown products, Glyphomax Plus, and other labeled glyphosate formulations—and paraquat products, including Gramoxone Inteon, Firestorm, and other labeled paraquat products, are too tightly bound to the soil to have residual activity. These herbicides are completely unavailable to plants after application. They remain tightly bound to the soil until broken down. Glyphosate is degraded or digested by soil microorganisms. Residual activity from glyphosate has been observed when used in greenhouses, on plastic mulch, and near hydroponic growing systems. Paraquat is degraded by sunlight and is less likely to cause problems when used on plastic mulch, in greenhouses, or near soilless growing systems.

Table 4.2. Herbicide water solubility and soil adsorption characteristics.

	SOLUBILITY	SOIL ADSORPTION
Residual Herbicides		
Callisto (mesotrione)	Moderate	Moderate/strong
Casoron/Norosac (dichlobenil)	Low	Moderate
Chateau (flumioxazin)	Very low	Not available
Dacthal (DCPA)	Very low	Not available
Devrinol (napropamide)	Moderate	Strong
Gallery (isoxaben)	Very low	Strong
Karmex (diuron)	Low	Strong
Kerb (pronamide)	Low to moderate	Strong
Norosac/Casoron (dichlobenil)	Low	Moderate
Princep (simazine)	Very low	Moderate
Prowl (pendimethalin)	Very low	Very strong
Sandea (halosulfuron)	Low to moderate	Moderate
Sinbar (terbacil)	Moderate	Weak
Solicam (norflurazon)	Low to moderate	Strong
Surflan (oryzalin)	Very low	Strong
Velpar (hexazinone)	High	Weak
Nonresidual Herbicides		
Formula 40 (2,4-D)	Not available	Not available
Fusilade (fluazifop-P-butyl)	Very low	Very strong
glyphosate products	Very high	Very strong
paraquat products	Very high	Very strong
Poast (sethoxydim)	Moderate to very high[a]	Moderate
Rely (glufosinate)	Very high	Weak
Select products (clethodim)	Not available	Weak
Scythe (pelargonic acid)	Not available	Not available
Stinger (clopyralid)	Moderate	Weak

Source: Weed Science Society of America (2002) *Herbicide Handbook*, 8th ed. *Controlling Weeds in Nursery and Landscape Plantings (*2007) Penn State College of Agricultural Sciences.

a. pH dependent

Trickle Irrigation and Herbicide Effectiveness

Efficiency, water conservation, and disease minimization are reasons to consider trickle irrigation. The crop can be irrigated using less water provided by a smaller pump delivered at lower pressure than with traditional overhead sprinkler systems. In addition, evaporation losses are lower. Since trickle lines and microsprinklers operate under the crop, the fruit and foliage remain dry, reducing the incidence of many diseases. Improved weed management is not a benefit of trickle irrigation when herbicides are used. Expect higher herbicide and application costs and less effective and less consistent weed control from herbicides in trickle irrigated fields.

No herbicide, not even the least soluble in water and most tightly bound to the soil, can withstand leaching from the volume of water that flows from an emitter hole in trickle irrigation tubing. Herbicide failure can be first observed in fields under trickle irrigation by small tufts of weeds growing at each emitter. As the season progresses, the weeds grow more readily, and the spot enlarges as a wider area is leached free of herbicide. Although the irrigation prevents the crop from water stress, weeds can be fierce competitors for nutrients and sunlight and can interfere with harvest. In many annual crops, the increased weed pressure and interference with cultivation has restricted trickle irrigation to use with plastic mulch for weed management.

Modifications to the trickle irrigation system can moderate the weed control problem. Any change in the system that reduces the volume of water applied at a point source will reduce herbicide leaching. Reducing the distance between the holes in traditional trickle tubing to increase distribution is not likely to eliminate the weed problem. Burying the tubing more than 4 inches deep before planting new fields or under several layers of organic mulch will effectively reduce the adverse effects on residual herbicides since their effectiveness is usually confined to the upper 2 to 4 inches of soil. Switching from trickle tubing that drips to microsprinklers in crops where they can be used also

effectively reduces the adverse effects of the irrigation on weed control.

When trickle irrigation will be used for the residual herbicide weed control program, during the irrigation season choose herbicides that are least soluble in water and most tightly adsorbed by the soil (see Table 4.2). Adjust the application timing in the spring so the herbicides can be activated by 1 to 2 inches of rainfall or overhead irrigation before the trickle irrigation is used. This will allow the herbicides to move into and be attached to the soil before being subjected to the intense leaching of the trickle irrigation. Remember that choosing the herbicide(s) that is least soluble in water and most strongly adsorbed to the soil will delay, but not prevent, herbicide failure and weed breakthroughs in trickle irrigated crops. Coarse-textured sandy soils and soils low in organic matter that require frequent irrigation increase the likelihood of weed control failure, especially during prolonged periods of heat and drought stress. Plan to use repeated applications of nonresidual postemergence herbicides on a regular schedule to manage weeds in trickle irrigated crops. Do not exceed maximum annual use rates. Time the application of residual herbicides to derive the maximum benefit from their use when harvest approaches and preharvest interval (PHI) restrictions will not permit the continued use of the nonresidual postemergence herbicides.

PROBLEM WEEDS

Troublesome species tend to become well entrenched in perennial plantings such as blueberries, brambles, and Ribes. In Chapter 7: Blueberries, these weeds' biological features that make them difficult to manage are discussed, as well as cultural and chemical strategies, when known, that have been found to be effective. Yellow nutsedge, field and hedge bindweed, Canada thistle, dandelion, goldenrod species, horsetail, poison ivy, quackgrass, Virginia creeper, and white heath aster are covered in detail in Chapter 7.

CHAPTER 5

Wildlife Damage Control in Commercial Plantings

CONTENTS

Introduction 41
Birds 41
Species of Birds 41
Damage 42
Legal Status 42
Damage Control 42
Summary 43
Mammals 43
Voles 43
Cottontail Rabbits 44
White-Tailed Deer 46
Conclusion 47

INTRODUCTION

To the passing robin or deer, your fruit planting appears to be a grocery store. In most cases, growers can tolerate a little damage from wildlife, but losses may become excessive if measures are not taken to control wildlife damage. In general, fruit-eating birds, such as robins and starlings, and browsing mammals, such as deer, voles, and rabbits, are the most common wildlife problems.

Effective management begins by anticipating the extent of damage and responding with the appropriate control. Before deciding on a control method, if any, you should consider the cost and benefits. Economic costs are not the only costs that should be taken into consideration. Time constraints and the impacts of the control methods on other nontarget wildlife should also be considered. In many instances, an integrated pest management (IPM) plan is the best approach.

BIRDS

On many farms, bird damage is minimal and growers choose to ignore the problem or just take the loss from birds into account as a management cost. For others, problems from birds can be substantial, resulting in the consumption of or damage to large portions of the fruit crop. Frequently, the amount of lost fruit is not apparent until after control measures are implemented.

The type and amount of damage caused, effective control methods, and legal protection vary among bird species. As a result, it is very important for a grower to be able to identify the birds causing damage. A number of field guides for identifying birds are available at bookstores or libraries. Listed below are the species that most often cause damage to fruit, along with a brief description of each bird and the type of damage it causes.

SPECIES OF BIRDS

All the species listed below can be problems on various fruit crops. Descriptions of damage to crops other than berry crops are included to aid in identification of causes of damage.

Crow

The American crow, *Corvus brachyrhynchos,* while primarily a problem in apple production, may be found in other fruit crops. It pecks deep, triangular holes in the fruit.

Grackle

The common grackle, *Quiscalus quisula,* has a black body, an iridescent head, and a keel-shaped tail. Grackles consume small fruit, such as blueberries, whole. They often slash large fruit, such as cherries and apples, and leave it damaged.

Starling

The European starling, *Sturnus vulgaris,* is an exotic (nonnative) species introduced into North America from Europe. It has a black-speckled appearance, short tail—a feature that differentiates it from grackles—and wings that appear triangular when the bird is in flight. Starlings are not protected by law. They can cause extensive damage to fruit because they often descend on plantings in huge flocks. At roost sites, starlings have been known to come in at 1,000 birds per minute. Starlings eat small fruit such as grapes and blueberries whole, and slash large fruit such as cherries. They peck holes in apples, consume the inside of the fruit, and leave the apple hollowed out.

House Finch

The house finch, *Carpodacus mexicanus,* is a relative newcomer to the eastern United States—its historic range is in the western part of the country. In the 1940s, it was released on Long Island, New York, and has been spreading in numbers and distribution since that time. The house finch has brown streaks and looks like a sparrow. The male has patches of orange or red under its chin and on its sides. The house finch starts at the top of a blueberry bush and pecks berries in rapid succession. Many are left damaged. It also pecks grapes open and feeds on the juice and pulp within. It leaves small, irregular nicks on apples, which often make the fruit susceptible to disease. The house finch causes extensive damage to fruit in the western United States. In the eastern United States, it is not a major problem but may become one in the future.

House Sparrow

The house sparrow, *Passer domesticus,* is also an exotic species introduced from Europe. The male can be recognized by his black bib and white cheeks. The female is drab brown. House sparrows damage grapes, cherries, and other small-sized fruit, generally by pecking holes. The house sparrow is not protected by law.

Robin

The American robin, *Turdus migratorius,* is a common and well-known bird. It is probably the species most frequently reported as consuming small fruits and cherries. Robins consume whole cherries, grapes, blueberries, and other small fruit and frequently cause substantial damage.

Others

A number of other species might cause similar problems, depending on the time of year and the habitat surrounding the orchard. Species include the cedar waxwing *(Bombycilla cedrorum),* gray catbird *(Dumetella carolinensis),* northern mockingbird *(Mimus polyglottos),* and Baltimore oriole *(Icterus galbula).*

DAMAGE

Damage to fruit does not occur randomly. By being familiar with patterns of damage, a grower may be able to reduce damage or the cost of control by concentrating control methods in particular areas and at times of the season when damage is most severe.

Although all farms and orchards are susceptible to damage, it usually is greatest on farms in close proximity to town environments where birds such as robins and starlings are abundant. Damage is generally higher in isolated plantings. In large areas of fruit production, so much fruit is available that the amount of damage on any one site is fairly low. The size of the planting also influences the amount of damage. As a pattern, small plantings generally experience a greater degree of damage than large plantings. Thus, damage can be an important problem for small-scale producers.

The time at which the fruit matures appears to influence the amount of damage. For strawberries, bird damage is highest on early maturing varieties. Bird damage to cherries and grapes is also greatest to early ripening varieties. Early ripening fruit may be damaged more frequently because it matures at a time when other fruits are not available.

LEGAL STATUS

Federal law protects all species of birds except starlings, house sparrows, and pigeons. All other species are protected and cannot be trapped or shot without a permit. The only exceptions to this rule are blackbirds, cowbirds, and grackles, which may be killed without a permit when they are observed committing or about to commit damage. When controlling birds through lethal methods, use extreme care in identifying the species causing damage.

DAMAGE CONTROL

The type of control you choose will depend on a number of factors. Use your knowledge of damage patterns and species behavior to decide when and where to use control methods and the types of control methods to use.

Netting

For many types of fruit, netting is the most effective way to reduce bird damage. Netting can be placed directly over the plants or bushes, but for some fruits, such as highbush blueberry, a framework is built and the netting is suspended over the frame. If placed on a framework of trellis wire strung across posts that are taller than implements and workers, inconveniences associated with netting are minimized. The major disadvantages of netting include the high initial cost, the time necessary to apply it, and the inconvenience of working around it. Although netting is expensive, it can be reused for a number of years if it is removed carefully and stored over winter. When deciding whether to use netting, growers should consider the costs of purchasing and installing it relative to the losses from bird damage. In many cases, it is likely that netting will be more economically viable in smaller plantings, both because of the greater percentage of losses and smaller area. Netting should be applied before berries color in order to minimize the number of birds attempting to circumvent the netting. Although netting is the most effective means of bird control for small fruits and isolated trees, other methods are available.

Scare Tactics and Noise Devices

Many growers use visual scare devices and noisemakers to frighten birds away from fruit crops. Visual scare devices include streamers, spinners, aluminum pie tins, plastic owl and snake models, and scare-eyes (large balloons with eyes painted on them). They are most effective when used in conjunction with sound devices. Because birds learn quickly that visual scare devices are harmless, they should be used only during short damage periods and should be changed regularly. Varying location, color, and type of scare devices enhances their effectiveness.

A number of noise devices are available. Cannons, exploders, sirens, and other noisemakers work best when the sound is presented at irregular intervals and its source is moved frequently. Be aware that the loud sounds will be objectionable close to residential areas. Taped distress calls are more effective, but the calls are usually species specific, so a grower must obtain a tape of the distress calls of the type of bird causing the damage. A problem with both visual and scare tactics is that birds become accustomed to them over time.

Chemical Repellents

One chemical repellent, methyl anthranilate (MA), currently is registered for use on small fruits in Pennsylvania. Methyl anthranilate is a colorless to pale-yellow liquid with a grape-like odor. It has been used as a food and drug flavoring for humans for years. In preliminary tests, fruit treated with MA were consumed significantly less than untreated fruit. In addition, human consumers could not detect a difference in taste between fruit that had been treated earlier in the season and fruit that had not been treated. MA should not be applied to blueberry plants, however, because it has been known to cause foliar burns in field studies and has not been cost effective. Methyl anthranilate is currently registered for use on fruits and turf.

In the past, the repellent methiocarb (Mesurol) was registered for use on cherries and blueberries; however, this product is no longer registered in Pennsylvania.

SUMMARY

For best results in reducing bird damage, growers should use a variety of simultaneous techniques and start the control program before birds have established a habit of feeding on the fruit. Control is much more difficult after feeding patterns have become established. Growers should also keep records of attempted control methods and their success rates. The methods listed above are only suggestions.

MAMMALS

Various mammal species can cause damage to fruit trees and shrubs. Rabbits and rodents such as mice and voles will damage the twigs, bark, and roots of plants if given the opportunity. Deer will browse on foliage and twigs and can damage the bark.

VOLES

Voles are small rodents with short legs, stocky bodies, small eyes and ears, and short tails. Two species, the meadow vole *(Microtus pennsylvanicus)* and the woodland vole, formerly called the pine vole *(Microtus pinetorum),* can damage any of the small fruit crops and become serious pests. The meadow vole is approximately 5.5 to 7.5 inches long. It has brown fur mixed with black, and its tail is approximately twice the length of its hind foot. The woodland vole is Pennsylvania's smallest vole. It is 4 to 5 inches long and has chestnut or auburn fur and a short tail approximately as long as the hind foot.

Voles are vegetarians, feeding on grasses, tubers, and seeds. They also consume the bark of young trees and bushes. Unlike many other small mammals, voles do not hibernate. Instead, they are active throughout the year, at both day and night, with peak activity at dawn and dusk.

Meadow voles create surface runways in the grass; in winter, they are active in these runways beneath the snow. Woodland voles build underground tunnels in loose, crumbly soil. As they build the tunnels, they push out dirt, producing small, conical piles of soil on the ground surface. Both types of voles build large globular nests of dry grasses and leaves. The nests are located close to tree trunks, in tussocks of grass, and at the end of burrows.

Voles are extremely prolific. Their peak breeding activity occurs between March and October, but when winters are mild, voles may breed all year long. A female meadow vole could potentially produce over 70 young in a year, and the young voles become sexually mature at the age of 1 month. As a result, under ideal conditions vole populations can reach densities as high as 270 voles per acre. Scientists have found that voles exhibit regular population fluctuations at approximately four-year intervals. Populations apparently crash to levels as low as 10 voles per acre after peak years and then begin to build up again. Voles can cause extensive damage to fruit plantings, particularly during peak population years.

Damage

Voles can cause extensive damage to plants by girdling canes and damaging roots. Damage occurs primarily during winter when other types of food are scarce. The most common form of injury caused by meadow voles is cane girdling at or near the ground surface. Since voles burrow in the snow, they might damage trunks as high as the accumulated snow. Young plants are especially susceptible to attack. Occasionally, meadow voles will burrow in the soil and damage roots, resulting in weak, unhealthy plants. Voles frequently become problems any time cover is present, such as in plastic-mulched and straw-mulched strawberries, mulched blueberry plantings, or when landscape fabric is used (e.g., in bramble plantings). They also can cause extensive damage to trickle irrigation tape, especially when it is not buried.

Damage from woodland voles is harder to detect because it occurs underground as voles consume small roots, girdle large roots, and eat bark from the base of trees and other plants. By the time growers note weak, unhealthy plants, the damage already is extensive.

Signs of Voles

The most identifiable sign of meadow vole presence is a system of surface runways in the grass. Meadow voles create these runways by their feeding activities and keep them free of vegetation. The runways are generally about 1.5 inches wide. Bits of freshly cut vegetation and accumulations of vole droppings (brown or green in color and shaped like rice grains) in the runway are positive evidence they are being used. Vegetation, small roots, or mold in the runways indicate that the voles are no longer using them. Pine voles do not use surface runways, so their presence is much harder to detect. Tiny, elongated tooth marks on fruit on the ground are signs of both meadow voles and woodland voles.

Legal Status

Voles are classified as nongame mammals and can be controlled when causing damage.

Damage Control

Natural Controls

Hawks, owls, snakes, weasels, raccoons, foxes, opossums, and house cats all feed on voles. These predators are beneficial because they help keep vole populations under control. Whenever possible, growers should encourage these predators, or at least not harass or kill them. When natural controls are inadequate, artificial methods must be used to control vole populations. The fall is the best time for initiating control programs. A number of different control methods are listed below. The greatest success is usually achieved by using a variety of techniques at once.

Habitat Modification

In plantings, the major food sources for voles are normally not the crop plants, but roots and stems of grasses and other groundcover. As a result, habitat modification (e.g., reducing or eliminating grasses and cover) is one of the best long-term methods of controlling voles. Repeated mowings that maintain groundcover at a low height both limit food and cover and expose voles to predators. Where possible, mow wherever grass is present in the planting. Delays between mowings result in excessive vegetation, which, when cut (especially with a sickle-bar mower) forms a thatch layer that protects voles. A flail or rotary mower is preferred to reduce thatch.

Establishing vegetation-free zones that extend at least 2 feet from the plants will discourage voles from living near the bases of plants, where they cause

the most damage. Vegetation-free zones can be established by mowing, applying herbicides, or cultivating shallowly. Do not allow mulch, prunings, or decaying vegetation to accumulate around the bases of plants or within the rows.

Repellents

Repellents containing thiram (a fungicide) or capsaicin (the ingredient that makes chili peppers hot) are registered for vole control. Little data is available on the effectiveness of repellents to deter vole damage; therefore, repellents should not be used as the sole method of vole control. A food-grade product certified as organic is being marketed as a repellent and is not labeled as a pesticide.

Thiram-based repellents are labeled for use only on *nonbearing* trees and shrubs (i.e., those that won't produce fruit for at least one year). Capsaicin-based products are labeled for use on ornamental trees, fruit and nut trees, fruit bushes and vines, nursery stock, shrubs, and lawns. Capsaicin should be applied only before the fruit sets or after the harvest. Capsaicin is registered for use on vegetable plants and agricultural crops only before edible portions and/or heads begin to form.

This is an area in which control measures are evolving, and available materials vary. However, to prevent a feeding pattern from developing, apply repellents before damage becomes significant or, in the case of monitored populations, before damage occurs. They must be reapplied frequently after a rain, heavy dew, or new plant growth. Always follow label directions for the repellent being used. Never apply repellents to any portion of a plant likely to be eaten by humans or livestock unless the label permits it.

Trapping

Trapping is not an efficient way of controlling voles in large plantings, but it is an effective and safe control method in small plantings or around selected plants. Use standard, wooden-base snap traps (mouse size) and bait them with peanut butter, oatmeal, or apple slices. For meadow voles, place the traps in runways, flush with the ground and perpendicular to the runway. Place the trigger end directly in the runway. For pine voles, locate a tunnel and place the trap within the tunnel and perpendicular to it.

Toxicants

Used in conjunction with habitat modification, rodenticides are an important component of most control programs because they provide the quickest and most practical means of bringing large populations of voles under control. To determine if a specific rodenticide can still be used, read the label very carefully. The label will provide information on rates and applications and list legal uses for the product. Note any restrictions placed on the product.

Bait type is an important consideration in vole control programs. Acute rodenticides, such as those containing zinc phosphide, are fast-acting poisons that usually require only a single feeding to achieve a lethal dose. In contrast, chronic rodenticides, which include anticoagulants such as those found in Rozol pellets, require multiple feedings over a period of several days before a lethal dose is achieved.

Both acute and chronic rodenticides are available in pelletted bait formulations, which are superior to grain baits because they are more effective against voles and are not as hazardous to ground-feeding birds and other nontarget wildlife.

Bait placement is critical to the success of a control program. Broadcast distribution and hand placing of pellets at recommended rates will work, but the best results are achieved by using bait stations. In addition, bait in stations is less available to nontarget wildlife.

Timing also influences the success of control programs. Wet weather reduces the effectiveness of rodenticides, so apply baits when weather is likely to be fair and dry for at least 3 days. Baits are most effective when naturally occurring foods, such as green vegetation and fruit drops, are limited. Late fall is an important time to bait voles because it serves to reduce populations before the onset of winter, when vole damage is most severe and snow cover precludes rodenticide use. When winter survival is high, baits should be applied in the spring before the breeding season and before renewed growth of groundcover diminishes bait acceptance. Most rodenticide labels stipulate that bait can only be applied during the dormant season, after harvest, and before bud burst in the spring.

For additional information on controlling voles, see Penn State's *Wildlife Damage Control 9: Voles* fact sheet, available as listed in Appendix E.

Summary

Keep the grass mowed as if it were your front lawn. This is an excellent way to control rodents. Rodents require lots of cover to keep their natural predators—hawks and cats—from finding them. If the cover is removed, voles won't stay in the area. Use snap traps to help maintain populations at low levels.

COTTONTAIL RABBITS

Cottontails are active year round and can been seen at dawn and dusk. They tend to concentrate in favorable habitat such as brushy fencerows or field edges, brush piles, or landscaped backyards where food and cover are suitable. They need cover such as burrows or brush piles to escape predators. Cottontails are rarely found in thick shrubbery or dense forests; they generally spend their entire lives in a 10-acre or smaller area. Lack of food or cover is usually enough motivation for a rabbit to relocate. Population density varies with habitat quality, but an average of three to five rabbits per acre is reasonable.

Description of Damage

Rabbits can feed on plants year round. Rabbits damage woody plants by gnawing bark or clipping off branches, stems, and buds. In winter, when the ground is covered with snow for long periods, rabbits can severely damage trees and shrubs. Some young plants are clipped off at snow height, and larger trees and shrubs can be completely girdled.

In addition, the character of the bark on woody plants influences rabbit browsing. Young canes have smooth, thin bark with green food material just beneath it. Such bark provides an easy food source for rabbits. The thick, rough bark of older canes often discourages gnawing. Even on the same plant, rabbits avoid the rough bark but girdle the young sprouts that have smooth bark.

Damage Identification

Rabbit damage can be identified by the characteristic appearance of gnawing on older woody growth and the clean-cut, angled clipping of young stems. Damage occurs primarily within 2.5 feet of the ground. The clipping of small twigs and buds appears as a knifelike slanting cut with no apparent tooth marks. When rabbits gnaw bark, they gnaw in patches. The average width of a cottontail's incisor is 0.1 inch. Squirrels and voles also gnaw bark, but their tooth marks are much narrower. Distinctive round droppings or rabbit tracks in the immediate area also are good signs of their presence.

Legal Status

Rabbits are classified as game animals and are protected as such. Exceptions may be granted to property owners by their states' game commissions, allowing them to trap or shoot rabbits outside the normal hunting season on their own properties if damage is occurring.

Damage Control

Many methods can be used to control damage by cottontail rabbits. Exclusion techniques, such as fences and tree wraps, offer the most effective damage control. Such techniques are the only methods to control damage in areas where rabbit populations are high. In areas with moderate damage, repellents have been used to successfully reduce damage. Because of the cottontail's high reproductive potential, trapping and other lethal techniques are not effective over long time periods.

Exclusion

One of the best ways to protect a small berry patch is to put up a fence. A fence of 2- to 4-foot chicken wire, with the bottom tight to the ground or buried a few inches, is sufficient to prevent young rabbits from getting through. The lower 1.5 to 2 feet should be covered with small-mesh wire. A fence might seem costly, but with proper care it will last many years and reduce damage caused by rabbits and other animals.

Cylinders of 0.25-inch wire hardware cloth will protect young plants. Due to economic considerations, use is more likely in small plantings. The cylinders should be placed 1 to 2 inches out from the trunk and should extend higher than a rabbit's reach when it stands on the expected snow depth. Small-mesh (0.25-inch) hardware cloth also protects against vole damage.

Rabbits commonly damage vegetation at a height of 2 to 3 feet, depending on the snow depth in winter. You can use larger mesh sizes, 0.5 to 0.75 inch, to reduce cost, but be sure the cylinder stands far enough away from the trunk that rabbits cannot eat through the holes. Commercial tree guards or tree wraps are other alternatives. When rabbits are abundant and food is in short supply, only hardware cloth will guarantee protection.

Repellents

Several chemical repellents discourage rabbit browsing. For best results, use repellents and other damage-control methods at the first sign of damage. Always follow the application directions exactly. Since pesticide registrations change frequently, check with your local Cooperative Extension service for information on repellents or other new products available for use in your area. Remember that some repellents are poisonous and require safe storage and use.

Most rabbit repellents are contact or taste repellents that render the treated plant parts distasteful. Taste repellents protect only the parts of the plant they contact; new growth that emerges after application is not protected, and heavy rains may necessitate reapplication. Odor repellents protect plants within a limited area and do not need to be touching the plant. The degree of efficacy is highly variable, depending on the behavior and number of rabbits and the availability of alternative food sources. When rabbits are abundant, use other control techniques along with chemical repellents.

Hinder and Deer-off are available for use on consumable plants such as fruits. Hinder consists of ammonium soaps of higher fatty acids. It is an odor repellent that may be sprayed or painted on the foliage. Hinder has been found to be effective in repelling rabbits and deer from crops and ornamental plants. Deer-off consists of garlic oil, capsaicin, and putrescent whole egg solids. It is an odor and taste repellent that can be applied to foliage, but edible fruits should be cleansed prior to consuming. Hot Sauce Animal Repellent, by Millers, which contains capsaicin (the heat source in hot sauce), can also be applied to fruit trees; however, it must be applied either before the fruit is on the plant or after it has been removed. Capsaicin is a taste repellent. The warm sensation it leaves in the throat of the animal is believed to cause the animal to avoid eating that plant again. The effectiveness of capsaicin-containing repellents varies depending on the availability of other food sources.

Trapping

Trapping can be used to remove rabbits from problem areas. Several excellent styles of commercial live traps are available from garden centers, hardware stores, and seed catalogs. Most commercial traps are made of wire and last indefinitely with proper care. Live traps can often be rented from animal control offices or pest control companies.

Dry corn and dried apples make very good year-round bait. Dried leafy alfalfa and clover are good cold-weather baits. Apples, carrots, cabbage, and other fresh, green vegetables are good baits in warmer weather, but these soft baits become mushy and ineffective once frozen. For best results, use baits similar to the fruit on which the target rabbits are feeding. Position the bait at the rear of the trap. Placing a trap involves the following easy steps:

1. Place traps where you know rabbits feed or rest. Check for runways along the edge of cover. To locate an active runway, look for rabbit droppings and clipped twigs. Place sticks in the ground in front of the trap to guide the rabbit into the trap.
2. In winter, face traps away from prevailing winds to keep snow and dry leaves from interfering with the door. Move traps if they fail to make a catch within a week.
3. Check traps twice a day to replenish bait or remove the catch. Laws exist in various states that define the minimum amount of time between trap checks. Legally, in Pennsylvania, traps must be checked every 36 hours; however, they should be checked every 12 hours, particularly in

suburban areas where neighborhood pets may be caught.

A commercial wire trap can be made more effective by covering it with canvas or some other dark material. This will cause the trap to resemble a safe, secure environment. Be sure that the covering does not interfere with the trap's mechanism.

Habitat Modification

Although frequently overlooked, removing brush piles, weed patches, dumps, and other debris near fruit plantings can be a useful way to manage rabbits. Keeping your grass mowed will remove potential cover that might attract cottontails. Filling old woodchuck or skunk burrows will remove their potential as rabbit homes. Encouraging the rabbit's natural enemies—or at least not interfering with them—may aid in reducing rabbit damage. Hawks, owls, foxes, mink, weasels, and snakes all help control rabbits.

Summary

The most effective method of reducing rabbit damage to your planting is fencing or other forms of exclusion along with habitat modification. If numbers of rabbits are low and alternative food sources are available, repellents also might be useful in reducing damage.

WHITE-TAILED DEER

The white-tailed deer is one of the most widely distributed and well-known mammals of North America, and it is a common species throughout the Mid-Atlantic. Deer prefer early successional forests that are in the shrub-tree sapling stage. They are also abundant in agricultural areas where field crops and orchards are interspersed with forest habitat.

Deer are most active during early morning and evening hours. They can have a home range of several square miles, but this varies with season, habitat, sex, and even individual characteristics. Whitetails are creatures of habit—most use the same home range year after year. They also tend to establish one part of their home range for feeding and another part for resting. For instance, if deer establish an orchard as a source of food, they will habitually move into the area a little before sunset to feed, and move back to the woods before dawn to rest.

The natural food habits of deer depend on the time of year and the plant species available. During the winter months, deer consume evergreen and dry leaves, as well as dormant buds. In the spring and summer, they eat new growth on woody and herbaceous plants. From late summer to early winter, fruits and nuts comprise a large part of a deer's diet.

Damage

Deer cause damage to fruit plants year round, but the most serious damage occurs on plasticulture strawberry plantings in the fall before row cover application and on any planting in the winter months when the availability of natural foods is limited. In winter, browsing on canes and dormant terminal buds may lead to stunted or misshapen growth and lower fruit production. Severe winter browsing can reduce plant vitality and even cause death.

During the spring and summer, natural sources of forage are readily available to whitetails; however, they still might browse new growth and eat ripening fruit. In autumn, deer might continue to browse and eat fruit within the planting.

Monitoring

The extent of deer damage can be monitored through direct and indirect observation. Deer might be "caught in the act" during their active periods in the evening and early morning. Indirect observation involves recognizing signs that deer leave behind.

Lacking upper incisor teeth, deer characteristically tear off vegetation, leaving jagged edges that identify browsed canes. In comparison, browsing by rodents and rabbits leaves a clean-cut surface. The height of the damage, however, might be the only factor necessary to eliminate any mammal other than deer. Another method for determining the source of damage is to search for tracks. Deer leave a distinctive split-hoofed track that can easily be seen in damp soil or snow. Monitoring your fruit plantings for damage is an important, ongoing process and the first step in a successful management plan.

Legal Status

White-tailed deer are classified by most states' game commissions as a game mammal. As such, they are protected. Deer may be harassed throughout the year, but harming deer is prohibited outside of the legal hunting season, unless your livelihood comes from growing crops or fruit.

Damage Control

Hunting

The white-tailed deer is a protected game species and the size of the deer herd is managed through regulated hunting of antlered and antlerless deer. As a landowner, you should encourage hunting in your area, especially if your fruit plantings are subject to heavy deer damage. Posted areas serve as refuges for deer during the hunting season and might compound the damage to a planting by concentrating the deer population. Before opening the area to hunters, make sure the orchard is a safe area for hunting. Consult your local wildlife conservation officer for information on opening your land to hunters or on eligibility requirements for hunting.

Shooting

Even though your land is open for hunting, you may still experience problems with deer when they are no longer in season. Many states allow taking deer for crop damage. Contact the local wildlife conservation officer before you act to ensure complete understanding of all the regulations.

Repellents

Repellents are most effective when integrated into a damage-control program that includes fencing, hunting, and several types of repellents. Apply repellents at the first sign of damage to prevent deer from establishing a feeding pattern at the site. Area repellents include tankage (putrefied meat scraps), ammonium soaps, bone tar oil, blood meal, and human hair. Contact repellents work by taste and must be applied directly to the plant. These repellents work best if you apply them in the dormant season on dry days when temperatures are above freezing. Examples of contact repellents are putrescent egg solids, thiram, and hot pepper sauce (capsaicin). Remember that whenever you apply a commercial repellent, you are required by law to comply strictly with the label. Home remedies often have limited success. Human hair

can be obtained from a local barber shop and placed in small bags (cloth or plastic—if plastic is used, punch three to four holes in the bottom). Tie up the tops and hang them around the planting or individually in trees. Soap bars can be placed in individual plants. Blood meal and tankage can be hung around the perimeter of the planting, initially 20 feet apart and then closer together if needed. Place these items about 30 inches off the ground, about the average height of a deer's nose. Remember, success depends on early preventative monitoring and alternation of materials.

Repellents containing thymol and benzyidlethyl ammonium saccharide, such as Ro-Pel, have been found to be less effective. These products may only be applied to plants during the dormant season or to young, nonbearing plantings. When applied to dormant plants, the new growth in the spring is not protected.

Repellents have variable results—what works for one grower might not work for another, and success differs from year to year. Some repellents do not weather well and require repeated applications during the season. Also, if deer are very hungry and the area lacks other more palatable food resources, they might ignore the repellents. Success must be measured by how much the damage has been reduced since it is rarely eliminated. In areas where deer density is low and damage is light, repellents may be a cost-effective part of your IPM strategy.

Fencing

Fencing deer out of the orchard is the most efficient way to reduce damage when deer density is high and damage is extensive. The conventional 8-foot, woven-wire fence effectively excludes deer by forming a barrier around the orchard. The fence consists of two widths of 4-foot woven wire and 12-foot posts. To prevent deer from crawling under the fence, keep the wire close to ground level. Unfortunately, deer-proof fencing is expensive, but it is effective, long lasting, and requires little maintenance.

An alternative to barrier fencing is an electric fence. This type of fence is designed to change the deer's behavior. Although deer can easily jump an electric fence, they will instead try to go through or under it. An electric fence takes advantage of this behavior and successfully trains the deer to stay 3 to 4 feet away from the wires.

Researchers at Penn State have developed a low-cost, five-wire electric fence. Through tests conducted statewide, the design has shown to be an adequate means of deer control. The fence incorporates high-tensile steel wire; in-line wire strainers; and high-voltage, low-impedance energizers. High-tensile fence can absorb the impact of deer and tree limbs, thereby eliminating some of the problems associated with soft-wire fences. In addition to Penn State's five-wire fence, other high-tensile electric fence designs are available. See *Managing Deer Damage in Maryland* by Jonathan Kays (Appendix E) for details on design.

The disadvantages of electric fences include required high maintenance and regular inspections. You must maintain a 6- to 8-foot-wide mowed strip along the fence perimeter to discourage deer from jumping and to decrease the weed load on the fence. You must also regularly check the electric current to ensure that the shocking power is sufficient for turning the deer. The advantages include a relatively low cost and, when properly maintained, a long life.

Scare Tactics

Another method of deer control in plantings is the use of guard dogs. Deer quickly learn the extent of a dog's range if it is chained. But free-ranging dogs can deter deer from feeding in any part of the planting. An electronic containment fence can be buried or placed on an existing fence. This will keep the dogs in the orchard but allow them free access to all areas. Most dogs will patrol the edge of their territory; therefore, a closely mowed strip along the fence line will enable them to patrol the entire area. Herding breeds are the most effective because of their natural tendencies to chase animals. Long-haired breeds may be more apt to patrol in colder weather and therefore come in contact with deer in more conditions than the shorter-haired breeds. Place doghouses and feeders near established deer trails if they exist on your farm. This will increase the likelihood of the deer coming in contact with the dog. Place dogs in the containment approximately one month before damage is anticipated. This will allow the dogs to get used to the containment system and the area.

Summary

Deer damage management is a complicated issue with many alternatives that depend on financial considerations and the amount of damage that can be tolerated. A combination of control methods such as fencing and repellents is most effective. If possible, opening your farm to hunters after considering safety and zoning regulations is a good way to reduce the deer herd on your property.

CONCLUSION

Wildlife damage can be reduced and maintained at a tolerable level if the species causing damage is properly identified and control methods are implemented before a damage pattern is established. Anticipation of potential problems is the key to effective damage control. The use of a variety of control techniques is essential since the offending species can become accustomed to a single method.

Wildlife damage to fruit is a seasonal problem. In many instances, damage will occur only over a short time period of days or weeks. Control methods might be necessary only during those short time periods. Observation of damage and damage trends can reduce the time and money allocated to damage-control techniques.

CHAPTER 6

Strawberries

CONTENTS

Introduction 49
Types of Plants 49
The Strawberry Plant 49
Anatomy and Morphology 49
Pollination 50
General Considerations in Choosing a Site 51
Topography 51
Crop History and Fumigation 51
Soil Characteristics 51
Irrigation Availability 51
Obtaining Plants 51
Cultural Systems 52
June-Bearers: Matted-Row Production 52
June-Bearers: Plasticulture Production 57
June-Bearers: Ribbon-Row Production 64
Day-Neutrals: Matted-Row Production 64
Day-Neutrals: Plasticulture Production 64
Considerations for Organic Production 67
Protected Culture 67
Harvest and Postharvest Handling 68
Economics 68
Pests 75
Diseases 75
Nematodes 78
Insects, Mites, and Molluscs 78
Weeds 102
Site Preparation 102
Weed Control After Planting 102
Plasticulture Weed Control 105
Matted-Row Weed Control with Herbicides 105
Sample Weed Control Program for Matted-Row Strawberries 105

INTRODUCTION

Strawberry growers in the Mid-Atlantic region are geographically well positioned to reach many major markets. While consumers have become accustomed to seeing strawberries year-round from other production areas, Mid-Atlantic producers should realize that they have a competitive advantage in being able to provide top-quality fruit (i.e., fully ripe when harvested) to this large consumer base, rather than attempting to compete with berries in the supermarket on the basis of price.

Most growers in the cooler and mountainous areas of the region utilize matted-row field production, while plasticulture production is more common in warmer areas. Both ribbon-row production and high tunnel production are also used, but to a lesser extent. In general, there appears to be increased interest in day-neutral production as consumers become more accustomed to the availability of "off-season" strawberries. Cultural information pertinent to all of these systems is described below, with information specific to each system described later in this chapter.

TYPES OF PLANTS

Two main types of strawberry plants are grown commercially. They are defined primarily by the time of flower bud initiation and therefore fruiting. Short-day or June-bearing types initiate flowers when days are short, less than 14 hours. Day-neutral types initiate flowers season-long within certain temperature ranges.

Short-day or June-bearing types are widely grown in the Mid-Atlantic region, producing most of the fruit harvested during the main May–June season. With this type of plant, flower buds are mainly initiated when days are short in the fall (late August through early November); however, short days in spring (March) also stimulate some flower bud initiation. Short-day types are actually facultative short-day plants—they will initiate flower buds either when days are shorter than 14 hours or when temperatures are below 60°F.

Day-neutral or everbearer types are less widely grown, performing better in the cooler regions of the area (zones 6a or cooler, and higher elevations) since they are sensitive to high temperatures. They produce branch crowns and flower buds throughout the season; however, initiation can be inhibited when temperatures are high. Plants will begin fruiting in mid-May to mid-June, producing an average-sized crop compared to short-day types. In most locations in this region, a second small crop is produced in midsummer. The third and heaviest crop is produced in late summer and early fall, usually beginning in August and ending with the first hard frost. However, in high-elevation locations, such as in western Maryland, the heaviest crop is produced in mid- to late summer.

THE STRAWBERRY PLANT

ANATOMY AND MORPHOLOGY

The strawberry plant is a nonwoody perennial made up of a crown, leaves, runners, and a root system (Figure 6.1). Many management practices were developed based on those features. The crown is a compressed modified stem where leaves, runners, branch crowns, and flower clusters (inflorescences) arise. Branch crowns, as their name implies, are smaller crowns that branch off from the main crown. Plants can have one or two additional flower clusters on each branch crown. Branch crown formation is promoted by the short, cool days of fall and can also occur in the spring.

Leaf size is variable. Older leaves usually die during the winter and are replaced by new leaves in the spring. Leaves are produced all season with most production occurring during long days, though the process slows when temperatures are above 86°F. Leaf production stops when temperatures are below 32°F in the fall. Having a well-established leaf canopy is important to provide energy for flower bud initiation.

Roots are most abundantly produced during the spring and fall and are active until the soil freezes. Strawberry plants have two types of roots. Primary roots conduct water and nutrients to the crown and last more than one season. In successive years, primary roots are produced higher on the crown, so about an inch of soil should be thrown over the

plants during renovation to encourage new primary root development. With good care, plants are able to produce new healthy primary roots above the old ones, thus allowing plants that have had a poor root system in the past to recover. Feeder roots branch off from the primary roots and live only for a few days or weeks. Their function is water and nutrient absorption. Strawberry plants have shallow root systems, which result in sensitivity to deficient or excess water and high salt levels in the soil. Those issues should be addressed when choosing and preparing a planting site. In light sandy soils, the roots penetrate the soil to 12 inches deep with half of the roots located in the lower 6 inches. In heavy soils, roots only grow about 6 inches deep.

Runners (stolons) are the plants' means of vegetative propagation, as daughter plants arise from them. Runners form during long days with warm temperatures, beginning in late spring and continuing until fall. For short-day or June-bearing types, runners form when days are more than 10 hours long and temperatures are at least 70°F. Formation stops when days are less than 10 hours long and temperatures are freezing. In day-neutral types, the majority of runners are formed when days are long and temperatures are moderate. Runner formation is more sporadic for day-neutral types than short-day types. After the development of numerous lateral roots, the daughter plants become independent of the mother plant, usually after 2 to 3 weeks of attachment. In matted-row production, daughter plants will be responsible for producing most of the fruit. Dormant plants in matted-row production should be planted as early as possible to allow time for them to establish and form runners and daughter plants. Daughter plants that have had more time to develop have larger crowns and more flower buds, which result in higher yields. In later years, taking good care of renovated plantings during the summer encourages earlier production of runners, early establishment of daughter plants, and higher yields the following year.

Flowers are borne in clusters (Figure 6.2). The terminal flower opens first and is referred to as the king or primary flower. The king flower yields the largest fruit, but because it opens first, it is more susceptible to frost than later-formed flowers. The secondary flowers open 1 to 2 days after the king flower, followed by tertiary flowers. Successive flowers produce smaller fruit.

POLLINATION

Strawberry flowers usually have five or more petals surrounding 20 to 35 stamens that differ in size and length within the same flower. Each stamen consists of the filament and the pollen-producing anther. Anthers are a deep golden yellow when they contain pollen, but they turn pale as pollen is released.

Inside the circle of stamens is a cone-shaped structure called the receptacle, which is an extension of the flower stem or pedicel. This portion develops into the berry. Each receptacle is covered with as many as 500 pistils arranged in a spiral pattern. At the base of each pistil is an ovary containing an ovule (potential seed).

Pollination is achieved when pollen from the anthers reaches the stigmas—self-pollination occurs when the pollen is from the same flower; cross-pollination occurs when pollen comes from a different flower. Following fertilization and achene (seed) development, receptacle tissue around the achenes swells to form the berry.

Some self-pollination is accomplished in strawberry flowers as the pollen matures and is released from the anthers

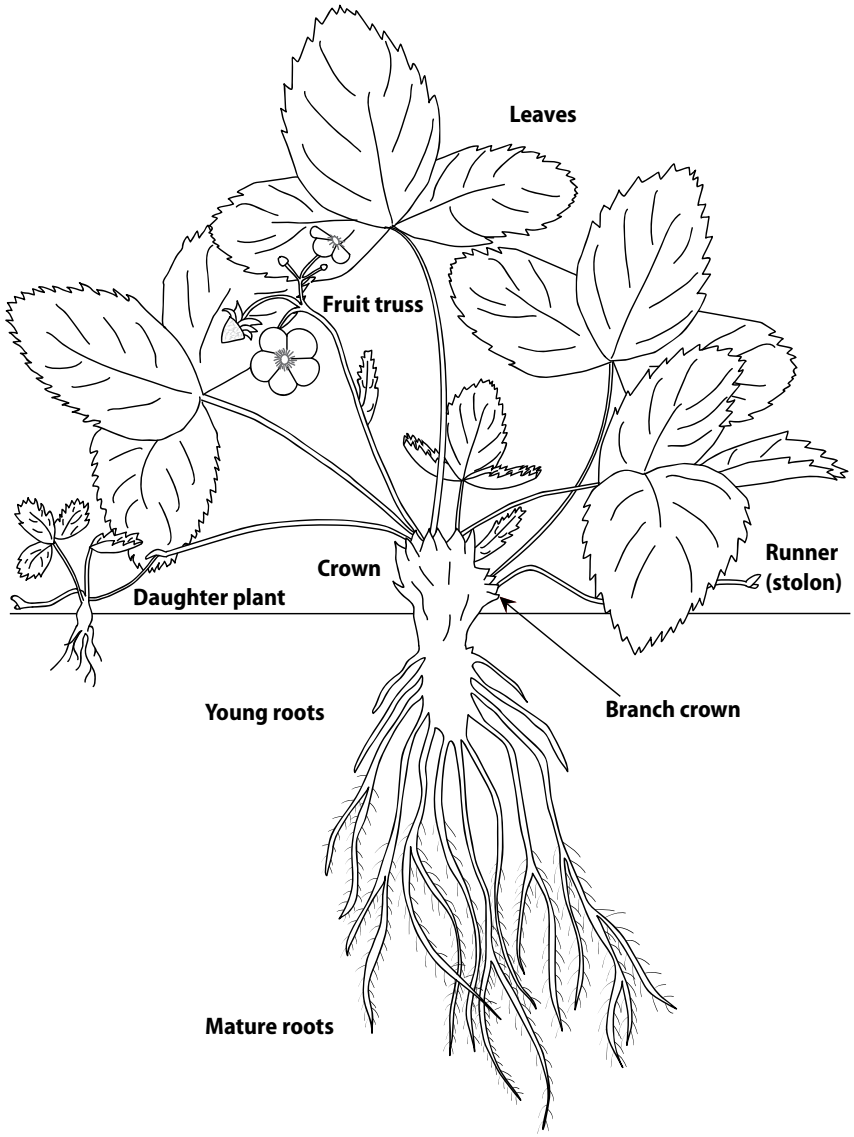


Figure 6.1. The strawberry plant.

when they split open. The shaking of flowers by the wind and raindrops serves to transfer pollen within the flower. Wind and self-pollination, however, seldom provide complete pollination of all pistils of a flower. Sometimes even flowers that have pollen-laden anthers seem to set fruit far better when cross-pollinated than when fertilized with their own pollen. Incomplete pollination results in small or misshapen fruits, thus pollen transfer by insects is recommended.

Honey bees and many species of wild bees visit strawberries for nectar and pollen, though strawberries are not especially attractive as pollen or nectar sources. Even though many types of insects visit strawberry flowers, only bees are of real consequence in transferring pollen effectively. Most growers would benefit from the consistent use of one colony of honey bees per acre, especially if wild bees are not plentiful enough for the flower to receive the recommended 16 to 25 bee visits.

King blossoms, besides being the first to open, are the largest, have the shortest stamens, possess the most pistils, and, if fully pollinated, produce the largest berries of greatest value. These flowers benefit the most from insect visits. As flowering continues down the cluster, pollen becomes plentiful, receptacles are smaller with fewer pistils, stamens are taller, and flowers are less likely to set fruit and more likely to produce smaller berries, thus requiring less pollinator activity.

Cool temperatures decrease the number of insect visits to flowers and slow down flower development. More malformed berries can be observed in cool, wet weather, with wind exposure, and during periods of heavy rainfall.

GENERAL CONSIDERATIONS IN CHOOSING A SITE

Considerations for all crops as discussed in introductory chapters apply to strawberries and should be consulted. Additional points that apply specifically to strawberries are given below.

TOPOGRAPHY

A slope of 5 to 7 percent will allow for adequate air drainage for frost avoidance, while slopes over 12 percent should be avoided due to erosion and tillage concerns. If steeply sloping sites must be used, plant wider rows across the slope or on the contour.

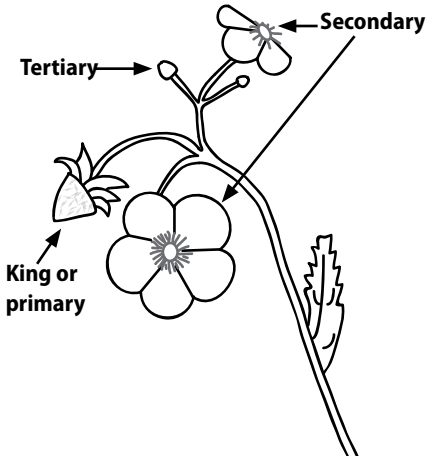


Figure 6.2. Arrangement of strawberry blossoms on fruit truss.

CROP HISTORY AND FUMIGATION

Strawberries perform best on soils with high organic matter that have never been planted to strawberries, or, alternatively, on land that has been in a proper crop rotation. Repeatedly coming back to the same field with strawberries, especially on a short rotational cycle, invites poor plant stands and low yields. See Chapter 1, Preplant Considerations, for discussions of problematic and preferred preceding crops. If a field has not been planted to problematic preceding crops or strawberries for the past five years, it probably does not need to be fumigated unless plant-parasitic nematode populations or disease pressure are high. Details on nematodes, fumigation and other potential alternatives to chemical fumigation are discussed in Chapters 1, 2, and 3 and Appendix A. If chemical fumigation is needed, plan to fumigate soil the fall before planting with matted-row culture and in late spring with plasticulture strawberries.

SOIL CHARACTERISTICS

Strawberries grow and produce satisfactorily in a wide range of soil types, with best yields achieved in deep fertile soils with high organic matter and good internal drainage. Black root rot is commonly diagnosed in strawberry plantings with compacted heavy soils. Organic matter can be improved before planting by adding manure, or by planting cover crops or green manure crops. For a complete discussion of these topics, see Chapter 2.

IRRIGATION AVAILABILITY

Irrigation is highly recommended for growing matted-row strawberries and is a necessity for plasticulture berries. Therefore, sites should be chosen where an ample water source is accessible. Trickle irrigation applies water only where it is needed, thereby using water efficiently and minimizing weed germination between the rows. It also serves double-duty as a way to apply nutrients quickly and efficiently through fertigation. However, because overhead irrigation also is necessary to protect blossoms from frost, relatively few matted-row growers install trickle irrigation. Plasticulture growers need both trickle and overhead irrigation.

Because strawberry plants are shallowly rooted, they need water in the form of rainfall or irrigation many times during the growing season. Water must be available during establishment, when runners are forming and daughter plants are rooting, and during flower bud formation. Plants first respond to severe moisture stress by decreasing runner production, thereby decreasing the number of daughter plants and the yield for the following season. Flower bud formation occurs in the fall preceding the fruit season (August 20 to October 30), during which sufficient water and fertilizer are important for producing the optimum number and size of berries. Plants should receive about 1 to 2 inches of water per week. Plantings on sandy soils will need to be watered more frequently than those on heavier soil types. Tensiometers can assist in determining when irrigation is needed, though they work best on lighter soils. See Appendix E: Sources of Additional Information to obtain information on their correct use and interpretation.

OBTAINING PLANTS

Purchase plants from a reputable nursery. See Appendix C for a listing of nurseries carrying small fruit nursery stock. Certified (disease- and insect-free), virus-tested plants that are true to name are essential for a successful operation.

Table 6.1. Number of strawberry plants per acre for different in-row and between-row spacings.

MATTED ROW/RIBBON ROW					
	Between-Row Spacing				
In-Row Spacing	36 inches	42 inches	48 inches	54 inches	60 inches
3 inches	58,080	49,783	43,560	38,720	34,848
6 inches	29,040	24,891	21,780	19,360	17,424
12 inches	14,520	12,446	10,890	9,680	8,712
18 inches	9,680	8,297	7,260	6,453	5,808
24 inches	7,260	6,223	5,445	4,840	4,356
PLASTICULTURE					
	Bed Spacing				
In-Row Spacing	48 inches	54 inches	60 inches	66 inches	72 inches
12 inches D*	21,780	19,360	17,424	15,840	14,520
14 inches D	18,669	16,594	14,935	13,577	12,446
16 inches D	16,335	14,520	13,068	11,880	10,890
18 inches D	14,520	12,907	11,616	10,560	9,680

*Signifies spacing between plants within each row of a staggered double row. Spacing between double rows does not change number of plants needed.

For the number of plants required per acre, consult Table 6.1.

Dormant crown plants should be ordered no later than the December before planting since cultivars in high demand often sell out rapidly. Request a shipping date that will allow you to have the plants as soon as the soil can normally be prepared. When plants arrive, check the roots for moisture and moisten if necessary.

Plug plants for use in plasticulture (see "Cultural Systems") should be ordered 6 months or more before planting. Call the producers to obtain information on cultivar availability.

CULTURAL SYSTEMS

Variation in cultivars, growing conditions, and available marketing channels make many different production systems feasible for strawberry producers in this region. Growers new to strawberry production may wish to contact local extension personnel or simply observe production methods used locally to help determine which production system(s) to try. Matted-row production, as the name implies, relies on the establishment of a filled-in row of strawberries from plants that are planted on a relatively wide spacing and is a relatively low-cost way of producing strawberries. Plasticulture production is more intensive and has a higher cost and, thus, is somewhat higher risk, but it may result in higher returns. Both June-bearing and day-neutral cultivars can be used in either system with modifications. Information is provided on each of these options below, as well as on less frequently used options such as ribbon-row production, protected culture (high-tunnel or greenhouse production), and organic production.

JUNE-BEARERS: MATTED-ROW PRODUCTION

Matted-row production was the standard system of strawberry production in the region for many years and is still the system used on most strawberry acreage in the region. One advantage of this system is a relatively low cost of establishment. This system is best suited to colder areas of the region and is most frequently used for pick-your-own operations.

Fertility

A soil sample should be tested during the summer or fall before planting. Testing during this timeframe allows the grower to apply lime and phosphorus during the fall before planting and to disk them down into the top 6 inches of soil. The optimum pH for strawberries is 6.0 to 6.5. After the initial soil fertility adjustment, only nitrogen is applied annually, unless tissue (leaf) analysis recommends other nutrients. Nitrogen, phosphorus, and potassium rates and timings are listed in Table 6.2. Rates are given as a general guide. Soil tests, leaf analyses, history, and plant vigor should be used as guides specific to your site, especially concerning nitrogen rates. Strawberry matted rows should be vigorous enough to reach 12 to 18 inches in width by mid-August. If the beds become wider and runners develop late into the fall, then nitrogen use is probably excessive, and rates should be reduced. If compost is used for nutrient addition, timing should be adjusted to allow time for breakdown and nutrient release in time for needs to be met. For example, since June-bearing strawberries have a high nutrient demand in the fall as they produce flower buds for the crop the following season, compost will need to be applied in midsummer.

Plants and Varieties (Cultivars)

Use certified dormant plants packed dry in polyliners. These plants can be stored at 30°F for a longer period than freshly dug plants. Plant only virus-free plants. Choose varieties that are suitable for your market needs, using several different varieties to spread the harvest over several weeks. Commonly grown standard cultivars across this region are Earliglow (early season) and Darselect and Allstar (midseason). Wendy is gaining in popularity for the early season. Honeoye (early midseason) and Jewel (mid-late season) are also commonly grown in cooler locations. Many other cultivars are also available and are described in Table 6.3 (including state-specific recommendations).

Planting

Planting should take place as early in the spring as possible after the ground will no longer freeze and as soon as possible after delivery of plants. If planting must be delayed, keep plants at 30 to 32°F in plastic bags in a refrigerator or walk-in cooler free from apples or other ethylene-producing harvest.

If cold storage is not available, keep the plants in a shady area, heeled-in if possible, until they are planted. Place roots in water about half an hour before planting and do not allow them to dry out during the planting process. Mother plants are set 18 to 24 inches apart in the row, with rows on approximately 3- to 4-foot centers, depending on

Table 6.2. Recommended fertilizer amounts for June-bearing matted-row strawberry plantings.

Rates are intended as approximations. Soil testing, leaf analysis, and plant vigor should be used to fine tune rates for your site. If phosphorus levels are above optimum, no additional phosphorus is typically recommended other than strategically placed low starter rates for spring planting.

Soil	Nitrogen (N) (lbs/acre)	Soil Phosphorus Level (P_2O_5) Low	Med	Opt	Soil Potassium Level (K_2O) Low	Med	Opt	Suggested Application Methods
ESTABLISHMENT YEAR								
Clays and clay loams	30	100	70	40	150	100	50	Broadcast and plow down or disk in
	20–30	0	0	0	0	0	0	Sidedress when first runners start
	20–30	0	0	0	0	0	0	Topdress in mid-August
	70–90	100	70	40	150	100	50	**Total recommendations for season**
Loams and silt loams	30	100	70	40	150	100	50	Broadcast and plow down or disk in
	30–40	0	0	0	0	0	0	Sidedress when first runners start
	30–50	0	0	0	0	0	0	Topdress in mid-August
	90–120	100	70	0	150	100	50	**Total recommendations for season**
Sandy loams, loamy sands, and sands	30	100	70	40	165	115	65	Broadcast and disk in deep
	20–30	0	0	0	0	0	0	Sidedress 2 weeks after planting
	20–30	0	0	0	0	0	0	Sidedress when runners start
	30–40	0	0	0	0	0	0	Topdress in mid-August
	10–20	0	0	0	0	0	0	Topdress in February or March
	110–150	100	70	40	165	115	65	**Total recommendations for season**
	Apply 1–2 pounds of boron (B) per acre with broadcast fertilizer unless tissue or soil test indicates above-normal levels.							
FIRST HARVEST YEAR AND LATER								
Clays and clay loams	30	100	70	40	150	100	50	Topdress at renovation
	15–20	0	0	0	0	0	0	Topdress in mid-August
Sandy loams, loams, and silt loams	30	100	70	40	150	100	50	Topdress at renovation
	20–30	0	0	0	0	0	0	Topdress in mid-August
Loamy sands and sands	40–50	100	70	40	165	115	65	Topdress at renovation
	20–30	0	0	0	0	0	0	Topdress in mid-August
All except for heavier soils in northern locations*	20–30*	0	0	0	0	0	0	Topdress in February or March*

*Growers on heavier soils in more northern locations do not need this application unless irrigation or rainfall has been excessive, and may experience soft fruit if excess nitrogen is spring applied.

equipment constraints. Place the plants in the soil with the roots spread out. The center of the crown must be level with the soil surface—not too low that it is covered by the soil, nor too high that the roots are left exposed. Planting strawberries too deep can result in poor plant performance and even death. Overhead irrigate strawberries immediately after planting to settle the soil next to the roots, reduce transplant shock, and promote establishment. A starter fertilizer used according to package directions helps plant growth.

Care during the Establishment Year

Nitrogen is recommended 3 to 4 weeks after planting and again in late August, and more frequently on sandy soils (see Table 6.2 for rates and timing). Allow runners to spread to fill a 12- to 18-inch matted row with at least a 24-inch walkway between each row. Increase the spacing of the walkway to fit your equipment, but limit each row to a width of not more than 18 inches. Flower buds of June-bearing strawberries should be removed the first year to prevent flowering and fruiting stress on the young plant. Removing the flowers allows plants to direct their resources into establishing a strong root system and developing a healthy leaf canopy that will "fuel" the following year's crop. Most blossoms can be removed in two passes two weeks apart. Weeds should be kept under control. Equipment that cultivates shallowly (rotary hoes or finger weeders) and that is equipped with shoes to sweep runners into the row is especially useful. Several herbicides are now labeled for use during the planting year (see section on weed management in this chapter), but pay close attention to following the labeled directions. Sinbar can also be used in early fall of the planting year to control winter annuals, while several herbicides can be used in late fall prior to mulch application. More specific information on weed management is presented at the end of this chapter and in Chapter 4.

Overwintering the Planting

Mulch strawberry beds during the winter to protect them from severe cold, fluctuating temperatures, and soil

Table 6.3. June-bearing matted-row strawberry cultivars.

	Recommendations for use in:							Susceptibility to:*					
Cultivar	NJ	MD	VA	WV	DE	PA	Season	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Description
Annapolis	Yes	Yes	No	Yes	Yes	No	Early	I	R	S	S	S	Medium to large fruit with good flavor. Produces many runners and dense beds, increasing botrytis incidence. Better for more northern sites.
Earliglow	Yes	Yes	Yes	Yes	Yes	Yes	Early	R	R	I	I	R	Still a great early season cultivar for flavor and disease resistance. Moderately productive; size runs down quickly.
Itasca	Trial	Trial	Trial	Trial	Trial	Trial	Early	U	R	R	U	S	Medium to large fruit, bright red with good size but somewhat soft. Flavor is average. First harvest begins with Earliglow, but long season results in high yields.
Northeaster	Yes	Yes	Trial	Yes	No	Trial	Early	R	R	S	I	I	Large aromatic fruit; may have a perfumy flavor. Similar yields and season to Earliglow. Early berries start out large, but still run down quickly.
Sable	No	No	No	No	No	No	Early	U	R	S	R	R	Dense foliage low to ground, results in susceptibility to Botrytis and angular leaf spot. Yields are high, but even the primary berries are small. Medium red fruit with sweet flavor.
AC Wendy	Trial	Trial	Yes	Yes	Trial	Trial	Early	S	MR	MR	U	U	Has color and firmness similar to Evangeline, one of its parents, but has improved size and excellent flavor. Productive.
Bish	Trial	Trial	No	Trial	Trial	Trial	Early–mid	U	U	U	U	U	Developed for plasticulture in North Carolina, but runners well in matted-row. Excellent flavor. In PA, many blossoms opened black resulting in low yields. Resistant to anthracnose fruit rot. Only available from a limited number of southern nurseries.
Brunswick	No	No	No	No	No	Trial	Early–mid	U	R	I	R	I	Yields well, but has average flavor. More likely to perform better in cooler locations. Susceptible to phytophthora crown rot.
Cavendish	Yes	Yes	Trial	No	Trial	Trial	Early–mid	I	R	S	R	R	Large fruit with good flavor. Productive, but ripens unevenly in some years.
Daroyal	Trial	Trial	Trial	Trial	Trial	Trial	Early–mid	U	U	U	U	U	From France. Berries are of dark red color with similar size to Darselect. Medium in firmness. No data available on performance In the Mid-Atlantic region.
Honeoye	No	Yes	Yes	Yes	No	Trial	Early–mid	S	S	T	R	R	Very productive, with a perfumy flavor, but becomes very dark, soft, and bland in hot weather. Better in cooler locations. Susceptible to twospotted spider mites.
L'Amour	Trial	Trial	Trial	No	Trial	Trial	Early–mid	U	U	U	R	I	Nicely shaped fruit with good size, medium-red color and above-average flavor. Perfect degree of firmness.

CONTINUED

Table 6.3. June-bearing matted-row strawberry cultivars, continued.

	Recommendations for use in:							Susceptibility to:*					
Cultivar	NJ	MD	VA	WV	DE	PA	Season	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Description
Allstar	Yes	Yes	Yes	Yes	Yes	Yes	Mid	R–T	R	T	R	I	Productive, with good flavor. Performs well across the region. Drawback is its light orange-red color when ripe. Very susceptible to angular leaf spot.
Clancy	No	No	No	No	No	No	Mid	U	R	U	R	S	Deep red color with good size, but yields were low in PA. Produces few runners. Growers in cooler locations may want to trial small amounts.
Darselect	Yes	Yes	Yes	Yes	Yes	Yes	Mid	U	U	U	I	S	Nice size, shape, and flavor. Yields are typically good but somewhat lower than expected. Quite susceptible to anthracnose fruit rot and powdery mildew. Fungicides required for successful production due to multiple disease susceptibilities. Not suited to organic production.
Delmarvel	No	Yes	Yes	No	Yes	No	Mid	R	R	U	R	R	Performed well in the Delmarva peninsula, with high yields and vigorous plants. Somewhat less impressive in PA. Susceptible to Rhizoctonia, especially after fumigation. May be difficult to find a source of plants.
Donna	Trial	Trial	Trial	Trial	Trial	Trial	Mid	U	U	U	U	U	From France. Conical to wedge-shaped glossy fruit that is firm and medium in size. No data available on performance in the Mid-Atlantic region.
Eros	Trial	Trial	No	No	Trial	Trial	Mid	S	R	U	I	I	Allstar hybrid. Productive. Good size and flavor, but light in color. Fruit can be very soft and prone to botrytis infection.
Kent	Trial	No	No	No	No	Trial	Mid	S	S	T	S	S	Cold hardy and vigorous. Fruit is large but borne on short pedicels, so fruit rots can be a problem, especially anthracnose fruit rot and Botrytis. Average flavor.
Lester	Trial	No	No	Yes	No	No	Mid	S	R	U	R	R	Productive berry with good flavor. Size starts out good, but runs down quickly. Fruit is susceptible to botrytis. May be difficult to find a source of plants.
Mesabi	Trial	No	Trial	Yes	No	Trlal	Mid	R	R	R	I	I	Productive, but fruit can be dark, soft, and flavorless in hot weather. Susceptible to twospotted spider mite damage.
Mira	Trial	No	Trial	No	No	Trial	Mid	S	R	I	I	I	Nice fruit, medium-red color, good flavor. Has produced very high yields in some PA locations.
Raritan	No	Yes	No	Yes	No	No	Mid	S	S	S	S	S	Flavorful. First fruits are large but size runs down quickly. Very susceptible to anthracnose fruit rot. May be difficult to find a source of plants.

CONTINUED

Table 6.3. June-bearing matted-row strawberry cultivars, continued.

	Recommendations for use in:							Susceptibility to:*					
Cultivar	NJ	MD	VA	WV	DE	PA	Season	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Description
Cabot	Trial	No	Trial	Yes	No	Trial	Mid–late	S	R	I	R	I	Huge fruit, high yields. Produces few runners. Primary berries are oddly shaped. Good flavor, but fruit center may be hollow. For pick-your-own. Sell by volume rather than weight. Susceptible to Phytophthora crown rot and cyclamen mites. Heavy foliage encourages problems with gray mold.
Herriot	Trial	Trial	Trial	Trial	Trial	Trial	Mid–late	U	U	U	R	U	From the NYAES-Geneva breeding program. Fruit is bright red and firm. Flavor is mild but very good with pineapple overtones. Fruit size is similar to that of Jewel. Plants are vigorous and productive.
Jewel	Yes	Yes	Yes	Yes	Yes	Yes	Mid–late	S	S	R	R	R	All-around good performer. Nice size and shape with good color and flavor. Productive.
Lateglow	No	No	Yes	Yes	No	Yes	Mid–late	R	R	T	R	R	Large fruit, but light colored and somewhat soft. Good flavor. Plants are very vigorous.
Mayflower	Trial	Trial	Trial	Trial	Trial	Trial	Mid–late	U	U	U	U	U	A variety bred in the UK on which little information is currently available.
Seneca	Yes	Yes	Trial	Yes	No	Trial	Mid–late	S	S	U	U	U	Firm berry with good size, round shape, and medium-red color. Flavor is mild. Good for shipping.
Sparkle	No	Yes	No	No	No	No	Mid–late	S	R	S	U	U	Soft berry with good flavor. Better suited for home gardens than for commercial production.
Winona	No	No	No	No	No	No	Mid–late	T	R	I	R	R	Berries may color unevenly and have short pedicels, so fruit is in close contact with the ground and is prone to various rots. Conical berries of average flavor.
AC Valley Sunset	Trial	Trial	Trial	Trial	Trial	Trial	Late	U	U	U	R	R	Large bright red berries with good flavor. May be somewhat perfumy. Somewhat softer than other berries.
Ovation	Yes	Yes	Trial	No	Yes	No	Late	U	U	S	T	I	Nicely shaped berries with medium-red color. Good flavor. Yields are low for the amount of foliage. Appears to be better suited for warmer areas.
Record	Trial	Trial	Trial	Trial	Trial	Trial	Late	U	U	U	U	U	Large dark berry with a somewhat flattened shape and medium firmness. Moderate yields. Susceptible to botrytis and fruit anthracnose. Has a hint of cinnamon In its flavor.

*R = resistant; T = tolerant; S = susceptible; I = intermediate; U = unknown

heaving. Mulch keeps soil temperatures relatively warm in the winter and cool in the spring, thereby delaying spring growth and reducing the damage from spring frost.

Mulch is generally applied in early to late December, depending on location, once plants have stopped growing and appear to be dormant. Plants reach dormancy after several hard frosts have occurred and take on a "flattened" appearance. With most cultivars, leaves develop a red tinge, indicating that nutrients have been translocated to the roots for winter storage. At this time, soil temperature at a 4-inch depth is at about 40°F. A soil thermometer inserted to this depth can be monitored as a guide for the correct time for mulch application. Apply 1½ to 2 tons of wheat or rye straw per acre. Straw should be free of weed seed. The mulch should be thin enough for part of the strawberry leaves to be visible in warmer (zones 6b and warmer) locations such as Maryland, New Jersey, Delaware, and Virginia. In cooler locations in Pennsylvania and West Virginia (zones 6a and cooler), a 4- to 6-inch layer of "fluffed" straw is recommended. Scatter any dense piles of mulch.

When new leaves start to develop, usually in mid-March to early April (soil temperatures will have risen to 40°F), pull the mulch back and leave it between the rows. Remove only enough to allow the plants to develop. Keep some mulch close to the plants to prevent rain from splashing soil on the fruit. If mulch was not applied in the winter, putting it between the rows before harvest is a good practice. Mulch protects the berries from waterborne fungal spores, such as those that cause leather rot, and provides a hospitable environment for harvesters, but increases slug populations.

Frost Protection

There is no one temperature at which frost damage occurs uniformly. Appendix A discusses the critical temperatures associated with frost and freeze damage to strawberries. The duration of temperature for damage can be nearly instant to 2 hours, depending on wind, humidity, and cultivar. Overhead irrigation is recommended, but if it is not available, late varieties can be planted to decrease the chances of blossom injury from frost. Row covers are often sufficient protection for the light frosts that occur near the last expected frost date. Additional information on frost protection is presented in Appendix A and in the plasticulture production section of this chapter.

Renovation

Strawberry beds must be renovated annually (immediately after harvest) to thin the plants, reinitiate root growth, retain vigor, and maintain berry size in subsequent years. Follow the steps below when renovating the beds.

1. Apply a postemergence herbicide for weed control. Most commonly, 2,4-D (Formula 40) herbicide is applied for broadleaf weed control. However, Stinger or a postemergence grass herbicide can also be used, depending on the target weed species. Wait 7 to 8 days for weeds to translocate the herbicide.
2. Mow off the leaves as close to the ground as possible without damaging the crowns.
3. Narrow the row widths to 6 to 12 inches using a cultivator or rototiller. Allow ½ inch of heavier soils and 1 inch of lighter soils to cover the crowns to stimulate new root growth.
4. Topdress older plantings at renovation with nitrogen (N), phosphorus (P), and potassium (K) as indicated in Table 6.2. Omit P or K if high.
5. Apply preemergent herbicides, most commonly Sinbar.
6. Irrigate to incorporate fertilizer and herbicide.
7. Continue to irrigate with 1 to 2 inches of water per week through August and into September, especially during dry spells. Neglecting the planting will decrease runner production and the number of flower buds initiated, resulting in lower yields next year.

Pest Management Notes Specific to Matted-Row Plantings

Because matted-row plantings are slower to dry out than plasticulture plantings and weeds are often a greater problem in this system, certain diseases and insects can be more problematic than with plasticulture plantings. Diseases that tend to be more problematic are root rots because plantings are maintained for several years and gray mold because moisture levels in the foliage tend to be higher. Particularly troublesome insects in matted-row plantings are spittlebugs, which lay their eggs in weeds in and around fields, root weevils because populations can build in the soil over the years, and tarnished plant bugs during later harvests since plant bug populations increase as the season progresses.

JUNE-BEARERS: PLASTICULTURE PRODUCTION

Plasticulture utilizes raised beds, black plastic mulch, trickle irrigation, high-density planting, and floating row covers. Capital input into this system is fairly high ($6,500 to $10,000 per acre for establishment), but yields and fruit quality have the potential to be very high. Plasticulture production is very intensive, so it is highly recommended that growers unfamiliar with this system start small. This system has given the highest yields in locations that have long growing seasons and are influenced by the moderating effect of a body of water, such as southeastern Pennsylvania, southern New Jersey, and the shore areas of Maryland, Virginia, and Delaware. Low yields are common in cooler areas (zones 6a and cooler) with shorter growing seasons due to an insufficient period available for plant growth and flower bud initiation in the fall. Earlier fall application of row covers can partially compensate for this constraint on marginal sites, but be aware that early application of row covers in the fall has a residual effect of advancing bloom and fruiting in the spring. Select fields protected from westerly winds and with a southern exposure to minimize wind desiccation and maximize heat accumulation. Availability of a means of frost protection is critical.

Soil Characteristics

As with any strawberry system, soil with a high organic matter content and in a proper rotation will produce the healthiest crop. Light- to medium-textured soils with medium (2 percent) to high (6 percent) organic matter levels are best for bed preparation, nutrition management, and plant development in strawberry plasticulture. If organic matter

Table 6.4. Recommended nutrients for annual plasticulture strawberry plantings.

Rates are intended as approximations. Soil testing, leaf analysis, and plant vigor should be used to fine tune rates for your site. Preplant applications are applied to the entire area to be planted. Post-bedding application rates are on a mulched-area basis. If phosphorus levels are above optimum, no additional phosphorus is typically recommended.

		Soil Phosphorus Level (P_2O_5)			Soil Potassium Level (K_2O)			
	N	Low	Med	Opt	Low	Med	Opt	
Soil	lbs/acre							Suggested Application Methods
Clays, clay loams, loams, and silt loams	50–60	100	70	40	150	100	50	Disc in before bedding
	20–30	0	0	0	0	0	0	Inject through drip at first flowering*
	70–90	**100**	**70**	**40**	**150**	**100**	**50**	**Total recommended**
Sandy loams, loamy sands, and sands	60–75	100	70	40	165	115	65	Disc in before bedding
	15–20	0	0	0	0	0	0	Inject at first flowering*
	15–25	0	0	0	0	0	0	Inject at fruit enlargment (2 weeks later)*
	90–120	**100**	**70**	**40**	**165**	**115**	**65**	**Total recommended**
	Apply 1–2 pounds of boron (B) per acre with broadcast fertilizer unless tissue or soil test indicates above-normal levels.							

*Ideally, spring N applications in the amounts listed above can be split into multiple applications calculated at 0.5 lb of N per acre per day, applied starting at green-up.

is too low (less than 1 percent), a cover crop should be grown for the season before planting. Since beds are typically formed in August, the cover crop can be grown earlier in the season the year of planting. Soil should be well worked prior to planting, as this is a prerequisite for making well-formed beds.

Fumigation

If needed, a fumigant such as Vapam can be injected through the trickle system at least 2 weeks before planting. Alternatively, other fumigation options can be employed as outlined in Chapter 3.

Fertility

The soil should be tested the spring prior to planting. The soil pH, phosphorus, potassium, calcium, and magnesium should be adjusted according to the soil test recommendations prior to planting. Depending on soil type and climate, the plants will need a total of 90 to 120 pounds of nitrogen per acre per season, with 120 pounds per acre needed on sandier soils in warm climates, and 90 pounds per acre needed on heavier soils with an early frost date. Apply two-thirds of the nitrogen (60 to 70 pounds per acre) prior to planting and the remaining 30 to 50 pounds per acre (higher end of range on sandier soils) in the spring through fertigation. Most or all of the nitrogen should be applied by early bloom for optimal yields, with split applications making more efficient use of applied nutrients. Timing and amounts are presented in Table 6.4.

Alternatively, organic sources of nitrogen (e.g., poultry manure) can be incorporated prior to bed forming, thereby providing nutrients in a slow-release form and eliminating the need for spring fertigation. Boron, often deficient on deep sandy soils, is an important minor element for strawberry production. Once visible deficiency symptoms ("bumpy" fruit and small crinkled new leaves) are noticeable, yield losses have already occurred. It is important to monitor boron tissue levels in the spring because they begin to decrease markedly as spring growth commences. If tissue levels fall below 20 ppm, an application of 1/8 pound of boron per acre (10 ounces of Solubor, 20 percent boron) injected through the drip irrigation system is recommended. Care must be taken to apply boron accurately because it is *extremely toxic* if applied in excess. The difference between enough boron and too much boron is small.

Plant nutrition is always important in any system. However, in plasticulture strawberry production, the short time available for plant growth, the large quantity of fruit produced and, hence, high plant demand for nutrients, and the critical role of top quality fruit in the economics of this system make optimum nutrition essential. Nitrogen is important for quantity and quality of fruit production. Potassium is important in flavor development and is transported into the fruit in large quantities during ripening. Calcium is important for firmness, and boron is needed for good fruit set.

Petiole sap testers can be used to monitor the plants' current nitrogen or potassium status in the field, and adjustments to the nitrogen rate can be made immediately. (See Appendix D for sources of petiole sap testers.) Current values were established in Florida (see Appendix E for the source of this information) and may need to be adjusted downward if plants appear too vigorous. Values between 600 and 800 ppm NO_3^-N when plants resume growth and prior to bloom, falling to 300 to 500 during bloom and 200 to 500 during harvest, are considered sufficient. Values are expressed as either NO_3 (nitrate) or NO_3^-N (nitrogen in the nitrate form), depending on the brand of sap tester. If the meter readout is given as NO_3, values will need to be divided by 4.43 to compare to the values presented above.

Tissue analysis kits should be used to submit samples of the most recently fully expanded leaves in the spring at early bloom. Values for interpretation at this time of the year are given in Appendix B.

Bed Preparation

A center-crowned firm bed with tight plastic is the goal. Soil should be well worked and free from clods before attempting to form the beds. Depending on the equipment, the steps of bed forming, fertilizer incorporation, fumigation shanking, installation of drip tubing, and plastic laying may be

combined into one operation. However, on heavier soils, it is often best to shape the beds with the fertilizer incorporated, then lay the plastic and drip tube.

High beds promote warmer soil temperatures, which increase plant growth in the fall and spring. They also improve soil and air drainage and make harvest easier and faster. Wide beds allow better sunlight penetration into the plants, which results in higher yields. Embossed black plastic 1¼ mil thick and 54 or 60 inches wide is generally used, with beds 30 to 40 inches wide at the top and 6 to 10 inches high. Beds are usually on 4- to 5½-foot centers. They should be oriented north to south, if possible. With east-to-west beds, the plants in the southern row on each bed grow larger, and fruit on the southern edge of the bed is more likely to be sunscalded. Water drainage from the field must be taken into account since beds will act as small dams if they block the areas of water flow from the field.

No herbicide with residual activity should be broadcast onto the plastic after it is laid since rainfall can concentrate these chemicals at the planting holes and cause crop injury.

Irrigation

Drip irrigation is essential in plasticulture production. With drip irrigation, less water is required than with overhead irrigation, diseases are reduced due to less wetting of the foliage, and soluble fertilizers can be applied throughout the growing season.

The soil type affects the distribution of water within the soil. Coarser soils with larger amounts of sand have limited lateral movement of water from the emitters. Water applied to soils with larger amounts of clay will move well laterally. To thoroughly wet the soil, growers with sandy soils should consider selecting drip tape with emitters that are closer together (4 to 6 inches) and place two drip tapes per raised bed, thus providing for greater wetting of the entire bed. Care must be taken to ensure that the tape is not directly in line with the planting row to avoid punctures. For growers that have soils with higher levels of clay and/or organic matter, it is sufficient to use one drip tape down the middle of the bed with emitters that are 12 inches apart. Drip irrigation tape should be installed 3 to 4 inches below the soil surface at the time of making beds and laying plastic.

Drip tape that is 6 to 8 mil in thickness is adequate for plantings that are expected to be used for only one growing season. Plantings that are expected to be fruited for two seasons should have 8- to 10-mil drip tape. The flow rate of the drip tape will affect the amount of water that is applied in a given amount of time; however, a range of flow rates can be used to apply a given amount of water. A common flow rate for drip tape is 0.45 gallons per 100 feet per minute. Another factor to consider when selecting the drip tape is the flow rate of the water source. To provide adequate water to the entire area that will be irrigated, the amount of water outputted from the emitters at one time cannot exceed the source flow rate.

Two to three days prior to planting, growers must ensure that the irrigation system is working and that the bed is thoroughly wetted. Typically, this is accomplished by turning on the trickle irrigation system and allowing it to run until the soil has been visibly wetted just to the outside of the bed. Since the drip tape may be installed in the middle of the bed, it may take many hours—typically at least 3 to 4 hours—in order to wet the soil laterally across the entire bed width. Wetting the beds 2 to 3 days before planting allows the soil to drain prior to planting so that the soil is moist but not muddy.

Plants that are well watered during the fall will make the most growth and produce the highest yields. Drip irrigation will be needed again in the spring since adequate moisture is critical for maintaining large fruit size, which is important for high value. Apply sufficient trickle irrigation to supply a minimum of 1 inch of water (more during hot spells) to the bed each week. To apply 1 inch of water to a bed that is wetted 2.5 feet wide using a trickle tape with a flow rate of 0.45 gallons per 100 feet per minute at 10 psi would require 5.8 hours of run time per week, or approximately three two-hour irrigation cycles. Overhead irrigation may be needed after planting to cool the plants; it will almost definitely be needed in the spring for frost protection.

Plant Types and Varieties (Cultivars)

Plants are available as plugs, runner tips that can be rooted into plugs, dormant (frigo) plants, or fresh-dug plants. Clean, virus-tested planting stock should be used regardless of the type of plant. Plugs are the standard for the region; if they are available for planting early enough, they result in the most consistent yields and stands. However, there is typically a strong demand for these plants. If you plan on using plug plants, place orders early. Contact nurseries during the winter to ask when they begin accepting orders.

Alternatively, runner tips are relatively easy to root into plugs if you have a mist system. It will take about 35 days from tip to plug plant. To root your own tips, first obtain tips from a reputable nursery (see Appendix C for nursery sources of tips). After you obtain the tips, inspect them and discard any tips that are of questionable quality. Trim the runner stubs to ½ inch, sort the tips by size, and plant similarly sized tips in the same tray. Trays with 50 cells are standard, and any standard soilless mix can be used. Because cleanliness is essential, use new media and make sure the trays have been disinfected if they are being reused. Place the "hook" of the tip in the media, making sure the crown is not buried. Place the trays under mist in an enclosed structure such as a greenhouse or high tunnel, setting the misting to keep the leaves wet for the first 7 days using fogger nozzles of an intermediate discharge rate. Using shade cloth is recommended when temperatures are hot. The time for misting will vary with degree of cloudiness, but 5 seconds of actual misting time every 15 minutes is a reasonable starting point. Only mist during the day. After the first week, gradually reduce the misting time until no mist is applied around day 12. The plants should have roots by this time. Be sure not to let the media dry out. When the plants are 2 weeks old, fertilize them with 100 ppm of nitrogen with calcium nitrate as the nitrogen source. At 3 weeks, place the trays outside, but not on bare soil, to start "hardening off" the plants. An area covered with landscape

fabric works well. Trays can also be kept in the structure if air flow is good. A broad-spectrum fungicide can be applied prior to planting. Also, plants should be inspected and treated for twospotted spider mites before planting. As always, growers should follow label restrictions and requirements closely. Producing plug plants outside is also possible (see Appendix E for sources of information). Be sure to put down a layer of ground-cover fabric before beginning outdoor plug production.

Dormant plants, used primarily in more northern locations, are less expensive than plugs, are available in a greater choice of varieties, and allow for earlier planting and plant establishment. However, planting, blossom removal, and runner removal require increased labor costs, and decreased viability of plants due to prolonged storage may require some replanting of the plants that fail to establish.

Fresh-dug plants, used in the southeastern states, are dug and shipped just prior to planting, which takes place in mid-October in Florida. Due to the late availability of plants, this option is of limited value for growers in the Mid-Atlantic region.

Chandler is the most widely available plug plant cultivar and the most consistent performer. Sweet Charlie, also available as plugs, is valuable for an early crop but produces relatively low yields and is decreasing in popularity within the region. Camarosa performs well in warmer areas. Wendy, Allstar, and Darselect, as well as Festival in warmer areas, appear to have potential. Additional information on cultivars is available in Table 6.5.

Planting

In the plasticulture system, high yields are dependent on plants producing branch crowns. Therefore, for this system, strawberry plugs should be planted late enough in the season to discourage excessive runner formation and early enough to promote plant establishment and branch crown formation. Plugs should be planted during early to mid-September in warmer locations of the region (zones 6b and warmer) and in mid- to late August for colder sites (zone 6a). Alternatively, dormant crowns can be used. Dormant crowns are planted during mid to late July in warmer locations and from mid-June to mid-July in cooler areas. This type of planting stock is probably most useful to growers in cooler areas of the region (zones 6a and cooler) or to those wishing to try cultivars not available as plug plants.

On each bed, double rows 12 inches apart with plants 12 inches apart within each row in a staggered pattern are commonly used. However, increasing the distance to 18 inches between the rows on each bed may improve yields without increasing plant costs (a 36- to 40-inch-wide bed is needed), while a closer spacing may compensate for late planting. Plant numbers needed per acre are given in Table 6.1.

Beds should be thoroughly wetted 2 or 3 days prior to planting. A water-wheel transplanter can be used to plant plugs or to punch holes for planting dormant plants. However, actual planting of dormant plants should be done by hand. For dormant plants, a V-shaped tool is useful for inserting roots into the soil. If the weather is warm, overhead irrigation should be used to cool the plants and plastic after planting.

Be sure to place the crown of the transplant at the soil level when planting (see Figure 6.1). Deep planting can promote decay of the plant, while shallow planting allows the plant to desiccate.

Care during Fall Establishment

Plants should not be water stressed during the fall since healthy fall growth is necessary for high yields next spring. Pests should be monitored closely and weeds that emerge from the planting holes should be hand pulled. Runners produced during at least the first half of the fall season should be removed to allow the plants to direct their resources to branch crown and flower bud formation. Clean cultivation can be used if erosion and water management are not problems on the site. Bare, undisturbed ground can provide some frost protection. If erosion is a concern, row middles can be seeded to a living mulch of annual rye grass to reduce soil loss. Broadcast 50 pounds of annual ryegrass seed per acre before holes are punched in the plastic. Apply overhead irrigation to encourage early germination and to wash any seeds off the plastic so that the ryegrass does not become a competitive weed problem when the planting holes are punched. The ryegrass will reduce soil washing in the aisles after heavy rains or irrigation for plant establishment. If a "living" mulch is grown for the fall and winter season, do not apply preemergence herbicides to the aisles until after the mulch is large enough to withstand potential injury or to accomplish its purpose even if injured.

Floating row covers should be applied when daytime highs outside the cover are in the low 70s (mid-October for most areas). The planting may need to be uncovered if a warmer spell occurs. The young planting is extremely susceptible to deer grazing, but floating row covers typically deter the deer at this time of the year. Heavier row covers (0.9 to 1.4 ounces per square yard) can be used for more than one year, resulting in lower per-year costs despite the higher initial cost. Covers can be held down by a number of means; the most effective holders are stone or gravel in netted, oyster-bottom bags.

Overwintering the Planting

Floating row covers are a must for winter protection because they reduce wind desiccation and buffer the planting from temperature extremes. In more northern locations, straw mulch, applied when soil temperatures at a 4-inch depth drop to 40°F, has been used successfully. However, keeping it on the plastic mulch is difficult if it is used without a row cover. In these locations, removing the row cover, placing the straw, and replacing the row cover over the straw to keep it in place has worked quite well. Once the plants are covered with straw, the plant no longer receives any sunlight to form branch crowns or flower buds. Therefore, this technique is only recommended on marginally cold sites. Straw should then be removed from the beds and placed in the walkways as soon as the plants resume growth (or soil temperatures reach 40°F 4 inches deep), and the row covers alone pulled back on. Row covers should be removed as soon as the plants begin to bloom. The plants will need to be covered again if frost is forecast.

Table 6.5. June-bearing strawberry cultivars for plasticulture production.

	Available as:											Susceptibility to:*						
Cultivar	Plugs	Tips	Dormant Plants	Fresh-Dug Plants	Season	NJ	MD	VA	WV	DE	PA	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Anthrac-nose	Description
Sweet Charlie	Yes	Yes	No	Yes	Early	Yes	Yes	Yes	Yes	Yes	Trial	U	U	R	I	U	R	Produces significantly lower yields and smaller fruit than Chandler. Utilized primarily for its earliness. Winter tender.
Florida Radiance	Yes	Yes	No	Yes	Early	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	U	U	U	Intended for the same growing climate as Festival. In FL, produces slightly higher yields and larger fruit than Festival. Mild flavor.
Galletta	No	No	Yes	No	Early	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	U	U	U	Released from the NC State breeding program. Produces fruit 7–10 days before Chandler. Fruit in other regions is large and nicely shaped.
Palomar	Yes	Yes	No	Yes	Early	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	U	U	U	Similar to Ventana in many characteristics but is less vegetatively vigorous. Untested in the region.
AC Wendy	Yes	No	Yes	No	Early	Trial	Trial	Trial	Trial	Trial	Trial	S	S	MR	U	U	U	Grower experience with this cultivar in this system has been good. Produces large, nicely colored fruit with excellent flavor.
Bish	Yes	Yes	No	No	Early–mid	Trial	Trial	No	Trial	Trial	No	U	U	U	U	U	R	Developed for plasticulture in North Carolina. Excellent flavor. In PA, many blossoms opened black resulting in low yields in a matted-row trial. Only available from a limited number of southern nurseries.
L'Amour	No	No	Yes	No	Early–mid	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	R	I	U	Fruit has nice size, shape, and color. Yield potential in this system is lower than for Chandler.
Allstar	No	No	Yes	No	Mid	Yes	Yes	Yes	Yes	Yes	Trial	R–T	R	T	R	I	S	Large, sweet fruit remains orange when ripe. High yields in plasticulture in warmer areas of NJ and MD. Low yields in cooler regions of PA and MD.
Camarosa	Yes	Yes	Yes	Yes	Mid	Trial	Yes	Yes	Yes	Yes	Trial	U	U	S	I	T	S	Large but very firm fruit. Fruit can develop very dark color while tips remain white.
Carmine	Yes	Yes	Yes	Yes	Mid	Trial	No	Trial	Trial	Trial	No	U	U	U	U	U	U	From the Univ. of Florida. Deep red fruit with good quality, but produced low yields and small fruit in PA trial.

CONTINUED

Table 6.5. June-bearing strawberry cultivars for plasticulture production, continued.

	Available as:											Susceptibility to:*						
Cultivar	Plugs	Tips	Dormant Plants	Fresh-Dug Plants	Season	NJ	MD	VA	WV	DE	PA	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Anthrac-nose	Description
Darselect	No	No	Yes	No	Mid	Trial	Trial	Yes	Trial	Yes	Trial	U	U	U	I	S	S	Good fruit quality. Disease susceptibilities, especially to fruit anthracnose, may limit adoption for this system.
Eros	No	No	Yes	No	Mid	Trial	Trial	Trial	Trial	Trial	Trial	S	R	U	I	I	U	Try on limited quantities in this system if this cultivar otherwise performs well on your site. Faster foliage drying in this system helps overcome Botrytis susceptibility.
Festival	Yes	Yes	Yes	Yes	Mid	No	Trial	Trial	No	Yes	Trial	U	U	U	U	U	S	Standard in Florida production. Variable performance in the Mid-Atlantic region. Fruit is conic and very firm. May perform better in tunnels than in the field.
Gaviota	No	No	No	Yes	Mid	No	Trial	No	No	No	No	S	U	PR	S	U	PR	Fruit can be small and yields low. Also tends to be soft. Has performed well in areas just outside the region, however.
Seneca	No	No	Yes	No	Mid	Trial	Trial	No	Yes	No	Trial	S	S	U	U	U	S	Large, blocky, very firm fruit with good color. Good for shipping.
Sonata	No	No	Yes	No	Mid	Trial	Trial	Trial	Trial	Trial	Trial	S	U	I	U	U	U	Popular in northern Europe. Susceptible to Phytophthora crown rot. Untrialed in the mid-Atlantic.
Ventana	No	No	Yes	No	Mid	No	No	No	Trial	Trial	No	S	U	R	S	U	U	Widely planted in CA. In PA, low yields in tunnel and field production, though fruit size, color, and flavor were good.
Cabot	No	No	Yes	No	Mid–late	Trial	Trial	Trial	Trial	Trial	Trial	U	R	S	R	I	U	Large fruit makes this a cultivar of interest. Try in limited quantities. Watch for crown rot and cyclamen mite susceptibilities.
Camino Real	Yes	Yes	No	Yes	Mid–late	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	U	U	U	In California, plants are compact and fruit has good flavor and is darkly colored. Untrialed In the Mid-Atlantic region.
Chandler	Yes	Yes	Yes	Yes	Late	Yes	Yes	Yes	Yes	Yes	Yes	U	S	R	S	T	VS	Large fruit with excellent flavor. A consistent performer across environments and the standard for this production system.
Ovation	No	No	Yes	No	Late	Yes	Trial	No	Trial	Yes	Trial	U	U	S	T	I	U	Nicely shaped fruit with good flavor. May tend to stay a bit light colored when ripe. Low yields.

* R = resistant; PR = partially resistant; T = tolerant; S = susceptible; VS = very susceptible; I = intermediate; U = unknown

Spring Frost Protection

Plants grown in the plasticulture system are extremely susceptible to frost damage since they will bloom earlier than plants grown in matted-row production. For this reason, plasticulture plantings should be grown on sites that have overhead irrigation capabilities. One layer of row cover alone will provide 2 to 6 degrees of frost protection on clear, still nights preceded by a sunny day, and 1 to 2 degrees of protection when the frost event is preceded by a cloudy day or if conditions are breezy. Pulling the covers on during midafternoon will allow heat to build up under the cover. Overhead irrigation alone or in addition to row covers can be used for frost protection. When used in conjunction with row covers, the irrigation system is set up on top of the covers, turned on when the temperature under the row cover drops below 33°F and turned off when it rises above 33°F. This typically cuts the time that irrigation must be run in half. A second option is to use a double layer of row cover, which provides additional protection. This technique is probably economically feasible only for small-acreage plantings and works best when a durable fabric is used that can be reused for multiple years. See the section on frost protection in Appendix A for additional information and operating guidelines concerning frost protection.

Harvest

When raised beds, black plastic, and floating row covers are used, bloom and harvest are advanced by as much as a month compared to matted-row plantings. This early fruit commands a high price, but at the cost of the burden of protecting the planting from spring frosts. To keep bloom from starting too early, the row cover can be removed as soon as growth begins in the spring and replaced only when temperatures are expected to drop low enough to cause damage to the plant. This may, however, result in lower yields than if the row cover was kept on. To spread out harvest dates, cover removal from different areas of one cultivar can be staggered, or different cultivars can be used. 'Chandler' will produce crops for a longer period of time than matted-row cultivars will, with 3 weeks common and 4 to 5 weeks of harvest possible. When insufficient growth and flower bud initiation has taken place, however, this harvest period will be greatly shortened. The high quality of the fruit produced in this system results in premium prices. Other harvest advantages of this system are that the fruit is easier to reach, containers fill faster due to larger-sized fruit, and harvest can take place soon after a rain since the beds dry out quickly. Many growers market the fruit of first-harvest-year fields for direct sale or wholesale product and then allow "u-pick" on renovated second-year fields since berry size tends to decrease and damage to plastic is of less concern. Straw mulches can be laid in row middles prior to fruit ripening and harvest. See "Harvest and Postharvest Handling" below for additional points.

Carrying over Plantings

Since establishment-year inputs are high and following-year inputs are quite low with the plasticulture system, many growers hold their plantings over for a second year of harvest. Yields from carryover plantings can be high if the planting is well managed, but berry size will decrease, harvest may not be quite as early, and pest pressure is higher. Renovating a planting for a second year of harvest consists of several steps:

1. After harvest, leaves should be mowed off as close to the crown as possible without damaging the crown. This will stimulate growth of new foliage. All loose foliage and fruit should be removed from the field as it is likely to harbor diseases.
2. Plants with five to eight branch crowns will benefit from crown thinning. To crown thin, insert an asparagus knife though the center of the crown and remove about half, being careful not to damage the remaining half.
3. Maintain irrigation throughout the summer.
4. Fertigate 40 to 60 pounds of nitrogen per acre in late August or early September, using the high end of the range in warmer areas (NJ and south).
5. Control weeds between the rows, but never spray any residual herbicide over the mulched beds since runoff greatly increases the actual application rate into the holes where the strawberry plants are located.
6. Do not apply floating row covers for the fall since there should have been sufficient time for plant growth and flower bud initiation during August and September.
7. Cover the planting with row covers for the winter in cooler locations (optional for zones 7a and warmer)

Double-cropping with another crop (replacing the strawberry plants using the same plastic) can be accomplished using warm-season crops in warmer areas and cool-season crops where the growing season is shorter.

Growers are sometimes tempted to hold over plasticulture plantings for a third harvest season. However, this is not recommended. As discussed under "The Strawberry Plant—Anatomy and Morphology," as strawberry plants grow, the crown elongates and new roots are produced above the old ones. In matted-row systems, the new roots establish in the soil that is thrown onto the plants during the renovation process, and younger daughter plants also help renew the planting. In plasticulture systems where only the original mother plants remain, the elongated crowns becomes more exposed to cold temperatures during the winter, increasing the likelihood of winter injury. The plant is also dependent on the original root system with few new roots able to establish since they are produced above the old roots but cannot root. These factors, together with a frequent buildup of insects and diseases in the planting, commonly results in poor plant stands, low yields, and numerous pest problems in older plasticulture plantings.

Pest Management Notes Specific to Plasticulture Plantings

Because plasticulture plantings are maintained for only one or two seasons, disease and insect pressure tends to be lower than in matted-row plantings. In addition, because of good soil and air drainage due to raised beds, root rots, botrytis, and leather rot tend to be less problematic. Because of increased air temperatures, however, anthracnose can be a very large problem, especially in

carryover plantings of Chandler, which is exceedingly susceptible to this disease. In addition, twospotted spider mites survive the winter very well under the row cover, and should be monitored in the spring. As mentioned briefly above, deer damage can be a major problem, though the deer are often deterred once row covers are applied in the fall.

Apply a fungicide to control leaf spots after plants are established. Apply a fungicide plus insecticide or miticide to also control aphids and mites just before covering plants with floating row covers if needed. Aphids and mites should be monitored, and if present, insecticides and miticides should be applied during the late summer and early fall to prevent them from reaching damaging levels in the spring. Removing dead leaves before new growth starts can help reduce disease and mite problems, especially gray mold and twospotted spider mites.

JUNE-BEARERS: RIBBON-ROW PRODUCTION

Ribbon-row plantings on raised beds have been successful in some areas, and, if managed properly, this system has high yield potential. It may also be used to avoid marginally wet soil conditions. In this system, strawberry plants are planted 3 to 6 inches apart on raised beds 10 to 12 inches high. Plants are allowed to produce fruit in the first season to suppress runnering. Any runners that do form are removed throughout the first season, directing the plant's resources into crown enlargement and branching, which then allows more sites for flower bud initiation on each plant. A heavy layer of straw mulch must be applied over the winter in areas without predictable snow cover since the likelihood of winter injury to the crowns is great. While this system can produce very high yields, be aware of the following:

1. Removing runners is labor intensive and thus costly.
2. Special attention must be given to maintaining optimal soil moisture levels in the raised bed. It dries out much more rapidly than the matted row.
3. Care must be taken to continually rebuild the raised bed because it erodes and settles over time. Soil should periodically be restored to the top of the ridge.
4. Winter injury may be much more severe on raised beds as compared to matted rows, probably a result of the mulch settling in the aisles and heat dissipation from the beds.
5. Removing weeds manually may erode beds.

DAY-NEUTRALS: MATTED-ROW PRODUCTION

Day-neutral strawberries can be grown in a matted-row system as described for June-bearers with some differences in management details. However, they may be most successfully produced in a plasticulture system (see below). For matted-row production, day-neutral strawberry cultivars, which usually tend to produce fewer runners than June-bearing strawberries, need to be planted at a close spacing, with plants 5 to 10 inches apart in the row. An efficient planting design is a staggered double row with plants set 7 inches apart, offset 4 inches from center with 4 feet or less between row centers. Runners must be removed throughout the first season and flowers should be removed for the first 6 weeks after planting. Mulching day-neutral plants is essential since mulch prevents large fluctuations in moisture availability and temperature. Use 4 inches of clean straw or a white-on-black plastic (white side up) to reflect heat. Plants fruit from mid-August through the first hard frost the first year and produce three crops in subsequent years, as discussed in the "Types of Plants" section. Fertilizer requirements are higher. Nitrogen should be applied at 20 pounds per acre each month from June through September of the planting year and also in May and September of the fruiting years. This amount should be increased to 30 pounds of nitrogen per acre in June, July, and August of the fruiting years. In a matted-row system, day-neutral plantings are normally kept for only 2 or 3 years as berry size decreases quickly. Tarnished plant bugs are especially problematic in plantings of day-neutral cultivars because high populations are reached by the end of the growing season. Cultivars are described in Table 6.6. The first set of flower trusses should be removed to encourage plant establishment. Plants may be held over for a second harvest year.

DAY-NEUTRALS: PLASTICULTURE PRODUCTION

Information on soil characteristics, bed preparation, irrigation, and harvest for June-bearer plasticulture production (outlined above) also largely applies to day-neutral plasticulture production. Differences between systems exist in timing of operations, plant sources, management of soil fertility, likely pest problems, and other cultural operations are detailed below.

Timing of Operations

Plants are normally planted in April or May when low temperatures are not expected to drop below the mid to upper twenties with harvest beginning in mid to late June. In plasticulture day-neutral production, plants are usually grown and fruited for only one year. In areas that are cool throughout the summer such as high elevation areas (maximum temperatures typically reaching the low to mid-eighties), the highest yields will be obtained during the summer. In areas where the summer becomes hot (temperatures typically reaching the high eighties or nineties), the highest yields will be obtained in the fall and little production will occur from late July to late August. Plantings may be held over for a second harvest season, but fruit size will drop off considerably. In warmer areas, by the time the second fall crop is produced, much of the fruit will be small as fruit size continues to decrease as the plants produce more branch crowns and grow larger.

Bed Preparation

Beds can be prepared and plastic should be laid as soon as the soil is workable in the spring. Beds are typically 4 to 10 inches high and should be a minimum of 24 inches wide at the top, preferably wider. An aluminized or white-on-black plastic (white side up) is recommended to reflect heat. This will keep soil temperatures cool and may shorten the length of time during midsummer that fruit production is suspended. Aluminized plastic is more expensive, but resultant higher yields have more than paid for the additional cost. Availability of aluminized

Table 6.6. Day-neutral strawberry cultivars.

	Recommendations for use in:						Susceptibility to:*					
Cultivar	NJ	MD	VA	WV	DE	PA	Vert. Wilt	Red Stele	Powdery Mildew	Leaf Spot	Leaf Scorch	Description
Albion	Trial	Yes	Yes	Trial	Yes	Trial	R	U	U	U	U	Recent release from Univ. of California. Grower reports from the Mid-Atlantic are positive. Produces lower yields than Seascape, but a high percentage of marketable fruit partly compensates for the difference. In PA trial, berries held up well even during prolonged wet spells. Extremely large fruit is nicely colored and slightly firm with good flavor. Cyclical in bearing habit; doesn't like heat.
Aromas	Trial	Trial	Trial	Trial	Trial	No	S	U	I	S	U	In PA trial, fruit were relatively large for a day-neutral and had a rich red color but were a bit too firm. Flavor was fair to good.
Diamante	Trial	Trial	Trial	Trial	Trial	No	U	U	U	U	U	Produces very large berries that are too firm, similar to or firmer than Camarosa. Flavor and color were good. Lower yields than Seascape.
Everest	No	Yes	No	Yes	No	No	S	R	R	U	U	Soft fruit with mild flavor. Watch rotations due to verticillium susceptibility. Very susceptible to fruit anthracnose. This cultivar's strong point is its high yields on suitable sites.
Evie 2	Trial	Trial	Yes	Trial	Yes	Trial	U	U	U	U	U	Fruit has improved size over Everest, but color is lighter. Fruit is very soft and flavor can be bland. Proper management of water and fertilizer is needed. In PA trial, yields were considerably lower than for Seascape or Everest.
Evie 3	Trial	Trial	Trial	Trial	Yes	Trial	U	U	U	U	U	Combines the high yields of Everest with the quality characteristics of Evie 2.
Fern	Trial	Trial	Trial	Trial	Trial	No	U	U	U	U	U	In PA trial, produced light-colored berries that were a bit soft with average size and not much flavor. Reminiscent of Latestar.
Mara Des Bois	Trial	No	Trial	Trial	No	Trial	U	U	U	U	U	From France. Considered a "gourmet" berry. Fruit is small but very flavorful. May be best suited for tunnel production to protect fruit. Very susceptible to fruit anthracnose.
Monterey	Trial	Trial	Trial	Trial	Trial	Trial	U	U	S	U	U	Large fruit with good flavor, not quite as firm as Albion. Plants are very vigorous. Susceptible to powdery mildew. Untested in the Mid-Atlantic region.
Portola	Trial	Trial	Trial	Trial	Trial	Trial	U	U	U	U	U	Large fruit that has been somewhat light in color in California. Vigorous plants. Untested in the Mid-Atlantic region.
Quinault	Trial	Trial	Trial	Trial	Trial	No	U	U	U	U	U	In PA trial, produced small squishy berries with odd shape, light color and little flavor.
Tribute	Yes	No	No	Yes	No	No	T	R	I	T	T	Flavor a bit milder than for Tristar, but still tart. Fruit size is relatively small. Firm. Plants are fairly vigorous.
Tristar	Yes	No	No	Yes	No	No	R	R	R	T	T	Flavor is good but can be tart. Firm fruit; size is small in hot weather.
San Andreas	Trial	Trial	Yes	Trial	Trial	Trial	U	U	U	U	U	Large fruit with very good flavor. May be somewhat light in color. Firm. Cyclical in bearing habit but berries are of excellent quality. Sensitive to heat. Reported to have more resistance to diseases than other Univ. of Calif. releases.
Seascape	Yes	Yes	Yes	Yes	Yes	Yes	U	S	S	I	R	Sweet flavor. Nice shape, medium-red color, good size for a day-neutral, high yields. Fruit tends to split during wet periods. This is currently the top day-neutral for overall performance in the Mid-Atlantic.
Selva	Trial	Trial	Trial	Trial	Trial	No	U	U	U	U	U	In PA trial, fruit was soft and light-colored with little flavor. Size was average.

*R = resistant; T = tolerant; S = susceptible; I = intermediate; U = unknown

plastic may be limited. Current suppliers of plastic are listed in Appendix E. Rows should be oriented north to south to minimize sunscald, unless other factors such as erosion potential are of greater concern.

Soil Fertility

A soil sample should be submitted during the fall prior to planting the strawberries. The pH should be between 6.0 and 6.5 for maximum availability of plant nutrients, so lime should be worked in well ahead of planting. Adequate nutrients must be available throughout the growing season to produce high yields. Because yields as high as 20,000 pounds of fruit per acre may be obtained from plants that are planted in the spring of the year, sufficient nutrient availability is important. Plant nutrient needs are thought to be similar to those of high-yielding June-bearing cultivars, which can produce similar per-acre yields. A soil test is recommended prior to planting, as some of the phosphorus and potassium may already be available from native or past added nutrients.

Plant nutrients can be worked into the soil prior to making the bed and applying the plastic, or they can be applied through the drip tape. A number of different sources can be used to provide nutrients. Organic inputs such as composts and green manure crops can provide adequate nutrition. Mineralization of nutrients from organic sources into plant-available forms is a gradual process, so organic nutrient sources should be worked into the soil a minimum of two weeks prior to planting. Also due to low mineralization rates (as low as 10 percent of the total nitrogen may become available per year) you may need to add considerable amounts of the product. Commercial granular fertilizers should be incorporated into the soil just prior to forming beds and applying the plastic.

If organic sources of nutrients are used, which tend to work as slow-release fertilizers, all of the nutrients can be applied prior to planting. If inorganic sources are used, either half can be worked in prior to planting with the remainder fertigated weekly, or all of the nutrients can be applied through fertigation one or two times per week during routine watering cycles.

Plant Sources

As with June-bearer plasticulture production, plug plants allow for ease of planting and rapid establishment of the planting. With day-neutrals, however, because production will begin shortly after planting, a larger plug size is recommended. Few sources of plug plants of recommended day-neutral cultivars exist, and shipping the larger size plants recommended for this system (see below) is generally not economically feasible. Thus, growers intending to use plug plants should plan for growing plug plants on their own. Plugs can be established easily in a nonheated greenhouse as long as temperatures inside the greenhouse do not reach below freezing.

Bare root day neutral plants should be obtained 8 to 10 weeks before the desired planting date. The plants' roots should be trimmed sufficiently to allow them to be planted into 32- to 40-cell planting trays without being "J-rooted." Using deep trays (3 inches) will allow for more roots to be retained and will encourage additional new root growth. The plants should be planted in a good quality soilless mix that is well drained. A slow-release fertilizer such as 20-20-20 with micronutrients should be incorporated into the mix at a rate of 1.5 ounces per cubic foot or as recommended by the manufacturer. Alternatively, plants may be watered with a 100 ppm N solution of soluble fertilizer beginning 3 weeks after planting. The plants should be kept cool, preferably between 40 and 60°F, as this will encourage root development and prevent the plants from getting too tall. During this time, remove flower trusses as they emerge and any runners that may appear. Plants should be monitored for pests such as two-spotted spider mites and foliar diseases and be treated if necessary. The plugs should be ready for planting into the field in approximately 8 weeks.

Dormant plants may also be planted directly through the plastic using a V-shaped planting tool after holes are punched. Production will not begin until 3 to 4 weeks after the time that plug plants would have begun producing, plus yield per harvest will be lower for an additional few weeks. Thus, yields will be somewhat reduced.

Variety Selection

Seascape is the most widely used day neutral variety in the East. Seascape has a sweet flavor, desirable shaped fruit, and medium red color. Its shortcomings are only average fruit size, a strong tendency to soften and split during adverse weather conditions, and susceptibility to powdery mildew. Albion produces considerably lower total yields, but its large fruit are durable even during rainy spells, resulting in a very high proportion of marketable fruit. Flavor is good when fruit is fully ripe. Additional information on these cultivars and characteristics of other day-neutral cultivars are outlined in Table 6.6.

Planting

Plants can take temperatures as low as 25°F before damage will occur to the crown. Plants may be planted any time after lows are expected to be higher than 25°F as long as air temperatures will remain above freezing for 2 to 3 days after planting. This will allow plants to become established.

Be sure to thoroughly wet the beds a day or two before planting. On each bed, a double row of plants should be planted that are 12 inches apart in each row and 12 to 16 inches between rows. Stagger the plants in the double rows to utilize the entire plastic surface as the plants mature. The plugs should be planted so that the roots are covered, but also make sure the growing point is not covered. Water the plants shortly after planting. Remove any blossoms at planting. A trial in Garrett County, MD, indicated that it is not necessary to remove blossoms from plug plants after the plants have been planted. While no recent studies have been done to determine the necessity of flower removal from dormant plants, it is recommended to remove the first flush of flower blossoms to allow the plants to become established without the additional stress of producing a crop.

Irrigation

Adequate moisture is critical for producing large fruit at any time, but especially during the summer months.

After the plants are established, apply sufficient trickle irrigation to supply a minimum of 1 inch of water to the bed each week, more during hot spells. For a bed that is wetted 2.5 feet wide using a trickle tape with a flow rate of 0.45 gallons per 100 ft per minute at 10 psi, this would require 5.8 hours of run time per week, or approximately three two-hour irrigation cycles per inch of water applied. As discussed above, nutrients may be fertigated during irrigation cycles.

Frost Protection

Frost protection may be a concern for fall production. Production may be extended considerably if row covers are pulled on during early frost events. For spring frost protection of plantings that are being fruited for a second year, see frost protection information mentioned in earlier sections and Appendix A.

Harvest Considerations

Because day-neutral strawberries produce fruit for a long period, conditions at harvest time will vary greatly during the season. Fruit quality will be greatest if the strawberries are harvested at least three times per week, but during wet or hot periods, even more frequent picking may be needed. See "Harvest and Postharvest Handling" below for additional details.

Pest Management Notes Specific to Day-Neutral Plantings

Because day-neutral plantings fruit for a longer period and at different times than June-bearers, pest issues can be slightly different. Tarnished plant bug and sap beetle populations build as the summer progresses; hence, it is important to scout for these pests and take corrective measures if needed. Long-necked seed bug, which produces symptoms similar to tarnished plant bug damage, has also been problematic in day-neutral plantings. Japanese beetles, typically only a sporadic problem on strawberry foliage, can burrow into fruit that is produced during the summer. Powdery mildew can be problematic on Seascape, and some day-neutral cultivars are quite susceptible to fruit anthracnose. Disease susceptibilities specific to various day-neutral cultivars are covered in Table 6.6. Because of frequent and constant summer harvest in some locations, only pesticides that have a very short to zero-day harvest interval can be used. In addition, due to the nearly constant presence of flowers, care should be taken to protect pollinators. See Table 3.1 for ratings of pesticide safety to honey bees.

CONSIDERATIONS FOR ORGANIC PRODUCTION

While consistency is improved with the institution of National Organic Standards, some of the standards may be interpreted differently. Therefore, working closely with your certifying agency is best to ensure that your interpretation is the same as that of your certifying agency so that your organic certification is not compromised.

While rotations are important in any production system, they are especially important in organic production as a preventative pest management strategy. Growers should rotate an area out of strawberries for a minimum of 5 years (longer if possible) between plantings. Also, avoid rotating in crops that host strawberry pests, such as verticillium wilt. Consider including cover crops in the cropping rotation to aid in pest management and improve soil fertility. Typically, strawberries in matted-row production are kept for 3 to 5 harvest years. Organic strawberry growers may find keeping plantings for a shorter time (maximum of 2 harvest years) beneficial to help avoid weed, insect, and disease problems that tend to increase in older plantings.

One question in organic production is whether the source plants need to be produced organically. The standards for planting plug plants and crowns are dependent on whether they will be used in an annual or perennial cropping system. Plug plants or crowns kept for only one year are considered annual seedlings or planting stock and must be organically produced (e.g., as with annual strawberry plasticulture, with day-neutral plantings harvested the first year, or if blossoms are not removed and berries are picked the first year in traditional matted rows). Berries picked more than one year from planting can be marketed as organic even if nonorganic plug plants and crowns were used, as long as the plants were managed organically for at least one year before berries were harvested in an organically certified system.

According to the National Organic Standard, organic growers using plastic mulch must remove it from the field "at the end of the first growing or harvest season." Interpretation of what this means for plasticulture production can vary by certifying agency.

PROTECTED CULTURE

Some growers have expressed interest in alternative production systems, primarily with the intent of producing berries earlier in the year or during the off-season when production otherwise might not be possible. Both high tunnel and greenhouse production involve higher costs than field production, and recommendations may not yet exist for solving some potential problems. Production difficulties can be considerably different in type or magnitude from those encountered in field production. For these reasons, growers are advised to proceed with caution when embarking on a new enterprise in these areas. We expect, however, that interest in these systems will grow and that the amount of production under protected cultivation will increase as more information becomes available.

High Tunnel Production

Strawberries can be grown in high tunnels using production methods similar to those used for strawberry plasticulture (see June-bearers: Plasticulture Production) with plug plants. Use of tunnel space for June-bearing strawberry production is somewhat inefficient, and in most cases, yield increases from tunnel production are not great enough to make up for the cost of the structure. Regardless, some growers wish to grow strawberries in tunnels to ensure that the crop will not be lost to adverse weather conditions. Because temperatures are warmer in the tunnel than in the field, plug plants can be planted later than in the field if necessary. Of June-bearing cultivars normally recommended for strawberry plasticulture, Chandler seems especially adaptable to this system. Sweet Charlie is likely to break dormancy far too early in high tunnels, flowering in January. Soil preparation and planting are carried out as for

field production, with the exception that narrower beds and/or closer bed spacing can be used to allow more strawberry plants to fit in the tunnel. Plants should be well watered during the fall. Row covers for winter protection are necessary in single-bay tunnels only in the coldest locations and will also be needed in multibay tunnels where the plastic is removed for the winter. Care during the spring is similar to that of field production, with the exception that pollinators may need to be introduced since resident pollinators are not likely to be active when the plants start to bloom. Bumble bees or mason bees have been used successfully for pollination, but care must be taken to keep temperatures in ranges within which they can survive. Honey bees can be used, but they tend to become disoriented in the tunnel. Yields can be easily advanced by 3 weeks over field plasticulture production and can be expected to be at least 25 percent higher.

If day-neutrals are grown in high tunnels, it may make more sense to plant them in late summer and fruit them for the fall and spring, rather than plant in the spring and fruit for the summer and fall. The high temperatures reached in high tunnels during the summer are not conducive to strawberry production, making the amount of fruit produced relatively low for the effort and cost.

Powdery mildew is likely to be a problem on either type of plant. Interpretation of which pesticides can be used in tunnels varies from state to state. In most cases, pesticides used in greenhouse production or those that don't specifically state that they are only for field production can be used. However, state regulations should be checked. Twospotted spider mites are very likely to problematic, so monitoring should be continual from the time of planting onward. Predatory mites have given good control when released while spider mite populations are still low (i.e., fewer than 20 mites on a few isolated leaves). In situations where tunnels have been kept closed during the winter, thus resulting in mild soil conditions, soil-dwelling insects such as sowbugs and earwigs may build to high populations. On occasion, they become a fruit-feeding pest, causing losses of marketable fruit.

Greenhouse Production

Considerable work on greenhouse strawberry production has taken place at Cornell University and at USDA's Appalachian Fruit Research Station in Kearneysville, West Virginia. Production costs will be fairly high. At Cornell, a break-even price of $3.00 per pint was calculated. Growers interested in additional information should consult the NRAES Strawberry Production Guide or other sources of information (see Appendix E to obtain). Briefly described, in this system dormant crowns are planted in pots, grown outdoors until late fall, and then cold stored at 28 to 30°F. Both June-bearing and day-neutral types have been used successfully. Plants are moved into the greenhouse at intervals for fruit production 10 to 13 weeks later. Supplemental light and a day/night temperature regime of 75/55°F is used. Nutrients are provided both in the mix and with a complete fertilizer solution that supplies 50 to 100 ppm nitrogen. Bumble bees were found to work well as pollinators.

Powdery mildew and twospotted spider mites are likely to be problems, as in high tunnel production. In addition, other insects that are common greenhouse pests (e.g., fungus gnats and thrips) and gray mold have been encountered as problems. Vigilant scouting and early release of biocontrol agents can prevent many of these pests from developing into significant problems.

Vertical Systems

Out-of-the-ground or elevated systems take advantage of high planting densities to produce high yields in small spaces. However, the use of vertical, tabletop, or other specialized systems for strawberry production in the eastern United States has yet to show significant advantages over production in the ground. The intensive management required for unconventional systems presents a challenge for many growers, and the high cost of these systems is often difficult to recoup. Growers should first gain experience and success with the crop using a conventional system before considering more specialized systems.

HARVEST AND POSTHARVEST HANDLING

Berries generally ripen 28 to 30 days after full bloom. Pick berries in containers no deeper than 4 inches. Fruit should be picked in the morning after plants have dried, and berries should be kept out of direct sun. Pick at least three times per week when berries are fully colored, retaining the caps. For longest shelf life, immediately cool berries to 33°F, using convection to remove field heat. Strawberries should then be refrigerated at 32 to 33°F. This is especially important if fruit is sold wholesale. However, since refrigeration may affect the sheen on the fruit, some growers who sell the fruit on their farms prefer avoiding refrigeration by picking only what they can sell the same day. Regardless of how fruit will be marketed, hiring enough labor to finish harvesting by noon is wise. This allows berries to be harvested before they build up field heat, which increases the rate of ripening and decay. This is of less concern with pick-your-own operations since the fruit is more likely to be used quickly.

ECONOMICS

The strawberry budgets given here were prepared to provide general information and do not apply to any specific operation. Use them, with appropriate modifications, as guides for preparing budgets for individual situations. Budgets can be used:

- for general farm business planning purposes
- as a basis for obtaining credit
- to project cash flows
- to assess profitability

Using these sample budgets as guides should help ensure that all costs and receipts are included in budgets you prepare for your farm. Costs are often difficult to estimate in budget preparation because they are numerous and variable. Therefore, you should think of these budgets as a first approximation and then make appropriate adjustments using the "Your Farm" column to add, delete, and adjust items to reflect your specific growing conditions and resource situation.

The sample cost of production budgets were developed using a computerized budget generator. Input data reflect recommended production practices and current input costs. Major subheadings in the budgets are variable costs, fixed costs, and total specified costs. They are defined as follows:

Variable costs are costs that vary depending on the level of production. These include such inputs as fertilizer, herbicides, insecticides, fungicides, and labor.

Fixed costs are costs that do not vary by level of production and are incurred by virtue of owning assets such as machinery and land. Depreciation and taxes are examples.

Total specified costs are the sum of variable and fixed costs. Most land-preparation activities are assumed to be custom hired in these budgets because the small acreages for many berry farms do not justify the ownership of these implements. If you use your own tillage equipment, the variable costs for custom hire should be subtracted from the budgets and your labor variable costs and machinery fixed costs should be substituted.

For matted-row production, cost-of-production budgets are presented for the years of land preparation (Table 6.7), planting (Table 6.8), and mature production (Table 6.9). For plasticulture production, cost-of-production budgets are presented for the year of land preparation and planting (Table 6.11) and the first harvest year (Table 6.12).

Returns to risk and management is the estimated profit attributable to the acceptance of risk and the contribution of management expertise by the grower (Table 6.10 for matted-row production and Table 6.13 for plasticulture production). The tables estimate the return to the grower for a range of prices and yields. Because yields, grades, and prices are so variable, growers should use representative values for their operations. It is important to account for cash flows over the life of the investment when assessing the overall profitability of the enterprise, so prorated land preparation and planting costs are subtracted in the estimates. Breakeven prices and yields are shown in the tables. Breakeven price is an estimate of the unit price required to cover all costs at a given yield; it is also the average cost per unit of production. Breakeven yield is an estimate of the yield required to cover all costs at a given price.

Berry production involves large initial investments and can be very risky; weather- and animal-related crop losses are common and crop prices can be highly variable. Use of whole-farm risk management tools such as AGR-Lite crop insurance can help you reduce these risks.

A land charge of $200/acre has been included in the budgets, but this charge can vary greatly from location to location. If you own the land, you could include your principal, interest payments, and property taxes as a fixed cost. If you lease the land, then the annual rental cost could be included as a variable cost.

Production assumptions used in generating the budgets in both systems include the following:

- Fumigation is not used in matted-row production, though under certain conditions, fumigation may be warranted. Fumigation is used for plasticulture production.
- Irrigation system costs are calculated assuming that water is applied to 5 acres.
- Fungicides are rotated to reduce the likelihood of disease resistance.
- The numbers of pesticide and irrigation applications are average. In any given year or location, growers will need to adjust these for their particular sets of circumstances.
- Berries are harvested and sold as ready picked in quart pulp containers.

Matted-Row Strawberry Budgets—Additional Assumptions

- Plant spacing is 24 inches within the row and 40 inches between rows (approximately 6,500 plants per acre).
- An overhead irrigation system is used for water application.

Plasticulture Production of Strawberries—Additional Assumptions

- Vapam is applied through the trickle irrigation system as a soil fumigant.
- Strawberry plugs are used for planting at the rate of 17,424 plugs per acre.
- An overhead irrigation system is used for frost protection and a trickle system is used in season for calculating water application.

Table 6.7. Summary of estimated costs per acre, 2011: year of land preparation for strawberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Soil test	acre	10.00	1.00	10.00	
Spread lime	acre	12.20	1.00	12.20	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	1.00	17.90	
Grass seeding	acre	11.20	1.00	11.20	
Herbicides					
Glyphosate 4	gal	12.78	0.50	6.39	
Seed					
Annual ryegrass seed	lb	0.35	25.00	8.75	
Labor					
Seasonal	hour	12.00	0.50	6.00	
Operator	hour	15.00	0.46	6.84	
Diesel Fuel	gal	3.50	1.12	3.92	
Repairs and Maintenance					
Tractors	acre	1.40	1.00	1.40	
Implements	acre	1.16	1.00	1.16	
Interest on Operating Capital		3.05			
Total Variable Cost				139.81	
FIXED COST*					
Tractors	acre	2.68	1.00	2.68	
Implements	acre	2.39	1.00	2.39	
Total fixed cost				5.07	
Land Charge	acre	150.00	1.00	200.00	
TOTAL SPECIFIED COSTS				344.88	

* Estimated fixed costs in this budget assume that all field operations for land preparation are done by custom operators. Ownership of tillage equipment, grain drills, and grass seeders is not economically justified for growers engaged solely in small fruit production. Fixed costs in this budget reflect the ownership of a sprayer and mower.

Table 6.8. Summary of estimated costs per acre, 2011: planting year for matted-row strawberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Moldboard plowing	acre	22.00	1.00	22.00	
Spread dry fertilizer	acre	9.85	2.00	19.70	
Disking	acre	17.90	1.00	17.90	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
10-10-10	lb	0.21	300.00	63.00	
Urea	lb	0.25	130.00	32.50	
Fungicides					
Captan 80W	lb	6.99	6.00	41.94	
Rally/Nova 40W	oz	3.31	5.00	16.55	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Sinbar WDG	lb	48.66	0.50	24.33	
Insecticides/Miticides					
Assail 30SG	oz	5.76	6.90	39.74	
Brigade WSB	lb	21.31	1.00	21.31	
Portal	oz	1.27	32.00	40.64	
Other					
Straw	ton	160.00	1.20	192.00	
Strawberry plants	thsd	145.00	6.50	942.50	
Overhead irrigation	acre	200.00	1.00	200.00	
Labor					
Seasonal	hour	12.00	57.38	688.50	
Operator	hour	15.00	4.10	61.50	
Diesel Fuel	gal	3.50	39.55	138.43	
Repairs and Maintenance					
Tractors	acre	29.12	1.00	29.12	
Implements and Irrigation	acre	82.16	1.00	82.16	
Interest on Operating Capital				120.07	
Total Variable Cost				2,927.69	
FIXED COST					
Tractors	acre	61.00	1.00	61.00	
Implements and Irrigation	acre	212.19	1.00	212.19	
Total fixed cost				273.19	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				3,400.88	

Table 6.9. Summary of estimated costs per acre, 2011: mature planting of matted-row strawberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Urea	lb	0.25	90.00	22.50	
Fungicides					
Captan 80W	lb	6.99	18.00	125.82	
Elevate 50WDG	lb	45.55	3.00	136.65	
Switch 62.5 WDG	oz	4.80	14.00	67.20	
Herbicides					
2,4-D amine	gal	14.82	0.25	3.71	
Chateau WDG	oz	6.34	3.00	19.02	
Devrinol W	lb	12.35	8.00	98.80	
Sinbar WDG	lb	48.66	0.25	12.17	
Insecticides					
Admire Pro	oz	3.19	24.00	76.56	
Brigade WSB	lb	21.31	1.00	21.31	
Endosulfan 3EC	gal	35.75	0.33	11.89	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Overhead irrigation	acre	200.00	1.00	200.00	
Plant analysis kit	each	25.00	1.00	25.00	
Straw	ton	160.00	2.00	320.00	
Pulp box, 1 qt	each	0.15	7,000.00	1,050.00	
Tray, 1 qt	each	1.35	875.00	1,181.25	
Labor					
Seasonal	hour	12.00	39.88	478.50	
Operator	hour	15.00	5.30	79.47	
Berry harvest	qt	0.75	7,000.00	5,250.00	
Diesel Fuel	gal	3.50	46.03	161.12	
Repairs and Maintenance					
Tractors	acre	35.56	1.00	35.56	
Implements and irrigation	acre	91.08	1.00	91.08	
Interest on Operating Capital				334.72	
Total Variable Cost				9,854.62	
FIXED COST					
Tractors	acre	74.27	1.00	74.27	
Implements	acre	229.95	1.00	229.95	
Total fixed cost				304.22	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				10,158.84	

Table 6.10. Returns to risk and management for matted-row strawberries, 2011.

	Yield (qt/A)					
Price ($/quart)	5,000	6,000	7,000	8,000	9,000	Breakeven Yield
$1.50	-$1,970	-$1,539	-$1,107	-$676	-$245	9,568
$2.00	$530	$1,461	$2,393	$3,324	$4,255	4,431
$2.50	$3,030	$4,461	$5,893	$7,324	$8,755	2,883
$3.00	$5,530	$7,461	$9,393	$11,324	$13,255	2,137
$3.50	$8,030	$10,461	$12,893	$15,324	$17,755	1,697
$4.00	$10,530	$13,461	$16,393	$19,324	$22,255	1,408
Breakeven price	$1.89	$1.76	$1.66	$1.58	$1.53	

Prorated land preparation and planting costs included based on a productive life of 3 years. A 1-quart pulp box of strawberries weighs approximately 1.4 pounds.

Table 6.11. Summary of estimated costs per acre, 2011: planting year for strawberry plasticulture.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Soil test	acre	10.00	1.00	10.00	
Spread lime	acre	12.20	1.00	12.20	
Moldboard plowing	acre	22.00	1.00	22.00	
Spread dry fertilizer	acre	9.85	1.00	9.85	
Disking	acre	17.90	2.00	35.80	
Fertilizer and Lime					
10-10-10	lb	0.21	300.00	63.00	
Urea	lb	0.25	75.00	18.75	
Lime	ton	14.50	2.00	29.00	
Other					
Black plastic mulch	ft	0.03	5,800.00	174.00	
Drip tape	ft	0.02	5,800.00	116.00	
Strawberry plugs	thsd	260.00	17.42	4,530.24	
Overhead irrigation	acre	200.00	1.00	200.00	
Row covers	ft	0.25	5,800.00	1,450.00	
Vapam	gal	11.00	27.30	300.30	
Labor					
Seasonal	hour	12.00	31.88	382.50	
Operator	hour	15.00	2.58	38.67	
Diesel Fuel	gal	3.50	37.61	131.63	
Repairs and Maintenance					
Tractors	acre	26.65	1.00	26.65	
Implements and irrigation	acre	56.96	1.00	56.96	
Interest on Operating Capital				123.31	
Total Variable Cost				7,730.86	
FIXED COST					
Tractors	acre	55.92	1.00	55.92	
Implements and irrigation	acre	149.34	1.00	149.34	
Total fixed cost				205.26	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				8,136.12	

Table 6.12. Summary of estimated costs per acre, 2011: mature planting for strawberry plasticulture.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Soluble 20-20-20	lb	1.90	60.00	111.00	
Fungicides					
Abound	gal	282.60	0.09	25.43	
Captan 80W	lb	6.99	6.00	41.94	
Elevate 50WDG	lb	45.55	3.00	136.65	
Topsin-M 70WSB	lb	11.84	1.00	11.84	
Switch 62.5 WDG	oz	4.80	14.00	67.20	
Herbicides					
Gramoxone Inteon	gal	32.83	0.09	3.10	
Insecticides					
Agri-Mek	oz	1.59	16.00	25.44	
Brigade WSB	lb	21.31	1.00	21.31	
Endosulfan 3EC	gal	35.75	0.33	11.89	
Other					
Overhead irrigation	acre	200.00	1.00	200.00	
Plant analysis kit	acre	25.00	1.00	25.00	
Pulp boxes, 1 qt	each	0.15	8,000.00	1,200.00	
Tray, 1 qt	each	1.35	1,000.00	1,350.00	
Labor					
Seasonal	hour	12.00	27.88	334.50	
Operator	hour	15.00	2.89	43.41	
Berry harvest	qt	0.75	8,000.00	6,000.00	
Diesel Fuel	gal	3.50	37.38	130.79	
Repairs and Maintenance					
Tractors	acre	26.93	1.00	26.93	
Implements and irrigation	acre	81.63	1.00	81.63	
Interest on Operating Capital				183.66	
Total Variable Cost				10,069.72	
FIXED COST					
Tractors	acre	56.47	1.00	56.47	
Implements	acre	211.35	1.00	211.35	
Total fixed cost				267.82	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				10,537.54	

Table 6.13. Returns to risk and management for plasticulture strawberries, 2011.

	Yield (qt/A)					
Price ($/quart)	6,000	7,000	8,000	9,000	10,000	Breakeven Yield
$2.50	-$1,881	-$450	$982	$2,413	$3,844	7,314
$3.00	$1,119	$3,050	$4,982	$6,913	$8,844	5,420
$3.50	$4,119	$6,550	$8,982	$11,413	$13,844	4,306
$4.00	$7,119	$10,050	$12,982	$15,913	$18,844	3,571
$4.50	$10,119	$13,550	$16,982	$20,413	$23,844	3,051
$5.00	$13,119	$17,050	$20,982	$24,913	$28,844	2,663
$5.50	$16,119	$20,550	$24,982	$29,413	$33,844	2,362
Breakeven price	$2.81	$2.56	$2.38	$2.23	$2.12	

Prorated land preparation and planting costs included based on a productive life of 1 year. A 1-quart pulp box of strawberries weighs approximately 1.4 pounds.

PESTS

Information on individual diseases and insects is presented below, with cultural controls discussed in the text. Pesticide information is presented in tables that follow. Because it is important to avoid buildup of resistant strains of fungi and insects, especially mites, activity groups (for rotational use to avoid buildup of resistant strains) of fungicides, and their efficacy on common diseases are presented in Table 6.14, and activity groups and efficacy of insecticides and miticides are listed in Table 6.15. Fungicides, insecticides, and miticides that can be used to assist in management are given in Table 6.16, arranged by various growth stages for the life cycle of the crop. Pests are listed at the stages where they are most likely to be problematic or when treatment is most effective. Information in Table 6.16 should be supplemented with the reading below. Table 6.17 presents additional restrictions beyond preharvest intervals and reentry intervals (REIs) that appear on the label.

DISEASES

Black Root Rot

Symptoms: An uneven "patchy" appearance in the strawberry bed. Usually, older plantings or replanted fields are affected. Plants become stunted and produce few berries and runners. Feeder rootlets disintegrate and structural roots of the mother plant blacken and deteriorate, leaving a white core. Brown lesions may be apparent on the normally white or tan roots.

Causal Agent: Several factors comprise this "disease complex." This complex is associated with a number of pathogenic soil fungi (most commonly *Rhizoctonia* and *Pythium* species), lesion nematodes, environmental conditions (e.g., drought, winter injury to the root system, and the freezing or water logging of the soil), nutrient deficiencies, fertilizer burn, pesticide injury, or a combination of all of these factors.

Epidemiology: Because this is a complex, a disease cycle is not as clear as that of other diseases. *Rhizoctonia* and *Pythium* are present in nearly all unfumigated soils, and poor plant health due to cultural or environmental conditions likely tips the balance, allowing these organisms to colonize the roots.

Controls: Planting in well-drained and well-aerated soils such as those with a high organic matter content (greater than 6 percent) is strongly recommended. Research found that black root rot incidence was reduced by using raised beds. Avoid soil compaction and excessive irrigation. Mulching in order to lessen winter injury, purchasing disease-free plants, and rotating crops for a minimum of 3 to 5 years are also factors in controlling black root rot. No fungicides are currently recommended for control.

Gray Mold (Botrytis Blight)

Symptoms: Under rain-free conditions, a characteristic gray, fuzzy coating or web develops on the fruit. Rot may first appear at the base of the fruit or when the berry is in contact with the soil, other damp surfaces, or other rotten fruit, and can destroy the berry within 48 hours. Gray "fuzz" may be absent in the field, but storing the fruit in a humid environment will cause it to become apparent within 1 to 2 days.

Causal Agent: The fungus *Botrytis cinerea.*

Epidemiology: *Botrytis cinerea* can live as a parasite as well as a saprophyte on decaying plant debris. This fungus is always present and the fruit rot starts with a blossom infection that eventually invades the developing fruits, causing them to rot. This is why timing bloom sprays appropriately (see below) is essential, particularly during a wet bloom season since this prevents the initial infection of the fungus into the flower parts. As the disease progresses, spores are produced and are easily blown or splashed onto healthy foliage. Once the fungus becomes established, it can produce spores continuously throughout the growing season.

Controls: Moisture is necessary for the spores to germinate and infect plants, so the disease is favored by high humidity and relatively cool conditions. Therefore, practices that help reduce humidity and increase air movement, such as controlling weeds and utilizing wider spacing of rows and plants, help control gray mold. The fungus thrives on debris, so sanitation is essential for control. Dead plants and fallen leaves should be removed and burned or buried. Several fungicides are effective for controlling gray mold. Bloom sprays are especially important and should be applied at early (5 to 10 percent) bloom and full bloom 7 to 10 days later. A third spray may be needed if excessively rainy conditions or a prolonged season of bloom exists.

Common Leaf Spot (Birds-Eye Leaf Spot)

Symptoms: Small, dark spots (1/8 to 1/4 inch across) that develop white to gray centers, which may fall out, leaving a hole with a purple margin (Figure 6.3). Symptoms are most easily noticeable on leaves, but leaf petioles, runners, berry caps, and even berries can show them.

Causal Agent: The fungus *Mycosphaerella fragariae.*

Epidemiology: In the spring, new leaves are infected by spores that originate from overwintering leaves. Infection can continue to take place anytime during the year except during hot, dry weather.

Controls: Any practice that encourages drying of foliage is helpful, as is removal of dead plants and leaves and mowing at renovation. Several fungicides are effective for control.

Leaf Scorch

Symptoms: Dark-red to purple spots on the leaves that gradually enlarge and may eventually merge to occupy large portions of the leaves. Unlike with common leaf spot, centers of the spots do not fall out and remain a similar shade as the rest of the spot, though dead leaf tissue may dry and turn brown (Figure 6.3). Lesions also develop on petioles and other aboveground portions, most noticeably the caps. Severe cases of scorch reduce plant vigor and yields.

Cause: A fungus, *Diplocarpon earlianum.*

Epidemiology: Leaf scorch is favored by long periods of leaf wetness and rain. The fungus can survive on both living and dead plant tissues and develops under a wide range of temperatures. However, extremely hot (greater than 86°F), cold (less than 36°F), or dry conditions slow its development.

Controls: Mowing and removal of foliage at renovation interrupts disease

progression. The disease is typically worse in older plantings. Some cultivars are resistant (see Tables 6.3, 6.5, and 6.6). Any practice that promotes drying of foliage is helpful. Fungicides applied for control of leaf spot may be effective on leaf scorch (see Tables 6.14 and 6.16).

Angular Leaf Spot

Symptoms: Water-soaked lesions on the lower leaf surface contained between small veins of the leaf. Small, light-green "blocks" on the leaf are apparent when the leaf is held up to the light and viewed. In severe cases, blocks of damaged tissue coalesce and die, making it difficult to differentiate this disease from other leaf spots. Symptoms accrue on older leaves. The fruit cap may turn brown or black while the berry otherwise appears normal. Under moist conditions, the bacterium produces an exudate that, when dry, appears as a whitish, scaly film. The pathogen not only infects the foliage and fruit crops but can also invade the plant's vascular system, causing a general decline.

Causal Agent: A bacterium, *Xanthomonas fragariae.*

Epidemiology: The disease originates in plant material from the nursery, but symptoms may never develop until the plants are exposed to prolonged cold, wet conditions. The bacteria that cause angular leaf spot are systemic (i.e., cannot be eliminated from the plant). This bacterium overwinters in infected plants and dead leaves. Exudate from infected leaves can be splashed to uninfected plants by water. Young tissue is easily infected. Temperatures just above freezing and moist conditions favor disease development. Thus, this disease is most problematic in years or on sites where frequent or prolonged overhead frost protection is needed.

Controls: Avoidance of this disease is currently almost impossible, as it appears that nursery stock is largely infected. Since the bacteria prefer cool temperatures and wet conditions, such as those that occur when overhead irrigation is used for frost protection, any practice that minimizes the amount of frost protection needed (site and cultivar selection) and maximizes drying of foliage is recommended. Healthier leaf tissue replaces damaged tissue following renovation and periods of dry warm weather. Cultivars vary in susceptibility, but none are resistant. Because this disease is caused by a bacterium rather than a fungus, fungicides have no effect.

Copper sprays applied early in the season at 7- to 10-day intervals or prior to expected wet spells may help, but phytotoxicity becomes a concern with multiple sprays. Discontinue use after four to five sprays or sooner if phytoxicity symptoms appear. There is some indication that copper hydroxide formulations may be more effective than copper sulfate formulations.

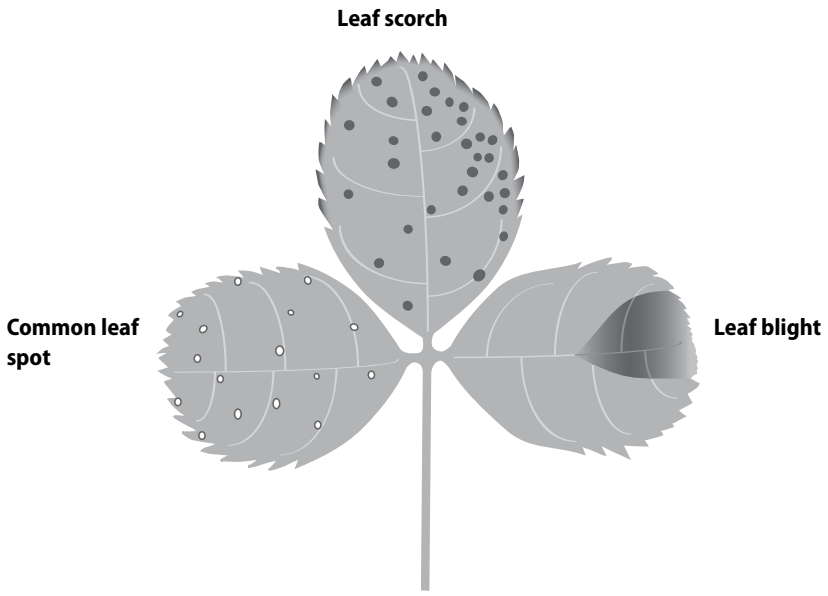


Figure 6.3. Common strawberry leaf diseases.

Other Leaf Spots

Besides common leaf spot, leaf scorch, and angular leaf spot, other types of leaf spots can infect cultivated strawberry and, often, wild strawberry species. These include black leaf spot (anthracnose leaf spot), septoria leaf spot, cercospora leaf spot, and alternaria leaf spot. These leaf diseases are caused by different fungi and more than one type of leaf spot is usually present. Usually, disease development is favored by rain and warm, humid weather conditions.

Phomopsis Leaf Blight

Symptoms: In the early stages, symptoms are very similar to those of leaf spots, but eventually spots develop into purple, V-shaped lesions with a brown central area that can occupy a large portion of the leaf. The wide portion of the V is toward the edge of the leaf (Figure 6.3). This disease can destroy much of the foliage, especially in late summer. Brown lesions also may form on petioles, runner stolons, and fruit trusses, disrupting translocation and negatively affecting growth of these plants parts. Leaf blight may also infect fruit caps, causing them to turn brown, as well as the fruit, causing phomopsis soft rot.

Causal Agent: The fungus *Phomopsis obscurans* (syn. *Dendrophoma obscurans).*

Epidemiology: The fungus overwinters on old attached leaves. Splashing rain spreads inoculum early in the season.

Cultural Controls: Cultural controls consist of removing the older leaves through mowing at renovation to reduce inoculum. Fungicides applied for other leaf spots, in addition to those applied specifically for leaf blight, will help in control.

Leather Rot

Symptoms: Symptoms vary depending on fruit stage. On immature, green fruit, infected areas appear dark brown or normal green with a brown outline. On ripe, mature fruit, they appear bleached

and range in color from light lilac to purple, or there may be no change in color. Infected fruits are characteristically tough and leathery, having a bitter taste. Fruit rot occurs when berries come in contact with the soil. A serious crown rot can develop along with the fruit rot.

Causal Agent: The soil-inhabiting fungus *Phytophthora cactorum.*

Epidemiology: When weather conditions are warm and rainfall is abundant, the pathogen releases its spores into the soil. These infested soil particles are dispersed to the fruits by splashing rain or wind. The fungus attacks berries in the field at all stages of growth.

Controls: Practices such as mulching with straw to keep the fruit off the ground aid in minimizing rain splash and help control leather rot.

Powdery Mildew

Symptoms: Powdery mildew is most often observed as a foliage disease, but it also occasionally causes a serious fruit rot. The pathogen can affect flowers and fruit in all stages of development. Flower parts may be invaded prior to pollination, resulting in poor fruit set, immature fruit becoming hard and not ripening normally, and mature, ripe fruit being soft and pulpy and maybe failing to color. When the fruit surface is affected, the mycelium may be seen primarily on seeds, which may loosen and easily rub off. In spring the fungus sporulates on leaves, causing leaflets to curl upwards along the edges. Lower leaf surfaces may turn reddish or purplish and a powdery, "frosty" growth of the fungus is often seen.

Causal Agent: The fungus *Sphaerotheca macularis.*

Epidemiology: The fungus causing this disease is an "obligate parasite," meaning that it needs to reside in a living host for its survival. It can be found overwintering in old but living leaves. Powdery mildew occurs on a wide range of hosts and almost everywhere strawberries are grown. Disease development is more likely under conditions of high humidity and warm temperatures.

Controls: Planting resistant cultivars and using adequate plant and row spacing aid in control. Removing overwintering leaves may be of some benefit. Several fungicides provide control.

Red Stele

Symptoms: Plants showing aboveground symptoms frequently occur in patches where the soil is wettest. Symptoms depend on the severity of root rotting. Severely diseased plants are stunted, the younger leaves turn a blue green and the older ones turn red, yellow, or orange. Plants eventually wilt and die. As the number of diseased roots increases, plant size, yield, and berry size decrease. When a young, infected root is cut open lengthwise, the stele or core above the rot is red. This diagnostic symptom occurs when the soil is cool. As the disease progresses, the lateral roots die, giving the main roots a "rattail" appearance.

Causal Agent: The soil-inhabiting fungus *Phytophthora fragariae.*

Epidemiology: Healthy roots are infected by spores produced on other infected roots. Spores move through the soil and penetrate the tips of roots, growing within the root system. A few days after infection, roots begin to rot, more spores are produced by the fungus within this rotted tissue, and eventually spores and rotted roots become incorporated into the soil.

Controls: Red stele, or red core, is the most serious disease of strawberries in areas of cool, moist soil conditions, especially heavy clay soils saturated with water during cool weather. The spores of this pathogen can travel long distances in surface water, so it's important to maintain good drainage in strawberry beds—a practice that also minimizes runoff. In addition, soil compaction should be avoided. Purchasing planting stock that has been inspected and tested for *P. fragariae,* as well as planting disease-resistant cultivars, is recommended for control of this root rot. There are several different strains of red stele fungi, and not all cultivars of strawberries marketed as "red stele resistant" are equally resistant to all strains of the pathogen. Ridomil and Aliette or Phostrol aid in managing red stele (see Table 6.16).

Verticillium Wilt

Symptoms: Strawberry plants are most susceptible in their first year of growth. The first symptoms appear rapidly in late spring, especially after periods of environmental stress. The outer and older strawberry leaves wilt and dry, turning a reddish yellow to a dark brown at the margins and between the veins. The inner leaves remain green and turgid until the plant dies. This symptom helps to distinguish verticillium wilt from the root and crown diseases caused by *Phytophthora* species, in which both young and mature leaves wilt.

Causal Agent: The soilborne fungus *Verticillium alboatrum.*

Epidemiology: Disease intensity may depend on fertilization practices and the amount of "residual" field inoculum from previous crops. Plants with lush growth owing to high nitrogen applications are more severely affected than plants receiving moderate amounts of nitrogen. Previous crops consisting of solanaceous plants (e.g., tomatoes, potatoes, eggplant, peppers) may have harbored the pathogen and caused a buildup of soil inoculum. It is advisable not to plant a new strawberry bed following crops of this family.

Controls: Planting resistant cultivars and disease-free plants will help control verticillium wilt. A rotation schedule of 3 to 5 years is also recommended.

Anthracnose

Symptoms: Anthracnose is a problem mainly in rainy, warm harvest seasons. It is especially troublesome in the plasticulture production system with susceptible cultivars such as Chandler. Symptoms of anthracnose fruit rot are light-brown spots on fruit that typically turn dark brown or black and then enlarge. Flowers and flower buds can also become infected and appear to dry out. The first symptom of anthracnose crown rot is that plug plants fail to grow following transplanting. However, symptoms are often not apparent until the plants collapse or die, usually in the fall or spring following transplanting during warm weather. When the crown is cut through lengthwise, a brownish, horizontal V shape can be found, originating near the base of a petiole. Leaf

spots either resemble ink spots or appear as irregular lesions at the tips or margins of leaves, depending on the species causing the infection. On the runners and petioles, lesions begin as small red streaks and then turn dark, sunken, and elongated.

Causal Agent: Several different *Colletotrichum* species cause the fruit rot, crown rot, and/or leaf spot, as well as lesions on petioles and runners.

Epidemiology: The primary source of the disease inoculum is infected transplants from the nursery. The plants normally do not show symptoms until after being transplanted to the production field. Inoculum overwinters mainly in infected plants and plant debris. The inoculum is primarily disseminated by splashing water. This fungus needs plant tissue to survive, so the inoculum does not remain in the soil for long periods of time as with many other rots.

Controls: Mulching with straw and using drip irrigation rather than overhead irrigation can decrease the spread of inoculum. The use of raised beds on plastic mulch seems to increase the incidence, possibly because of higher microenvironment temperatures or because water drops bounce and splash off the plastic. Immediate plowdown of infected areas of a field, if occurring only in certain areas, may keep infection from occurring throughout the entire field. Several fungicides aid in control.

NEMATODES

Plant-parasitic nematodes are economically significant pathogens on small fruit and cause a variety of problems. The symptoms of nematode damage may not be immediately obvious in new plantings; therefore, by the time the symptoms are noticed, it is usually too late for corrective measures to be effective. Because of the insidious nature of nematode problems, growers must be aware of the risk to new plantings and the options available for nematode control.

Parasitic nematodes have sometimes been called the "hidden enemy" in agriculture. Without diagnostic testing, their presence is often not evident until it is too late for corrective measures. Thus, the first step in nematode control should be a diagnostic test to determine which nematodes are present and what their population levels are. A properly collected soil sample can be sent to a nematode diagnostic lab for analysis. Results will determine if the site is at risk. See Chapter 1 and Appendix B for information on sampling for nematodes.

Lesion Nematodes

Symptoms: Often, the first symptoms noticed are that the plants are small and fail to make expected growth. Plants should be checked for small, dark lesions present on the roots as a result of the damage caused by nematode feeding, hence the name lesion nematode. As can be expected, higher populations result in increased damage to the planting, causing stunted, weak plants that are predisposed to secondary root-rotting pathogens. This organism is implicated in the disease complex known as black root rot (see above).

Causal Agent: While there are several species of root lesion nematodes, *Pratylenchus penetrans* is most often associated with black root rot of strawberries.

Epidemiology: All stages of the life cycle of lesion nematodes can be found in strawberry roots. *P. penetrans* attacks nearly 400 species of plants including both weed and crop hosts. Besides directly causing damage to the plant by feeding, the injury sites on the roots serve as open entry points for fungi to invade the root tissue.

Controls: Nematode problems, once well established, are difficult to control. Therefore, good nematode management should focus on preventative measures. In general, nematodes can be controlled by using fumigants (see Chapter 3). Decisions regarding chemical control options should be based on the site's history and the results of a nematode diagnostic test (see Appendix B).

Dagger Nematodes

Symptoms: While dagger nematodes feed on the roots of plants, the main concern is their efficiency as vectors of tomato ringspot and tobacco ringspot viruses. Consequently, viral symptoms and/or poor growth are often the first symptoms noticed. Tomato ringspot and tobacco ringspot viruses cause serious problems in raspberries, blackberries, blueberries, and strawberries. As a vector of plant disease, dagger nematodes, even in low numbers, can cause major problems in susceptible crops.

Causal Agent: Several species in the genus *Xiphinema*.

Epidemiology: Dagger nematodes feed from outside of the roots, rather than living within them. These organisms use specialized feeding mouthparts known as stylets to penetrate the root, causing direct damage to the root and also transferring viruses from plant to plant. Survival and movement of the organism is dependent on soil conditions. Dagger nematodes survive best and move most easily in soils low in organic matter, while very wet or very dry soils are detrimental to them.

Controls: Nematodes must be controlled before the crop is planted. Cover cropping with rapeseed as a biofumigant over two successive years as part of a rotation or growing two crops of rapeseed within one year can be effective (see Chapter 2 and Appendix A for additional information). Fumigation can also be used prior to planting.

INSECTS, MITES, AND MOLLUSCS

Managing insect pests is an important part of growing strawberries. The numerous species of insects that attack strawberries may injure plants by feeding on the leaves, flowers, buds, roots, fruits, or crowns. Many important pests are not easy to detect, such as root feeders (grubs and root aphids), nighttime feeders (cutworms, strawberry rootworms, and the adults of most types of root weevils), or those that are extremely small (cyclamen and spider mites). However, their damage is apparent, and they can devastate a crop if left unmanaged.

The current approach to managing pests is referred to as integrated pest management (IPM). With IPM, control is achieved through understanding an insect's biology and utilizing this knowledge to determine optimum strategies. In many cases, using effective cultural practices allows the grower to avoid pest problems in the first place. When insecticides must be applied, the

grower applies them when they will be most effective and minimizes destruction of beneficial insects.

Insects in the following sections are divided by their feeding sites, which will help growers determine where to look for symptoms of damage or for the insect itself.

Flower and Fruit Feeders

Tarnished Plant Bug and Other True Bugs, Lygus *spp. (Heteroptera: Miridae)*

Symptoms of Damage: Tarnished plant bugs tend to feed on the seeds and underlying fruit tissue at the tip of the young berries. Consequently, the tips do not expand, causing the injury known as "button berry" or apical seediness. Although feeding from several plant bugs and the long-necked seed bug causes similar symptoms, the tarnished plant bug appears to be the chief culprit. Small, underdeveloped berries may be caused by other factors, most notably poor pollination and cold injury. However, poorly pollinated fruits will not have developed seeds, while cold injury usually manifests itself as folding of the fruit, causing the seeds to be clumped on the side of the berry rather than at the tip.

Identification: The adult tarnished plant bug, about ¼ inch long, is brownish marked with yellowish and black dashes and has a "brassy" appearance (Figure 6.4). These insects are very active, taking to flight with the slightest disturbance. This inconspicuous sucking plant bug is a general feeder that attacks a wide variety of cultivated and wild plants.

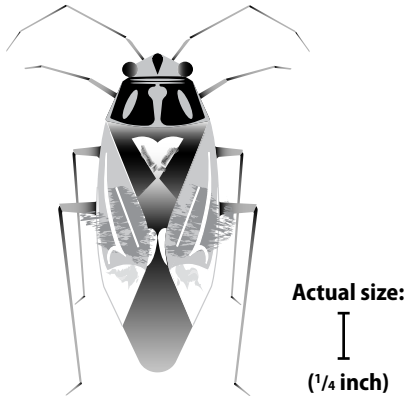


Figure 6.4. Tarnished plant bug adult.

Life Cycle: Adults overwinter in protected places. They return to fields about the time of bud burst and feed on all sorts of tender foliage and plant parts. Tarnished plant bugs often disperse into strawberry plantations when weeds, especially blooming broadleaves, or other crops (e.g., alfalfa) in surrounding areas are mowed or disked. Several generations occur each year—adults and nymphs of all stages are found from April until heavy frost in the fall.

Monitoring and Controls: Growers should sample fruit clusters on a weekly schedule when fruit begins to form. Shaking flower and fruit clusters over a light-colored plate or sheet of paper will dislodge nymphs and allow them to be seen more easily. Sample 30 to 50 flower clusters throughout the field. Divide the number of trusses sampled by the number of plant bug nymphs found. When this number is 4 or less (i.e., if there is more than one nymph per four trusses on average), a spray is advisable. An insecticide application may also be necessary if nymphs are present just before bloom. For specific materials, see Table 6.16. Do not spray pesticides toxic to bees during bloom (see Table 3.1 in Chapter 3). According to research from New England, the varieties least susceptible to plant bug injury are Canoga, Catskill, Honeoye, Sparkle, and Veestar. Darselect is very attractive to tarnished plant bug. Later maturing cultivars and day-neutrals in late summer are more severely affected as tarnished plant bug populations increase.

Long-Necked Seed Bug, Myodocha serripes *(Hemiptera: Rhyparochromidae)*

Symptoms of Damage: Long-necked seed bugs, as their name indicates, feed on seeds, resulting in "button berry" or apical seediness. Symptoms are nearly identical to those of tarnished plant bug. See the above section on tarnished plant bugs for other possible causes of deformed berries. Infrequently, a large proportion of the fruit is affected by this insect.

Identification: The adult is about 3/8 inch long and a varied shade of brown. The most distinctive feature of these insects is their disproportionately itty-bitty head relative to their bodies. Their heads are slender and elongated at the base, giving the insects the appearance of having long necks. These insects are very furtive, quickly hiding under fruit, mulch, or dead leaves when the foliage is disturbed. It is likely that their presence is frequently unnoticed.

Life Cycle: Very little is published on this species. However, it is likely that the adults overwinter in nearby woods. They are reported to frequently feed on seeds of St. Johnswort, goldenrod, and strawberry but also appear in lawns and gardens.

Monitoring and Controls: Because these insects feed on other types of seeds, their presence in strawberry plantings appears to be rather unpredictable. No insecticides are labeled specifically for this insect. However, materials with a non-species-specific label can be used, plus it is likely that insecticides applied for other insects may make treatment for this insect alone rarely needed.

Strawberry Sap Beetle, Stelidota geminata *(Coleoptera: Nitidulidae)*

Symptoms of Damage: Adult sap beetles bore into ripe or nearly ripe fruit, making small holes usually where the fruit touches the ground. When disturbed, adult beetles quickly drop out of the fruit and disappear into the mulch layer or cracks in the ground, which makes them easily missed, except at high populations.

Identification: The adult strawberry sap beetle is a small, brown, oval beetle less than ⅛ inch long (Figure 6.5). In extremely overripe berries, another beetle, the picnic beetle *(Glischrochilus quadrisignatus* or *G. fasciatus)*, may also be found. The picnic beetle is larger and

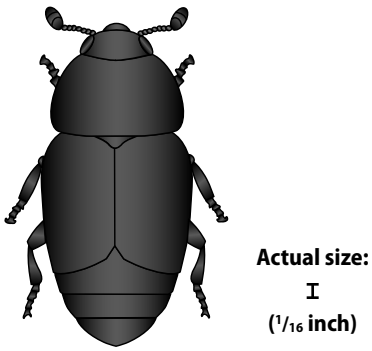


Figure 6.5. Strawberry sap beetle adult.

usually has four orange blotches on its back (Figure 6.6).

Life Cycle: Sap beetles lay eggs in the fruit, and their small (⅛ to 3/8 inches long), white larvae may be seen in the fruit, hopefully not first by the consumer. As the berries begin to ripen in May and June, adult sap beetles are attracted from their overwintering sites in nearby woods to the patch. They bore into ripe, nearly ripe, or decaying fruit, and lay eggs. The larvae then feed on the fruit. Mature larvae leave the fruit and burrow into the soil to pupate briefly before emerging as a new generation of adults and moving to other crops.

Monitoring and Controls: Sap beetles are huge problems on farms where large amounts of ripe fruit are left behind during harvest; therefore, they are often a larger problem in pick-your-own operations than in grower-harvested operations. Cultural controls consist of harvesting as much fruit as possible from the field and collecting and destroying unmarketable fruit. Do not plant more strawberry acreage than can be properly managed during harvest. Renovating the field as soon as possible after harvest will destroy remaining uncollected fruit and disturb the pupating beetles in the ground. A heavy layer of mulch can also encourage sap beetle buildup.

When other cultural practices encourage a buildup of the sap beetle population, heavy damage can occur even when there is not an abundance of overripe fruit. Sap beetles attack a succession of ripening fruits and vegetables such as sweet corn, brambles, cucumbers, peaches, melons, tomatoes, grapes, and apples, so minimizing and plowing down residue in these fields soon after harvest removes potential breeding sites. A pesticide may be used, but chemical control practices are not as effective against the hidden beetles and larvae as cultural control practices.

Figure 6.6. Picnic beetle adult.

Spotted Wing Drosophila, Drosophila suzukii Matsumura (Diptera: Drosophilidae)

Symptoms of Damage: The first symptom typically noticed is the presence of small, white larvae in otherwise marketable fruit. Day-neutral cultivars are much more likely to be infested than June-bearing cultivars, as populations of spotted wing drosophila are much higher in the fall than in early summer. Tiny holes in the fruit made by oviposition wounds might be observed along with collapse of surrounding tissue.

Identification: This pest is very similar in size and shape to common vinegar flies (also known as fruit flies). Distinguishing characteristics are that nearly all males of spotted wing drosophila have a large, black wing spot just forward of the wing tip on each wing, and all males have two black bands (sex combs) on each front leg. This is the only species to have these bands. Certain other species of vinegar flies also have spots on their wings, but their spots are either located right at the tip of the wing or the spots are smaller. Females are distinguished from other vinegar fly species by their large sawlike ovipositor. Females have no spots on the wings or bands on the legs.

Life Cycle: It is not known how well spotted wing drosophila adults will survive the winters in this region. Even if they survive poorly, new flies could be readily introduced in fruit that is bought from other regions. Each female can lay between 200 and 600 eggs. Eggs hatch in only 1 to 3 days, and larvae then feed in the fruit for 5 to 11 days before pupating either in the fruit or on the ground for 4 to 15 days. It is thought that 8 or 9 generations may develop per growing season in the Mid-Atlantic region. The number of generations will vary depending on temperatures. Very high temperatures cause the males to become sterile, and thus populations may drop during periods of hot summer temperatures.

Monitoring and Controls: Vinegar traps can be used to detect whether adults are present and thus when management steps should be taken, but they will not trap sufficient numbers of flies to make a difference in populations. Important cultural controls are to keep harvest intervals as short as possible and pick very cleanly. Cull fruit should always be removed from the vicinity and destroyed. Composting the fruit only allows spotted wing drosophila to continue to multiply as decomposed fruit also serves as a food source. Insecticides that contain pyrethroids or spinosyns as the active ingredient have been effective and also have relatively short preharvest intervals. See Table 6.15 for ratings. Because this pest has many generations per growing season, development of resistance to pesticides is a very large concern.

Slugs (Mollusca)

Symptoms of Damage: While slugs are not insects, they can cause considerable damage similar to insect damage. Slugs of all sizes make small, moderately deep holes in ripening berries, which can be almost anywhere on the fruit, although feeding usually takes place under the cap. As slugs move about they leave a trail of slime, which can be a tell-tale sign of their presence even after the trail has dried. Most of the feeding takes place at night or on dark, overcast days; however, the Arion slug is very aggressive and has been seen feeding on bright, sunny days. Most injury from slugs is encountered during damp, rainy, spring months.

Identification: Slugs and snails, both of which are mollusks, look alike in the early stages, but slugs do not form a shell in their older stages. Slugs are ¼ to 8 inches long, depending on the species. They vary in color from cream to grayish black, with some species being spotted.

Life Cycle: Slugs are favored by mulch in the field and are able to overwinter in protected places beneath the mulch. Eggs are laid in groups in cracks and holes in the soil. Thus, the entire life cycle may be completed in the strawberry field. Slugs require 3 to 7 months to attain adulthood.

Monitoring and Controls: Slug control begins with removing nesting and

breeding places, such as boards, stones, trash piles, and compost piles. Traps made of wet boards or burlap bags may be set in the evening. Remove and destroy the trapped slugs in the morning. If slug damage is severe, a pesticide application may be necessary. Bait formulations usually provide control where slugs are a problem. Diatomaceous earth, a desiccant, may also be applied. For smaller plantings, traps using beer in shallow cans have been effective when used repeatedly.

Flower Thrips (Thysanoptera: Thripidae)

Symptoms of Damage: Thrips feed in and on the blossoms. They make numerous, very shallow punctures on tender parts of the flowers from which they suck out plant juices. Injured blossoms drop off or the young berries may remain hard and brown, and fail to grow. Damage is more prevalent during dry seasons.

Identification: Thrips are tiny, cigar-shaped insects that feed on flower parts. Several species occasionally infest the flowers of strawberries. The adults are slender, winged, about 1/25 inch long, and orange or yellow. Young thrips are smaller, wingless, yellowish, and active.

Life Cycle: Thrips breed on grasses and weeds in spring, moving to strawberries at blooming time. They insert their eggs in plant tissue at the base of flowers and in tender, new foliage.

Monitoring and Controls: Thrips can be easily scouted by placing 10 blossoms in a small, resealable plastic bag and counting the thrips. Fewer than 100 thrips (10 per blossom) are not thought to cause significant losses. Sprays should be applied during the prebloom period or during the night to minimize toxicity to bees and in a manner to optimize coverage. Thrips seldom become so abundant that control is required. A heavy infestation is necessary to reduce the set of fruit. If infestations are severe, an insecticide application may be needed. Growers who use insecticides to control tarnished plant bug or strawberry clipper typically have not had crops that have been affected by thrips.

Sowbugs/Pillbugs (Arthropoda: Crustacea)

Symptoms of Damage: Sowbugs typically are not a problem in strawberry production, feeding on dead or decaying organic matter only. However, within the region sowbugs have been observed as pests in high tunnel culture or in field production where an organic matter source may have transported large populations of sowbugs into the planting. Sowbugs burrow into and feed on strawberry fruit, typically where it is in contact with the ground. To date, there have been no reported problems of sowbugs girdling plants, though this has been reported with other crops.

Identification: Sowbugs and pillbugs are up to ¾ inch long, and have an elongated oval shape and no wings. They are commonly a grayish brown, though the shade varies. Their bodies consist of a overlapping plates, and they have seven pairs of legs. They are frequently found in damp places hiding underneath mulch, dead foliage, or any object that provides cover. Pillbugs can roll up completely into a little ball when disturbed, while sowbugs can only partially curl up.

Life Cycle: Individuals can live up to three years and reproduce at any time of the year but most commonly in the spring. There can be one or two generations per year. The female has a brood pouch on her underside in which she carries eggs for 3 to 7 weeks and young for an additional 6 to 8 weeks.

Monitoring and Controls: Removal of hiding place and minimizing use of mulches may be necessary. Allowing the soil to dry out to the extent possible between plantings may help, as these creatures require high moisture levels because they are crusteaceans and breathe with gills. In high tunnels, removing the plastic covering for the winter may help, thus allowing the soil to freeze. Sluggo Plus, a bait with active ingredients of iron phosphate and spinosad, appears to give fairly good control.

Strawberry Bud Weevil or Strawberry Clipper, Anthonomus signatus *(Coleoptera: Curculionidae)*

Symptoms of Damage: The stems of fruit buds are girdled and clipped by the weevil, and the buds are left dangling in midair or lying on the ground. Flower petals may have a shot-hole appearance when they open due to adult clippers feeding on pollen through the sides of the blossoms prior to their opening. Damage is generally worse in rows near the woods. Some cultivars may compensate for clipper damage to primary berries by increasing size of later fruit.

Identification: This dark reddish-brown weevil is about 1/10 inch long, with the head prolonged into a slender, curved snout about half as long as the body. Its back has two large black spots.

Life Cycle: Adults overwinter in fence rows and woodlots. They move into strawberry fields around the end of April and feed on immature pollen. The female deposits a single egg inside nearly mature flower buds, then girdles the bud and clips its stem so it hangs by a thread or falls to the ground. This process provides shelter for the egg and developing larvae. The eggs hatch in about a week into white, legless grubs, which mature in 3 or 4 weeks. Adult weevils emerge from the buds in June, feed on the pollen of various flowers, and then seek hibernating sites in midsummer. Weevils remain in these sites until the following spring. Only one brood appears each year.

Monitoring and Controls: Mulches and full canopies may appeal to emerged adults, encouraging them to remain in the field, which causes successively more damage in succeeding years. Harvesting crops from a field for less than 3 years, mowing leaves at renovation, and plowing under old beds immediately after harvest help lessen the chances of clipper damage. Starting shortly after flower bud emergence when temperatures are above 65°F, growers should check their fields carefully for the first signs of clipped buds and perforated flower petals. Scouting should continue at least weekly until most flower buds have opened. Pay particular attention to fields near woods and hedgerows.

Sample five separate 10-foot sections. Count the number of clipped buds, noting whether they are still fresh and green or turned brown. Newly cut buds mean the weevils are still active. Divide the total number of freshly cut buds observed by the total number of linear row feet inspected. If more than one freshly cut bud per linear row foot is found, a pesticide treatment is justified (see Table 6.16 for specific recommendations). Treatment of only the field border rows may be sufficient in some instances. If a spray application is made, check again 7 days later. If one live clipper or one freshly cut bud per foot of row is found, a second application may be needed. Established fields with no history of clipper injury or new plantings may need either no clipper control or only one well-timed spray when the above threshold is reached.

Ground Beetles, Harpalus *spp. and other species (Coleoptera: Carabidae)*

Symptoms of Damage: These insects are normally considered beneficial because they attack and feed on such destructive pests as cutworms and armyworms. However, they will attack ripening strawberries lying on the ground. The skin of the injured fruit is broken and the entire surface is eaten on some berries. Examining the injured berries under a dissecting scope indicates that the beetles feed primarily on strawberry seeds.

Identification: Ground beetles are hard shelled, black or brown beetles with nocturnal habits. During the day they may be found under rocks and other objects.

Life Cycle: There are many species of ground beetles, with little known about their life cycles in general.

Monitoring and Controls: Damage by these insects is rare, so controls are not generally recommended just for this pest, nor is routine monitoring needed. However, the symptoms of damage are puzzling when they appear.

Foliage Feeders

Leafhoppers (Homoptera: Cicadellidae)

Symptoms of Damage: Leafhoppers are sucking insects that remove nutrients from plants with their needlelike mouth parts. Potato leafhopper adults and nymphs feed along veins on the undersides of strawberry leaves. While feeding, they plug the sap-conducting vessels, causing the leaves to become curled, stunted, and yellowed. Young plants suffer the most, with injury resulting in short petioles and small, distorted leaves that bend down at right angles. With potato leafhopper damage, the leaves have roughly triangular, chlorotic (yellowed) blotches at the leaf edges.

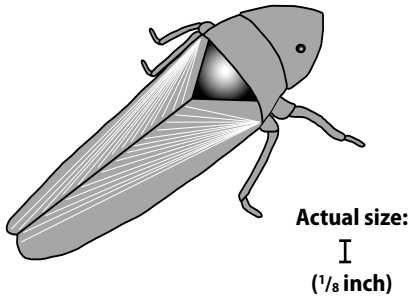


Figure 6.7. Potato leafhopper adult.

Identification: Adults are brownish to green insects about 1/8 inch long. With strawberries, the potato leafhopper, *Empoasca fabae* (Harris), is the most common problem species (Figure 6.7). Adults fly quickly when disturbed. Young nymphs are tiny, light green, and easily identified by the habit of moving sideways.

Life Cycle: Potato leafhoppers are migratory and arrive in the Mid-Atlantic region from their southern overwintering grounds sometime in May. The timing of migration relies on the movement of weather fronts. Leafhoppers attack a wide range of plant species that include several fruits.

Monitoring and Controls: Increased pressure from leafhoppers in strawberries may be observed after the surrounding vegetation has been harvested or mowed. Apply an insecticide if leafhoppers become a problem.

Spider Mites, Tetranychus *spp. (Acari: Tetranychidae)*

Symptoms of Damage: At low populations, a slight amount of fine stippling of the lower leaves is present. Heavily infested fields lose their healthy green color and take on a dusty appearance, sometimes described as "bronzing." Feeding and egg deposition occur on the undersides of leaves, and fine webbing may appear there. Because the mites suck sap from the leaves and can interfere with normal physiological processes such as sugar production, plants may become stunted and yield may be greatly reduced. Since mites are small and feed on the undersides of leaves, they may be overlooked until the population is so large that serious damage has occurred.

Identification: The eight-legged adult, about 1/50 inch in length, varies in color from pale greenish yellow to green and is usually marked with two dark spots. With the aid of a magnifying lens, nearly clear spherical mite eggs can also be seen.

Life Cycle: These mites overwinter as mature, fertile females in protected places in the field. The length of the life cycle varies with seasonal and weather conditions but may be completed in about 2 weeks. Reproduction may be continuous from early spring until late fall. The female lays two to six eggs per day up to about 70 eggs per mite. Eggs hatch in about 4 days, so there can be 10 to 15 generations per year. Hot, dry weather favors rapid population increases.

Monitoring and Controls: Starting in the spring as soon as mulch or row covers are removed, examine the undersides of leaves weekly for mites using a 10x hand lens. Overwintered twospotted spider mites will be reddish orange in color. Removing dead leaves early in the spring helps with control. Plasticulture plantings should also be checked before row covers are applied in the fall since the protected warm environment under the row covers allows spider mite populations to survive well over the winter. Spider mites have many natural enemies that often keep them in check, including insects and other mites. Insecticide treatments often cause spider mite outbreaks by destroying these natural enemies.

Commercially available mite predators provide excellent control of twospotted mite populations if released while spider mite populations are low. Cultural practices such as annual reno-

vation of strawberry beds reduces the potential for twospotted mite outbreaks. Cultivars vary in their tolerance or resistance to mites. Honeoye is especially susceptible, as is Mesabi. Local growing conditions greatly influence resistance. If more than 25 percent of inspected leaves have mites present, a sharp population rise is noted, or if plant symptoms worsen, then a miticide is needed. When applying miticides, thorough coverage is a must, so use plenty of water (at least 100 gallons per acre) and pressure high enough to treat the undersides of the leaves. To help manage resistance, miticides with different modes of action should be alternated during subsequent applications. Because these mites can be borne by the wind in their silken webbing, newly planted fields can become quickly infested. In certain fields or areas within fields, "hot spots" of mite activity may develop. Early treatment of hot spots may be sufficient for control.

Strawberry Whitefly, Trialeurodes packardi *(Homoptera: Aleyrodidae)*

Symptoms of Damage: The nymphs secrete a sweet, sticky substance known as honeydew, which collects on the leaves and serves as an ideal medium for the growth of sooty mold. This fungal growth gives the plants a black appearance and the foliage may lose vitality and decay. In addition, honeydew on leaves during harvest can result in an unpleasant stickiness.

Insect Identification: The adult is a small (1/16 inch), white, four-winged flylike insect.

Life Cycle: This species overwinters as an egg attached to the underside of a leaf by a short stalk. The egg hatches into a pale-green, louselike insect that crawls over the leaf, punctures it with its bristlelike mouthparts, and feeds on the sap. It soon takes on the appearance of a scale insect. About a month after egg hatch, the adult emerges to begin a new brood. The insects are often most abundant later in the season.

Monitoring and Controls: If nymphs are abundant in the spring, a need for control is indicated. The insecticidal soap M-Pede provides effective control of whitefly populations without seriously disturbing the natural enemy complex.

Strawberry Rootworm, Paria fragariae *(Coleoptera: Chrysomelidae)*

Symptoms of Damage: The most severe damage is caused by adult beetles eating holes in the leaves. When adults become abundant, leaves are riddled with holes and plants are sometimes killed. The larvae eat the rootlets. Heavy infestations reduce plant growth and runner formation.

Insect Identification: The strawberry rootworm is a shiny, oval beetle, usually brown varying to black, with four darker blotches on the wing covers. It is slightly more than 1/8 inch in length.

Life Cycle: The beetles hibernate under mulch, in crevices in soil, or in other protected places. They begin feeding and laying eggs when warm weather arrives. Feeding punctures have been observed in May and gradually grow more numerous until mid-June. Eggs are laid during this period on older leaves near the ground. As the larvae hatch, they burrow into the ground up to 6 inches, where they feed on plant roots for about 2 months. Adults of the first generation have been observed in July, with continued emergence throughout August. The newly emerged beetles feed extensively on the foliage of strawberries in early fall.

Monitoring and Controls: To be sure that this pest is the one causing leaf perforation, examine the field after dark with a flashlight. Populations are easier to detect from mid-July into the fall. Ten to twenty beetles per square foot is considered quite high. Foliar feeding in late summer and fall is usually more severe than that observed in spring.

Flea Beetle, Altica ignita *(Coleoptera: Chrysomelidae)*

Symptoms of Damage: Adults and larvae feed on leaves, flowers, and young fruit, but the symptom most frequently noticed is damaged leaves riddled with small holes.

Insect Identification: The adults are shiny, greenish metallic bronze jumping beetles about 1/6 inch long. Mature larvae are hairy, about 3/16 inch long, and dull yellowish to dark olive green.

Life Cycle: The adults hibernate in winter and appear in spring to lay eggs on strawberry foliage. One generation of these insects occurs in a year in northern regions; two generations occur in southern regions. They are not usually seen during hot weather but appear with cool weather in the fall.

Monitoring and Controls: Practicing clean culture is important because the beetles prefer to feed and breed on certain weeds.

Strawberry Leafroller, Ancylis comptana fragariae*, and Other Leafrollers (Lepidoptera: Tortricidae)*

Symptoms of Damage: In the early stages, a larva may feed on either side of a leaf. As the larva becomes larger, it usually feeds on the upper surface. Here, by means of fine, silken threads, it folds the leaflet at the midrib and feeds inside this enclosure. Only the epidermis of the leaf is eaten, but continuous feeding causes the entire leaflet to turn brown and die. Sometimes two adjacent leaflets are tied together and, in heavy infestations, an entire leaf or even several leaves may be webbed together. Sometimes newly formed leaves are attacked and webbed together before they unfold. This type of damage may be seen during late May and in June when first-generation larvae are abundant. The same damage is caused by larvae of the second generation in late July and August.

Insect Identification: The adults are reddish-brown moths that have a wingspread of about ½ inch. Strawberry leafrollers are the caterpillars (larvae) of moths. Young larvae are usually pale green but change to gray brown as they become fully grown, reaching about ½ inch long. No special markings or distinguishing characteristics are present. Larvae change into yellowish-brown pupae, which remain inside the folded leaf until ready to emerge as moths. Other leafrollers such as the oblique-banded and the variegated leafroller may also be a problem.

Life Cycle: Two or more generations may occur each year. The time required for the second generation to complete its development is somewhat shorter than that of the first generation because of higher daily temperatures. First-generation moths are active from about April to June, and second- and third-generation moths are present from July

through late September. First-generation moths deposit small, translucent eggs on the foliage of strawberries, usually on the undersides, about mid-May.

Monitoring and Controls: Strawberry leafrollers are very susceptible to attack by various hymenopterous and dipterous parasites, which usually keep their populations below economic levels. Although these parasites vary greatly in abundance from season to season, they have been responsible for controlling leafrollers when there are two or fewer larvae per plant. This insect rarely causes serious damage in the region. If insecticides are needed, apply during the early larval stages, usually mid- to late May. Products containing *Bacillus thuringiensis* (e.g., Dipel) provide good control of young larvae, do not disturb the natural enemy complex, and are safe for bees. Good coverage is critical for *Bacillus thuringiensis* products to be effective.

Japanese Beetle, Popillia japonica Newman *(Coleoptera: Scarabaeidae)*

Symptoms of Damage: Adults are typically only a concern when foliage feeding reaches high levels on June-bearing plants since the beetles typically are not found in high numbers until after the harvest season has passed. However, on day-neutral strawberries, Japanese beetles have bored into green fruit, causing up to 40 percent loss on individual harvest dates. A well-known pest of fruits and ornamentals, Japanese beetles feed on more than 275 host plants. Adults that fall into harvest containers burrow toward the bottom of the container and can be found as nuisance insects in the sold product. Larvae cause damage to roots as part of the white grub complex (see below).

Identification: Adults are just under ½ inch long and are metallic green to bronze with some coppery red color on the wings. Larvae are C-shaped, white grubs that feed on the root system.

Life Cycle: One generation occurs per year. Grubs that overwinter in the soil pupate in late May with adults emerging from mid-June through mid-July. Adults will live for 30 to 45 days and can be found throughout the summer. Females lay approximately 50 eggs in the soil, which hatch after 2 weeks. Larvae feed on roots until the soil temperatures cool and then remain dormant until spring.

Monitoring and Controls: When numerous, adults can be controlled with the use of broad-spectrum insecticides, though growers should watch for spikes in twospotted spider mite populations following application. Entomopathogenic nematodes are effective for larvae, but they have a limited shelf life and must be applied strictly according to directions.

Stem and Crown Feeders

Meadow Spittlebug, Philaenus spumarius *(Homoptera: Cercopidae)*

Symptoms of Damage: Most noticeable are spittle masses on plants that can deter harvesters. The spittle masses first appear on the stems and leaves at about the time of bloom. Spittlebugs have sharp beaks, which they use to pierce the stems of plants and suck the plant juices. Feeding activities of large numbers of these insects cause plants to become stunted and berries to fail to attain full size.

Insect Identification: Meadow spittlebug nymphs are small, orange to green insects enclosed in white, frothy, irregular masses ½ inch or more in diameter.

Life Cycle: The insect overwinters as an egg. Nymphs appear in May or June and complete their development in 5 to 8 weeks. The insects first feed at the base of the plants but later move up to the more tender foliage. Egg laying occurs primarily during September and October. Eggs are inserted into the lower parts of the strawberry plant. Only one generation appears each year.

Monitoring and Controls: Control may be indicated if nymphs (without frothy masses) are present when the first blossom clusters separate. An insecticide spray may be applied before bloom when two or more spittle masses are found per foot of row. Weedy fields are more heavily attacked.

Cyclamen Mite, Steneotarsonemus pallidus *(Acari: Tarsonemidae)*

Symptoms of Damage: The cyclamen mite feeds on the young, unfolding leaves in the crown of the plant, which causes them to appear stunted, crinkled, and malformed when they emerge. A damaged plant takes on a characteristically "flat" appearance. Foliar symptoms are sometimes mistaken for herbicide damage. Later, the mite feeds on the blossoms and causes a distortion of the fruits. Infested plants usually become unproductive within a season.

Insect Identification: This mite is so tiny ($^{1}/_{100}$ of an inch) that it is nearly invisible to the unaided eye. Magnification at 20x or greater eases identification. The cyclamen mite is white to caramel colored in its adult stage and milky white in its immature stage. Eggs are clear and oval shaped.

Life Cycle: Adult females overwinter in crowns and at the bases of petioles of leaves. Immature development may be completed in less than 2 weeks, making a rapid population increase possible. Populations begin to rise in April when blossoming starts and peak during fruiting. A sharp decline occurs during July and August, and a second lower peak occurs near the end of September.

Monitoring and Controls: Cyclamen mites may be killed by hot, dry summers in some areas and may also be held in check by predators. In establishing a new planting, using plants free of cyclamen mites is important. After the mite becomes established, control is difficult and may be more of a problem in plantings maintained over longer periods of time. Localized populations of this pest can be spot treated with pesticides. Use high water volumes (200 gallons per acre) when spraying. Use of some broad-spectrum insecticides may cause increases in cyclamen mite populations by killing their predators.

Strawberry Aphid, Chaetosiphon *spp. (Homoptera: Aphididae)*

Symptoms of Damage: Heavy feeding can cause leaf distortion; however, virus transmission is the main concern. Aphids suck the nutrient-rich juices from plants and cause weak vegetative growth and lower yields. While feeding, aphids excrete large quantities of honeydew, similar to whiteflies.

Insect Identification: Aphids are small, slow-moving, green insects. Winged forms are found in the spring and fall.

Life Cycle: Aphids pass the winter on the undersides of old leaves lying on the soil. Winged forms first appear in spring and may be found through May and June. Wingless females, the most common form, are white at first and later become greenish white to yellow. During the growing season most aphids are found feeding on new shoots and buds, the undersides of young leaves, and petioles.

Monitoring and Controls: Because virus transmission is the main concern, eliminate all wild strawberries from fence rows and neighboring fields. Look for signs of aphid activity on the undersides of young leaves and new shoots in spring, after harvest, and in the fall. Where virus diseases are a problem, aphids should be controlled.

Root Feeders

Garden Symphylan, Scutigerella immaculata *(Symphyla)*

Symptoms of Damage: Garden symphylans feed on the roots of strawberry plants, weakening or killing them. Infestations seldom encompass an entire field but rather involve one or more small areas. Usually, the first indication of a symphylan infestation is a small area of stunted, unhealthy plants. Crop losses continue in the same area of the field year after year, with the infected area increasing in size by about 10 to 20 feet each year.

Insect Identification: Symphylans are not insects but are more closely related to centipedes and millipedes. Symphylans have 12 pairs of legs and 14 body segments. Mature symphylans are white, slightly less than ¼ inch in length, and have a pair of long, beaded antennae.

Life Cycle: Symphylans overwinter in the soil as adults. In spring they move into the top 6 inches when the soil temperature rises above 45°F. Eggs are deposited in soil crevices and tunnels in late April, May, and June. The eggs hatch 2 to 3 weeks later into tiny, white nymphs that resemble the adults in appearance except that they have only 6 pairs of legs. As the nymphs develop, they grow bigger and add a pair of legs at each molt until they have 12 pairs. Development from egg to adult requires about 3 months. The adults remain in the upper 6 inches of soil until extreme dryness or cold weather drives them deeper into the soil. Their entire life cycle (1 to 2 years) is spent in the soil.

Monitoring and Controls: Controlling symphylans before or at the time of planting is best. To check for symphylans, turn over at least 10 shovelfuls of soil. Sift the soil while looking for active symphylans. An average of one symphylan per shovelful signals that a treatment is necessary before planting. If symphylans are abundant, an insecticide should be broadcast and incorporated into the soil of the infested area before planting takes place.

Root Weevils (Coleoptera: Curculionidae)

Symptoms of Damage: Adults of all species eat notches in the leaves, but this injury is not significantly detrimental to the plant. Larval or grub feeding on the roots is highly destructive to plants from midsummer through fall and into early spring. At first grubs feed on feeder roots and then move early in spring to the large roots, sometimes completely girdling them. Injured plants look stunted and darker, and symptoms on above-ground portions can look similar to those that might be caused by a root rot.

Insect Identification: Several species of root weevils attack strawberries. In the Mid-Atlantic region, the species most frequently cited is the black vine weevil *(Otiorhynchus sulcatus* Fabricius), but the strawberry root weevil *(O. ovatus* L.) and rough strawberry root weevil *(O. rugostriatus* Goeze) are also implicated. Green leaf weevils have been present in large numbers in a few areas, mostly in northwestern Pennsylvania or in fields bordered by woods. Adults of black vine weevil are black, flightless, about 3/8 inch long, and have a pronounced nose or snout. The black vine weevil has small golden tufts of scales on its pitted wing covers. All adults are females and are active night feeders. When disturbed they drop quickly to the ground. During daylight hours adults hide in dark places on stems of very dense plants or in ground litter and mulch. Strawberry root weevil and rough strawberry root weevil are also black and vary from 3/16 to 3/8 inch in length. Green leaf weevils, which are small and metallic green, differ from the species of root weevils listed above in that adults can fly and are active during the day. Root weevil larvae have no legs, distinguishing them from white grubs, which have three pairs.

Life Cycle: Black vine weevils overwinter in the soil as immature, legless, ¼- to ½-inch long, C-shaped white grubs. Mature grubs form resting (pupal) cells in the soil in early spring. Adults usually emerge during late May through mid-June. Black vine weevils require 30 to 60 days to feed on foliage before producing as many as 500 eggs over a period of 14 to 21 days in July and August. Eggs are laid in the soil near the bases of host plants. They hatch in 10 to 14 days into small, white grubs that feed until fall temperatures drive them deeper into the soil, where they overwinter. Only one generation of the pest occurs per year in the region, though some adults may survive the winter and continue to lay eggs.

Monitoring and Controls: Sprays may be directed toward adults while they are feeding aboveground but before egg laying commences; however, this is seldom completely effective. Evening sprays are more likely to be effective. Old plantings may be destroyed and plowed under, but to avoid mass migration of adults to new fields, leave a row or two of the old planting as a trap crop in which the adults can lay their eggs. Then plow under these rows in late fall or early winter and plant rye. Recently, thiamethoxam became available to control larvae, but control has varied, perhaps due to uncertainty concerning the most effective time to apply the material. Insecticidal nematodes may be used for controlling root weevils on strawberries. *Heterorhabditis bacteriophora* and *Heterorhabditis marelatus* have been used successfully against black vine weevil larvae feeding on strawberry crowns and roots. Insecticidal nematodes must be protected from extreme air and soil temperatures (soil temperatures should be between 60 and 85°F) and they require moist soil (irrigate before and after applying) to obtain larval control. Failing to follow package recommendations may result in little or no control.

White Grubs (Coleoptera: Scarabaeidae)

Symptoms of Damage: Damage is most likely to occur when strawberries are planted on newly plowed sod that had been infested with grubs. Grubs feed on the roots of strawberry plants and either kill or severely weaken them. The most severe damage usually occurs between the time of planting and runner development.

Insect Identification: White grubs can be the larvae of Japanese beetles, Oriental beetles, and May beetles or "June bugs." See the description above for Japanese beetles, and Oriental beetle in the blueberry chapter for identification of those species. Larvae of May beetles are large, thick bodied, and dirty white. When fully grown, they range from about 1 to 1½ inches in length. When dug from the ground, the larvae always lie in a curved position that forms the letter "C." May beetles are dark brown and vary from ½ to 7/8 inch in length. They are often attracted to lights and can sometimes be seen in considerable numbers around street lights during May. The beetles remain concealed near the soil during the day, but at dusk they emerge and fly to ornamental and forest trees to feed. They return to the soil just before dawn.

Life Cycle: Eggs are deposited 1 to several inches deep in the soil. They are apparently deposited most abundantly in sod that has not been disturbed for years, although they occur in almost any soil porous enough to permit female beetles to crawl into it. Eggs hatch in 2 to 4 weeks. Tiny larvae feed largely on vegetable matter in the soil for the rest of the first season. When cold weather comes, most species of white grubs burrow below the frost line and remain there until the following spring. Grubs spend all of the next summer feeding on the roots of plants. Depending on species, the life cycle may be complete in one year or as many as three.

Monitoring and Controls: Avoid planting strawberries on newly plowed grassland. Danger of insect damage can be reduced by rotating crops and cleanly cultivating the crop that precedes strawberries. If necessary, a soil treatment of insecticide may be used, especially on land recently in sod.

Strawberry Root Aphid, Aphis forbesi *(Homoptera: Aphididae)*

Symptoms of Damage: Infested plants are characterized by a lack of vigor, unnaturally pale foliage, and immature or desiccated fruit. Second-year plants rarely suffer as much damage as new plantings because they are well established and have many more roots to support the population.

Insect Identification: Bluish-green insects feeding on new leaves or roots.

Life Cycle: In autumn, females deposit their shiny black eggs on the stems and leaves of strawberry plants. The eggs hatch early the following spring and the young, bluish-green nymphs feed on newly developed strawberry leaves. When the aphids become abundant, they are soon found by ants, which carry them to strawberry roots. Here the aphids feed by sucking the sap from root tissues. The ants also take aphids from one plant to another, thus spreading the infestation. In return the ants feed on a sugary excretion produced by the aphids. A number of generations of wingless females are produced during the summer. Under favorable conditions, growth may be completed in as little as 2 weeks, after which the females are soon capable of giving birth to 50 or more living young. When cold weather approaches in the fall, winged forms again appear and move from the roots to the foliage.

Monitoring and Controls: When preparing ground for a new strawberry planting, make a thorough and deep cultivation early in the spring to help destroy ant colonies. This will reduce the chances of a root aphid infestation. Other cultural practices include not planting strawberries in light sandy soil after corn or melons, keeping plants in a vigorous growing condition and irrigating if possible, practicing rotation, and destroying infested strawberry beds and volunteer plants.

(Text continued on p. 102)

Table 6.14. Activity groups and effectiveness of fungicides for strawberry disease control.

Not all fungicides listed below are labeled for all the diseases listed. This table is intended to provide information on effectiveness for diseases that appear on the label, plus additional diseases that may be controlled from application. See Table 6.16 for labeled uses. Products that are mixes of two active ingredients contained in products below are not listed; activity would be expected to be similar to that of a tank mix if rates of active ingredient applied are similar to those that would be applied in a tank mix.

Fungicide	Activity Group[a]	Phomopsis Leaf Blight	Leaf Spot	Leaf Scorch	Angular Leaf Spot	Powdery Mildew	Gray Mold	Anthracnose Fruit Rot	Leather Rot
Abound	11	+[b]	+	—	0	++	+	++	+++
Aliette	33	0	0	—	0	0	0	0	+++
Cabrio	11	++	++	++	0	++	++	+++	+++
Captan	M	++	++	++	0	0	++	++	+
Captevate	17+M	+	+	++	0	0	+++	++	+
Copper	M	0	0	0	+	0	0	0	0
Elevate	17	0	0	—	0	0	+++	0	0
Evito	11	—	—	—	—	++	—	++	—
Flint	11	—	—	—	—	++	—	—	—
Orbit, Tilt	3	—	++	—	0	+++	0	0	0
Ph-D	19	—	—	—	—	—	+	—	—
Phostrol	33	0	0	—	0	0	0	0	+++
Pristine	7+11	++	+++	+++	0	+++	+++	+++	+++
Procure	3	—	0	—	0	+++	0	0	0
Quintec	13	0	0	—	0	+++	0	0	0
Rally	3	+++	++	+++	0	+++	0	0	0
Ridomil Gold	4	0	0	0	0	0	0	0	+++
Rovral	2	+	+	+	0	0	+++	0	0
Scala	9	0	0	—	0	0	+++	0	0
Syllit	M	++	++	++	0	—	—	—	—
Switch	9+12	0	+	++	0	0	++	++	0
Thiram	M	++	++	++	0	0	++	+	+
Topsin-M	1	++	++	+++	0	+++	+++	0	0

a. Chemistry of fungicides by activity groups: 1 = benzimidazoles and thiophanates; 2 = dicarboximides; 3 = demethylation inhibitors (includes triazoles); 4 = acylalanines; 7 = carboxamides; 9 = anilinopyrimidines; 11 = strobilurins; 12 = phenylpyrroles; 13 = quinolines; 17 = hydroxyanilides; 19 = polyoxins; 33 = unknown (phosphonates); M = chemical groups with multisite activity. Fungicides with two activity groups listed contain active ingredients from two activity groups.

b. 0 = not effective; + = slight effectiveness; ++ = moderate effectiveness; +++ = very effective; — = insufficient data.

This table is modified from Table 6, Fungicide Effectiveness for Strawberry Disease Control, in the *2012 Midwest Commercial Small Fruit and Grape Spray Guide.*

Table 6.15. Activity groups and effectiveness of insecticides, miticides, and molluscides on strawberry pests.

Not all insecticides listed below are labeled for all the insects listed. This table is intended to provide information on effectiveness against insects that appear on the label, plus additional insects that may be controlled from application. See Table 6.16 for labeled uses. Products that are mixes of two active ingredients contained in products below are not listed; activity would be expected to be similar to that of a tank mix if rates of active ingredient applied are similar to those that would be applied in a tank mix.

Pesticide	Activity Group[a]	Aphids	Clipper	Cyclamen Mite	Leaf-hoppers	Leaf-rollers	Adult Root Weevils	Slugs	Sap Beetles	Spider Mites	Spittle-bug	Spotted Wing Drosophila	Tarnished Plant Bug	White Grubs
Acramite	un	—[b]	—	—	—	—	—	—	—	+++	—	—	—	—
Actara	4A	+++	—	—	+++	—	—	—	—	—	—	—	++[c]	—
Admire Pro	4A	+++	—	++	+++	—	—	—	—	—	—	—	—	+++
AgriMek	6	—	—	++	++	—	—	—	—	++	—	—	—	
Assail	4A	++	—	—	+++	+	—	—	+	—	—	—	++	—
Aza-Direct	un	—	—	—	+	+	—	—	—	—	—	—	—	—
Brigade	3	+++	+++	—	++	++	++	—	+++	+	+++	+++	+++	—
Coragen	28	—	—	—	—	+++	—	—	—	—	—	—	—	—
Courier	16	—	—	—	+	—	—	—	—	—	—	—	—	—
Danitol	3	++	+++	—	++	++	++	—	++	+	+++	+++	+++	—
Deadline	—	—	—	—	—	—	—	+++	—	—	—	—	—	—
Diazinon	1B	+++	—	+	+	++	+	—	++	+	++	+++	+	++
Dibrom	1B	++	—	—	—	—	—	—	++	—	—	—	—	—
Dipel	11	—	—	—	—	++	—	—	—	—	—	—	—	—
Esteem	7	++	—	—	—	++	—	—	—	—	—	—	—	—
Intrepid	18	—	—	—	—	+++	—	—	—	—	—	—	—	—
Kanemite	20	—	—	++	—	—	—	—	—	++	—	—	—	—
Kelthane	un	—	—	++	—	—	—	—	—	++	—	—	—	—
Lorsban	1B	++	+++	—	—	++	—	—	—	—	—	—	++	++
Malathion	1B	+++	—	—	++	—	—	—	+	—	++	+++	++	—
M-Pede	—	++	—	—	—	—	—	—	—	+	—	—	—	—
Oberon	23	—	—	—	—	—	—	—	—	++	—	—	—	—
Platinum	4A	+++	—	—	+++	—	—	—	—	—	—	—	—	—
Portal	21	—	—	+++	—	—	—	—	—	+++	—	—	—	—
Provado	4A	+++	—	—	+++	—	—	—	—	—	—	—	—	—
Pyganic	3	+	—	—	—	—	—	—	—	—	—	++	—	—
Radiant	5	—	—	—	—	+++	—	—	—	—	—	—	—	—
Rimon	15	—	—	—	—	+++	—	—	+	—	—	—	—	—
Savey	10	—	—	—	—	—	—	—	—	+++[d]	—	—	—	—
Sevin	1A	+++	+	—	++	+	—	—	++	—	++	+	++	—
Sluggo	—	—	—	—	—	—	—	+++	—	—	—	—	—	—
Spintor, Entrust, Success	5	—	—	—	—	+++	—	—	—	—	—	+++	—	—
Synapse	28	—	—	—	—	+++	—	—	—	—	—	—	—	—
Thionex	2A	+++	0	+++	++	+	—	—	+	—	+++	+	+++	—
Vendex	12B	—	—	—	—	—	—	—	—	++	—	—	—	—
Zeal	10	—	—	—	—	—	—	—	—	+++[d]	—	—	—	—

This table is modified from Table 7: Effectiveness of Pesticides for Control of Strawberry Insects and Mites in the *2012 Midwest Commercial Small Fruit and Grape Spray Guide.*

a. Chemical activity group or subgroup: 1A = carbamates; 1B = organophosphates; 2A = chlorinated cyclodienes; 3 = pyrethrins and synthetic pyrethroids; 4A = neonicotinoids; 5 = spinosyns; 6 = avermectins; 7 = juvenile hormone mimics; 10 = mite growth inhibitors with unknown or nonspecific sites of action; 11 = Bt microbials; 12B = organotin miticides; 15 = benzoylureas; 16 = chitin biosynthesis Inhibitor, type 1;18 = ecdysone agonists/molting disruptors; 20 = Site II electron transport inhibitors; 21 = Mitochondrial complex I electron transport inhibitors; 23 = lipid synthesis inhibitors; 28 = anthranilic diamides; un = unknown mode of action.

b. 0 = not effective; + = slight effectiveness; ++ = moderate effectiveness; +++ = very effective; — indicates that insufficient data exists to rank effectiveness of this insecticide or miticide on these pests.

c. Moderate effect on nymphs, but little or no effect on adults.

d. Effective on eggs and immatures, but has little or no effect on adults.

Table 6.16. Pesticides for strawberry disease and insect control.

Note: The recommendations below are correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. If control cannot be achieved with a particular material, it is possible that resistant populations exist. Use a material in a different activity group, which will have a different mode of action. See Table 3.2 for use status, chemical names of active ingredients, and reentry intervals. See Table 3.1 for toxicity to nontarget organisms, and Tables 6.14 and 6.15 for activity groups and efficacy ratings to help determine products that best suit your situation. See Table 6.17 for other use restrictions such as quantity allowable per season. Information was current as of July 1, 2012.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
BEFORE PLANTING		
Insects		
White grubs	These subterranean arthropod pests should be controlled before planting. Never plant strawberries in newly turned earth, especially after sod. Before planting strawberries, plant nonpreferred cover crop for two years, or apply insecticide. Do not apply Lorsban after berries start to form or when berries are present.	Lorsban 4E, 2 qt (prebloom, 21)
Root weevil (larvae)	Parasitic nematodes *(Heterorhabditis bacteriophora)* should be applied during evening or early morning, and when soil is moist to increase likelihood of successful colonization.	Parasitic nematodes, 1–2 billion per acre
Nematodes		
Dagger or lesion nematodes	No nematicides are available for sale as of this writing. Sales of Nemacur were prohibited after May 31, 2008. Existing stock may be used until depleted. Fumigation can also be used for control. See Chapter 3 and discussion in this chapter for additional information.	
AT PLANTING		
Diseases		
Red stele	As a preplant dip of the crowns and roots for 15–30 minutes. Plant within 24 hours after dipping.	Aliette WDG, 2.5 lbs/100 gal of solution (0.5), ***or*** Phostrol, 2.5 pt/100 gal of solution (—)
Insects		
Aphids, whiteflies, grubs, strawberry root weevil, leafhoppers	Just prior to or during transplanting as a plant material or plant hole treatment. Admire and Platinum are systemic. See label for additional information.	Admire Pro, 10.5–14 fl oz (14), ***or*** Platinum, 5.0–12.0 fl oz (50)
ESTABLISHMENT YEAR		
Diseases		
Leaf spot	As symptoms appear. Fungicides applied for common leaf spot may assist with control of other leaf spotting diseases such as scorch and blight. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides. Note that for products containing captan, the REI is 24 hr.	Captan 50W, 3–6 lb (0) or Captec 4L, 1.5–3 qt (0), ***or*** Rally 40W, 2.5–5.0 oz (0), ***or*** Cabrio EG, 12–14 oz (0), ***or*** Pristine[a], 18.5–23 oz (0)
Leaf blight	As symptoms appear. Few fungicides are labeled for this use. Fungicides applied for leaf spot may give some control.	Rally 40W, 2.5–5.0 oz (0)
Powdery mildew	As symptoms appear. See footnote "b" below concerning severe toxicity of Abound to McIntosh, Gala, and related apple cultivars. Abound, Cabrio, and one of the active ingredients in Pristine are in the same chemical class, and cannot be rotated with each other for resistance management purposes. Do not make more than two sequential applications of fungicides from this activity group. See fungicide efficacy table for classes of fungicides.	Abound[b], 6.2–15.4 oz (0), ***or*** Cabrio EG, 12–14 oz (0), ***or*** Rally 40W, 2.5–5.0 oz (0), ***or*** Pristine[a], 18.5–23 oz (0), ***or*** Procure 480SC, 4–8 fl oz (1), ***or*** Evito 480SC, 2.0–5.7 fl oz (1), ***or*** Flint, 2.0–3.2 fl oz (0), ***or*** Quintec, 4–6 fl oz (1), ***or*** Orbit, 4 fl oz (0), ***or*** Tilt, 4 fl oz (0)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Insects and Mites (unless blossoms have not been removed and are open)		
Spider mites	Savey and Zeal are effective on eggs and immatures, but not adults, and therefore must be used when mite populations are low. Brigade and Danitol are also labeled for spider mites but must be used at high rates with good coverage when applied for spider mites, or they may decrease predatory mite numbers without controlling spider mites. Releases of predatory mites can also give good results. See text for additional information on this subject, and Table 3.1 for toxicity of insecticides to predatory mites. Athena is a premix of a miticide and insecticide that may be used when control of common insect pests is also needed.	Agri-Mek 0.15EC, 16 fl oz (3), ***or*** Acramite 50WS, 0.75–1.0 lb (1), ***or*** Oberon 2SC, 12–16 fl oz (3), ***or*** Vendex 50WP, 1.5–2.0 lb (1), ***or*** Kanemite 15SC, 21–31 fl oz (1) ***or*** Portal, 2 pt (1), ***or*** Athena, 13.5–17 fl oz (3), ***or*** Savey 50DF, 6 oz (3), ***or*** Zeal, 2–3 oz (1)
Spittlebugs	Spittlebugs are frequently a larger problem in weedy fields. Good weed control will discourage large populations of spittlebugs from establishing in the planting. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Dibrom 8, 1 pt (1), ***or*** Danitol 2.4 EC, 10.67 oz (2), ***or*** Sevin 4F, 1–2 qt or 80S, 1.25–2.5 lb (7), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
Plant bugs (Lygus bugs)	Tarnished plant bugs are attracted to certain weed species for egg laying, and tend to be a larger problem with late-season cultivars. Rimon should be targeted against nymphs. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Dibrom 8, 1 pt (1), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Brigade WSB, 6.4–32 oz (0) ***or*** Danitol 2.4EC, 10.67 oz (2), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Rimon, 12 fl oz (1), ***or*** Sevin 80S, 1.87–2.5 lb or 4F, 1.5–2 qt (7)
Aphids	As needed. See labels of individual insecticides for additional information. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled. Admire can be applied as a foliar and soil-applied material.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Diazinon 50WP, 1 lb or AG500, 1 pt (5), ***or*** Dibrom 8, 1 pt (1), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Aza-Direct, 16–56 fl oz (0), ***or*** Actara, 1.5–3.0 oz (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1), ***or*** Voliam Flexi, 2.0–4.0 oz (3)
	As a soil application through drip irrigation or as otherwise described on the label. Admire and Provado have the same active ingredient, as do Actara and Platinum. See labels for additional information.	Admire Pro, 10.5–14.0 fl oz (14), ***or*** Platinum, 5.0–12.0 fl oz (50)
Leafhoppers	When injury appears. See text discussion. No cultural controls are effective. M-Pede is an insecticidal soap, and should be targeted against first-generation nymphs. Courier also should be targeted against nymphs.	Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1), ***or*** Actara 1.5–3.0 oz (3), ***or*** Sevin 80S,1.25–2.5 lb or 4F, 1–2 qt (7), ***or*** Voliam Flexi, 2.0–4.0 oz (3), ***or*** Courier SC, 9.0-12.0 fl oz (3), ***or*** M-Pede, 2.0% solution (0)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Whiteflies	As needed. See labels of individual insecticides for additional information. M-Pede is an insecticidal soap, and should be targeted against first-generation nymphs. Courier also should be targeted against nymphs. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled. Admire can be used as a foliar and soil-applied material.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Oberon 2SC, 12–16 fl oz (3), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Esteem 0.86EC, 10 fl oz (2), ***or*** Actara, 3.0–4.0 oz (3), ***or*** M-Pede, 1–2% solution (0), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Courier SC, 9.0-12.0 fl oz (3), ***or*** Vetica, 12.0–18.5 fl oz (3), ***or***
	As a soil application through drip irrigation or as otherwise described on the label. Admire and Provado have the same active ingredient, as do Actara and Platinum. See labels for additional information.	Admire Pro, 10.5–14.0 fl oz (14), ***or*** Platinum, 5.0–12.0 fl oz (50)
Strawberry root weevil (adults)	When damage appears or adults are present. Adults feed at night.	Brigade WSP, 8–32 oz (0), ***or*** Actara, 4.0 oz (3), ***or*** Malathion 8F, 1.5–2 pt (3) or 57 EC, 1.5–3.0 pt
Japanese beetle (adults)	Treatment is only necessary if feeding damage becomes severe. Activity of Pyganic is short in duration.	Sevin 80S, 1.25–2.5 lb, or 4F, 1–2 qt (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Coragen, 3.5-5.0 fl oz (1), ***or*** Pyganic EC 1.4 II, 1–4 pt (0)
HARVEST YEAR(S): LEAF EMERGENCE		
Diseases		
Leaf spot	As symptoms appear. Fungicides applied for common leaf spot may assist with control of other leaf spotting diseases such as scorch and blight. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides. Note that for products containing captan, the REI is 24 hr.	Captan 50W, 3–6 lb (0) or Captec 4L, 1.5–3 qt (0), ***or*** Rally 40W, 2.5–5.0 oz (0), ***or*** Cabrio EG, 12–14 oz (0), ***or*** Pristine[a], 18.5–23 oz (0)
Leaf blight	As symptoms appear. Few fungicides are labeled for this use. Fungicides applied for leaf spot may give some control.	Rally 40W, 2.5–5.0 oz (0)
Powdery mildew	As symptoms appear. See footnote "b" below concerning severe toxicity of Abound to McIntosh, Gala, and related apple cultivars. Abound, Cabrio, and one of the active ingredients in Pristine are in the same chemical class, and cannot be rotated with each other for resistance management purposes. Do not make more than two sequential applications of fungicides from this activity group. See fungicide efficacy table for classes of fungicides.	Abound[b], 6.0–15.5 oz (0), ***or*** Cabrio EG, 12–14 oz (0), ***or*** Rally 40W, 2.5–5.0 oz (0), ***or*** Pristine[a], 18.5–23 oz (0), ***or*** Procure 480SC, 4–8 fl oz (1), ***or*** Orbit, 4 fl oz (0), ***or*** Tilt, 4 fl oz (0), ***or*** Evito 480SC, 2.0–5.7 fl oz (1), ***or*** Flint, 2.0–3.2 fl oz (0), ***or*** Quintec, 4–6 fl oz (1)
Leather rot	After the ground thaws but before first bloom. Apply to soil as a band application or through drip irrigation.	Ridomil Gold SL, 1 pt/treated A (0)
Red stele	After the ground thaws but before first bloom. Apply to soil as a band application or through drip irrigation.	Ridomil Gold SL, 1 pt/treated A (0)
	When plants start active growth (foliar application). Repeat at 30- to 60-day intervals if conditions favoring disease development persist.	Aliette WDG, 2.5–5.0 lb (0.5), ***or*** Phostrol, 2.5–5.0 pt (—)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Insects and Mites		
Spider mites	Twospotted spider mite females are ready to lay eggs now. Scout in early spring. Overwintered twospotted mites will be reddish orange in color. If 25% of leaflets have two-spotted mites, control is needed. Savey and Zeal are effective on eggs and nymphs, but not adults, so they must be used when mite populations are low. Brigade and Danitol are also labeled for spider mites but must be used at high rates with good coverage for mite control, or they may decrease predatory mite numbers without controlling spider mites. Releases of predatory mites can give good results. See text for additional information and Table 3.1 for toxicity of insecticides to predatory mites. Athena is a premix of a miticide and insecticide that may be used when control of common insect pests is also needed.	Agri-Mek 0.15EC, 16 fl oz (3), ***or*** Acramite 50WS, 0.75–1.0 lbs (1), ***or*** Oberon 2SC, 12–16 fl oz (3), ***or*** Vendex 50WP, 1.5–2.0 lb (1), ***or*** Portal, 2 pt (1), ***or*** Kanemite 15SC, 21–31 fl oz (1), ***or*** Athena, 13.5–17.0 fl oz (3), ***or*** Savey 50DF, 6 oz (3), ***or*** Zeal, 2–3 oz (1)
Cyclamen mites	Miticides must penetrate into the crown for control. Therefore, apply when foliage is minimal. Use high water volume (200 gal/acre) and pressure. Avoid infested planting stock. Certain species of predatory mites can help with control. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Portal, 2 pt (1)
Aphids	As needed. See labels of individual insecticides for additional information. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Diazinon 50WP, 1 lb or AG500, 1 pt (5), ***or*** Dibrom 8, 1 pt (1), ***or*** Provado, 3.8 fl oz (7), ***or*** Voliam Flexi, 2.0–4.0 oz (3), ***or*** Aza-Direct, 16–56 fl oz (0), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
	As a soil application through drip irrigation. See label for additional information. Watch days-to-harvest limitation.	Platinum, 5.0–12.0 fl oz (50)
Whiteflies	As needed. See labels of individual insecticides for additional information. M-Pede is an insecticidal soap, and should be targeted against first-generation nymphs. Courier should be targeted against nymphs as well. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Oberon 2SC, 12–16 fl oz (3), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Provado, 3.8 fl oz (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** M-Pede, 1–2% solution (0), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Courier SC, 9.0-12.0 fl oz (3), ***or*** Esteem 0.86EC, 10 fl oz (2), ***or*** Vetica, 12.0–18.5 fl oz (3), ***or***
	As a soil application through drip irrigation. See label for additional information. Watch days-to-harvest limitations.	Platinum, 5.0–12.0 fl oz (50)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
HARVEST YEAR(S): FLOWER BUD EMERGENCE		
Diseases		
Leaf spot, leaf blight, and powdery mildew	See comments for materials applied at leaf emergence.	Same materials as at leaf emergence.
Angular leaf spot	See text discussion of angular leaf spot for details on application.	Copper hydroxide or copper sulfate, various formulations and rates.
Insects and Mites		
Spider mites	See management notes for at leaf emergence.	Same materials as at leaf emergence.
Cyclamen mites	See management notes for leaf emergence applications.	Same materials as at leaf emergence.
Spittlebugs	Spittlebugs are frequently a larger problem in weedy fields. Good weed control will discourage large populations of spittlebugs from establishing in the planting. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4 EC, 10.67 oz (2), ***or*** Dibrom 8, 1 pt (1), ***or*** Sevin 4F, 1–2 qt or 80S, 1.25–2.5 lb (7), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
Aphids	See management notes for leaf emergence applications.	Same materials as at leaf emergence except for Platinum or Admire.
Strawberry bud weevils (clippers)	Tend to be a larger problem in rows near woods. The threshold for treatment is one cut bud per linear foot of row. Only rows near woods may need to be treated. Do not apply Lorsban after berries start to form or when berries are present.	Lorsban 4E, 1 qt (prebloom, 21), ***or*** Sevin 4F, 1–2 qt or 80S, 1.25–2.5 lb (7), ***or*** Danitol 2.4EC, 16–21.3 oz (2), ***or*** Brigade WSB 6.4–32 oz (0)
Whiteflies	See management notes for leaf emergence applications.	Same materials as at leaf emergence except for Platinum or Admire.
HARVEST YEAR(S): WHEN BLOSSOMS IN CLUSTER SEPARATE		
Diseases		
Same as for flower bud emergence, if problematic		
Insects		
Spittlebugs	See management notes for applications made at flower bud emergence.	Same materials as at flower bud emergence.
Strawberry bud weevils (clippers)	See management notes for applications made at flower bud emergence.	Same materials as at flower bud emergence.
Plant bug (Lygus bugs)	Scout for tarnished plant bugs by tapping flower clusters over a white surface such as a plate or sheet of paper. Treatment threshold is one nymph per 4 flower clusters. Tarnished plant bugs are attracted to certain weed species for egg laying, and tend to be a larger problem with late-season cultivars. Rimon should be targeted against nymphs. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Dibrom 8, 1 pt (1), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4EC, 10.67 oz (2), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Rimon, 12 fl oz (1), ***or*** Sevin 80S, 1.87–2.5 lb or 4F, 1.5–2 qt (7)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Strawberry leafroller	Apply just before bloom. Insecticides rarely needed for control as parasitic wasps often provide sufficient control. Bt products can provide safe control, but good coverage is a must. Do not apply Dibrom if temperature is above 90°F.	Diazinon 50WP, 1 lb or AG500, 1 pt (5), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Dibrom 8, 1 pt (1), ***or*** Sevin 80S, 1.25–2.5 lb or 4F, 1–2 qt (7), ***or*** Malathion 57EC, 1.5–3.0 pt or 8F, 1.5–2 pt (3), ***or*** Synapse, 3–5 oz (1), ***or*** Bt, various products and rates (0), ***or*** Vetica, 12.0–18.5 fl oz (3) ***or***
	Apply when pest is newly hatched or young. Entrust is OMRI approved.	Radiant SC, 6–10 fl oz (1), ***or*** Success, 4–6 fl oz (1), ***or*** SpinTor 2SC, 4–6 fl oz (1), ***or*** Entrust, 1.25–2.0 oz (1)
Aphids	See comments for applications made at leaf emergence.	Same materials as at leaf emergence except for Platinum or Admire.
Thrips	Do not apply Dibrom if temperature is above 90°F.	Dibrom 8, 1 pt (1), ***or*** Malathion 8F, 1.5–2 pt (3), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or***
	Apply when pest is newly hatched or young. Entrust is OMRI approved.	SpinTor 2SC, 4–6 fl oz (1), ***or*** Success, 4–6 fl oz (1), ***or*** Entrust, 1.25–2.0 oz (1), ***or*** Rimon, 9–12 fl oz (1), ***or*** Radiant SC, 6–10 fl oz (1)
Whiteflies	As needed.	Same materials as at leaf emergence except for Platinum or Admire.
HARVEST YEAR(S): EARLY (5–10% BLOOM)		
Diseases		
Botrytis fruit rot (gray mold)	Blossom protection is critical for gray mold control. Unopened blossoms are not in danger, but newly opened and aging blossoms are. Research consistently has shown that excellent gray mold control can be achieved with just two fungicide sprays, applied at early bloom and full bloom. However, if the bloom period is prolonged or wet, an additional application at late bloom might be needed. Repeat at harvest, if wet conditions occur. Note that for products containing captan, the REI is 24 hr.	Elevate 50WDG, 1.5 lb (0), ***or*** Switch 62.5WDG, 11–14 oz (0), ***or*** Captan 50W, 3–6 lb or Captec 4L, 1.5–3 qt (0), ***or*** Thiram 75WDG, 4.4 lb (3), ***or*** Topsin M 70WSB, 0.5 lb (1) plus Captan 50WP, 3 lb or Captec 4L, 1.5 qt (0), ***or*** Pristine[a], 18.5–23 oz (0), ***or*** Captevate 68WDG, 3.5–5.25 lb (0), ***or*** Scala SC, 18 fl oz if used alone, or 9–18 fl oz in tank mixtures (1), ***or*** Ph-D, 6.2 oz (0)
Leaf spot and leaf blight	See comments for materials applied at leaf emergence. Topsin M is also labeled for leaf scorch.	Same materials as at leaf emergence, ***or*** Topsin M 70WP, 0.75–1.0 lb (1)
Angular leaf spot	See text discussion of angular leaf spot for details on application.	Copper hydroxide or copper sulfate, various formulations and rates.
Leather rot	Begin foliar application between 10% bloom and early fruit set, and continue on a 7- to 14-day interval as long as conditions are favorable for disease development. When disease pressure is heavy, use the minimum time interval, high rates, and the maximum number of applications.	Aliette WDG, 2.5–5.0 lb (0.5), ***or*** Phostrol, 2.5–5.0 pt (—)
Insects		
Do not apply insecticides during bloom.		

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
HARVEST YEAR(S): MIDBLOOM		
Diseases		
Botrytis fruit rot (gray mold)	See comments for early bloom.	Same materials available as at early bloom. Alternate materials from different pesticide classes for resistance management.
Leaf spot and leaf blight	See comments at leaf emergence.	Same materials as at leaf emergence. Alternate materials from different pesticide classes for resistance management.
Angular leaf spot	See text discussion of angular leaf spot for details on application.	Copper hydroxide or copper sulfate, various formulations and rates.
Insects		
Do not apply insecticides during bloom.		
HARVEST YEAR(S): LATE BLOOM		
Diseases		
Botrytis fruit rot (gray mold)	This fungicide application may not be necessary unless a prolonged bloom period or wet conditions occur.	Same materials available as at early bloom. Remember to alternate or tank-mix materials for resistance management.
Leaf spot and leaf blight	Same comments as at leaf emergence.	Same materials available as at early bloom. Remember to alternate or combine materials for resistance management.
Insects		
Do not apply insecticides during bloom.		
HARVEST YEAR(S): GREEN FRUIT		
Diseases		
Angular leaf spot	See text discussion of angular leaf spot for details on application.	Copper hydroxide or copper sulfate, various formulations and rates.
Anthracnose fruit rot	Before disease develops, then on a 7- to 10-day schedule. Abound, Cabrio, Evito and one of the active ingredients in Pristine are in the same chemical class, and cannot be rotated with each other for resistance management purposes. Do not make more than two sequential applications of fungicides from this activity group. See fungicide efficacy table for classes of fungicides. Note that for Captevate and products containing captan, the REI is 24 hr.	Abound[b], 6.0–15.5 oz (0), ***or*** Captan 50W, 6 lb (0), ***or*** Cabrio EG, 12–14 oz (0), ***or*** Pristine[a], 18.5–23 oz (0), ***or*** Evito 480SC, 2.0–5.7 fl oz (1), ***or*** Captevate 68WDG, 5.25 lb (0), ***or*** Switch 62.5WDG, 11–14 oz (0)
Leather rot	At fruit set. Do not use more than 1.5 qt per treated acre per year. Apply to soil as a band application or through drip irrigation.	Ridomil Gold SL, 1 pt/treated A (0)
	Begin foliar application between 10% bloom and early fruit set, and continue on a 7- to 14-day interval as long as conditions are favorable for disease development. When disease pressure is heavy, use the minimum time interval, high rates, and the maximum number of applications.	Aliette WDG, 2.5–5.0 lb (0.5), ***or*** Phostrol, 2.5–5.0 pt (—)
Insects and Mites		
Plant bugs (Lygus bugs)	Same comments as when flower buds in cluster separate.	Same materials available as when flower buds in cluster separate.

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Spittlebugs	Spittlebugs are frequently a larger problem in weedy fields. Good weed control will discourage large populations of spittlebugs from establishing in the planting. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4 EC, 10.67 oz (2), ***or*** Sevin 4F, 1–2 qt or 80S, 1.25–2.5 lb (7), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
Strawberry leafroller	See comments for when flower buds in cluster separate.	Same materials available as when flower buds in cluster separate.
Spider mites	See comments made at leaf emergence concerning miticides.	Same materials available for use as at leaf emergence. Remember to alternate activity groups for resistance management.
Aphids	As necessary. Scout on new growth during the season. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Diazinon 50WP, 1 lb or AG500, 1 pt (5), ***or*** Dibrom 8, 1 pt (1), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Voliam Flexi, 2.0–4.0 oz (3), ***or*** Aza-Direct, 16–56 fl oz (0), ***or*** Actara, 1.5–3.0 fl oz (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
Strawberry root weevil (adults)	When damage appears or adults are present. Adults feed at night.	Brigade WSP, 8–32 oz (0), ***or*** Actara, 4 oz (3), ***or*** Malathion 8F, 1.5–2 pt (3) or 57EC, 1.5–3 pt (3)
Whiteflies	As needed. M-Pede is an insecticidal soap, and should be targeted against first-generation nymphs. Courier also should be targeted against nymphs. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Esteem 0.86EC, 10 fl oz (2), ***or*** Oberon 2SC, 12–16 fl oz (3), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Provado 1.6F, 3.8 fl oz (7), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Courier SC, 9.0–12.0 fl oz (3), ***or*** Actara, 1.5–3.0 fl oz (3), ***or*** M-Pede, 1–2% solution (0)
Leafhoppers	When injury appears. See text discussion. No cultural controls are effective. M-Pede is an insecticidal soap and should be targeted against first-generation nymphs. Courier also should be targeted against nymphs.	Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Sevin 80S, 1.25–2.5 lb or 4F, 1–2 qt (7), ***or*** M-Pede, 2.0% solution (0), ***or*** Voliam Flexi, 2.0–4.0 oz (3), ***or*** Courier SC, 9.0–12.0 fl oz (3), ***or*** Actara, 1.5–3.0 oz (3), ***or*** Assail 70WP, 0.8–1.7 oz or 30SG, 1.9–4.0 oz (1)
Japanese beetles (adults)	Feeding on fruit is likely to be a problem only for day-neutral cultivars.	Sevin 80S, 1.25–2.5 lb, or 4F, 1–2 qt (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Coragen, 3.5-5.0 fl oz (1), ***or*** Pyganic EC 1.4 II, 1–4 pt (0)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
HARVEST YEAR(S): PINK FRUIT THROUGH HARVEST		
Diseases		
Anthracnose fruit rot	See comments made at green fruit stage.	Same materials available as at green fruit stage. Remember to use materials from different pesticide classes for resistance management.
Botrytis fruit rot (gray mold)	Apply if symptoms appear.	Same materials available as at early bloom. Note days-to-harvest limitations for all products. For products containing captan, note that the REI is 24 hours even though the PHI is 0 days.
Angular leaf spot	See text discussion of angular leaf spot for details on application.	Copper hydroxide or copper sulfate, various formulations and rates.
Insects and Molluscs		
Slugs	Applied as a soil surface treatment. Most effective if applied in evening after rain or irrigation. Do not allow Deadline to contact fruit. Mechanical traps are effective.	Deadline Bullets, 10–40 lb (—), ***or*** Sluggo, 20–44 lb (0)
Plant bugs (Lygus bugs)	Scout by tapping flower clusters over a white surface. Treatment threshold is one nymph per 4 flower clusters. Tarnished plant bugs are attracted to certain weed species for egg laying, and tend to be a larger problem with late-season cultivars. Rimon should be targeted against nymphs. Note that materials with long days-to-harvest limitations will not be usable closer to harvest. Do not apply Dibrom if temperature is above 90°F. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. Labels on product bought before initiation of the phase-out may have shorter PHIs than what is indicated here but could only be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or*** Dibrom 8, 1 pt (1), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4EC, 10.67 oz (2), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Rimon, 12 fl oz (1), ***or*** Sevin 80S, 1.87–2.5 lb or 4F, 1.5–2 qt (7)
Sap beetles	As necessary. Keep ripe fruit harvested. This cultural control is highly effective. Rimon only affects larvae and should be applied when adults are noticed.	Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4EC, 16–21.3 oz (2), ***or*** Rimon,12 fl oz (1), ***or*** Assail 70WP, 1.7–3.0 oz 30SG, 4.0–6.9 oz (1)
Thrips	Do not apply Dibrom if temperature is above 90°F.	Dibrom 8, 1 pt (1), ***or*** Malathion 8F, 1.5–2 pt (3), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or***
	Apply when pest is newly hatched or young. Entrust is OMRI approved.	SpinTor 2SC, 4–6 fl oz (1), ***or*** Success, 4–6 fl oz (1), ***or*** Entrust, 1.25–2.0 oz (1), ***or*** Rimon, 9–12 fl oz (1), ***or*** Radiant SC, 6–10 fl oz (1)
Spittlebugs	Spittlebugs are frequently a larger problem in weedy fields. Good weed control will discourage large populations of spittlebugs from establishing in the planting. Materials with long days-to-harvest limitations will not be usable closer to harvest. Thionex use is being phased out. Thionex may not be used on annual (plasticulture) strawberries after July 31, 2012, or on perennial (matted-row) strawberries after July 31, 2016. The PHI is 4 days for annual strawberries and 12 days for perennial strawberries. Labels on product bought before initiation of the phase-out may have shorter PHIs than those indicated here and can be used until July 31, 2012, as labeled.	Thionex 3EC, 1.33 qt or 50WP, 2 lb (12) *perennial strawberries only* (see comments), ***or***Provado 1.6F, 3.8 fl oz (7), ***or*** Brigade WSB, 6.4–32 oz (0), ***or*** Danitol 2.4 EC, 10.67 oz (2), ***or*** Sevin 4F, 1–2 qt or 80S, 1.25–2.5 lb (7), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Assail 70WP, 0.8–1.7 oz 30SG, 1.9–4.0 oz (1)

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Leafhoppers	When injury appears. No cultural controls are effective. Materials with long days-to-harvest limitations will not be usable closer to harvest. M-Pede is an insecticidal soap and should be targeted against first-generation nymphs. Courier also should be targeted against nymphs.	Malathion 8F, 1.5–2 pt or 57EC, 1.5–3.0 pt (3), ***or*** Sevin 80S, 1.25–2.5 lb or 4F, 1–2 qt (7), ***or*** Assail 70WP, 0.8–1.7 oz or 30 SG, 1.9–4.0 oz (1), ***or*** Voliam Flexi, 2.0–4.0 oz (3), ***or*** Courier SC, 9.0–12.0 fl oz (3), ***or*** Actara, 1.5–3.0 oz (3), ***or*** M-Pede, 2.0% solution (0)
Aphids	See comments for green fruit. Materials with long days-to-harvest limitations will not be usable closer to harvest.	Same materials available as at green fruit.
Strawberry root weevil (adults)	When damage appears or adults are present. Adults feed at night. Insecticide applications made at night may enhance control.	Brigade WSB, 8–32 oz (0), ***or*** Actara, 4 oz (3), ***or*** Malathion 8F, 1.5–2 pt or 57EC, 1.5–3 pt (3)
Whiteflies	See comments for green fruit. Materials with long days-to-harvest limitations will not be usable near harvest.	Same materials available as at green fruit.
Japanese beetles	Feeding at this time is likely to be of concern only for day-neutral cultivars. Watch days-to-harvest limitations.	Sevin 80S, 1.25–2.5 lb, or 4F, 1–2 qt (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 1.9–4.0 oz (1), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Coragen, 3.5–5.0 fl oz (1), ***or*** Pyganic EC 1.4 II, 1–4 pt (0)
Spotted wing drosophila	Because spotted wing drosophilapopulations are highest in the fall, infestation is likely to be of concern primarily for day-neutral cultivars. Danitol rates appear on a 2(ee) label.	Danitol 2.4 EC, 10.67–21.3 oz (2)
Brown marmorated stink bug	Brown marmorated stink bug has not been a problem on strawberries to date, though potential for damage to day-neutral strawberries exists.	Danitol 2.4 EC, 10.67–21.3 oz (2)
HARVEST YEAR(S): RENOVATION		
Diseases		
Red stele	After harvest in the fall. Apply to soil as a band application or through drip irrigation.	Ridomil Gold SL, 1 pt/treated A (—)
	For annual plantings, begin foliar applications 14–21 days after planting and continue on a 30- to 60-day interval as long as conditions favor disease development. For perennial plantings, begin applications when plants start active growth in spring. If disease conditions persist or reoccur, make additional applications on a 30- to 60-day interval. When disease pressure is heavy, use the minimum time interval, high rates, and the maximum number of applications. Chemical treatment cannot compensate for an excessively wet site.	Aliette WDG, 2.5–5.0 lb (0.5), ***or*** Phostrol, 2.5–5.0 pt (—)
Insects and Mites		
Cyclamen mites	Same materials available as at leaf emergence.	Same materials available as at leaf emergence.
White grub complex	White grub complex refers to any or all of the grubs(larvae) of Asiatic garden beetle, European chafer, Japanese beetle, or Oriental beetle. Admire must be soil incorporated with at least 0.25 inches of water within 2 hours of application. Admire may be applied in spring or at renovation, but not at both times in the same year.	Admire Pro, 7.0–10.5 fl oz (14), ***or*** Platinum, 5.0–12.0 fl oz (50)
Leafhoppers	See comments made for pink fruit through harvest.	Same materials available as at pink fruit through harvest.

CONTINUED

Table 6.16. Pesticides for strawberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A (Days to Harvest)
Japanese beetles	Treatment is only necessary if feeding damage becomes severe. Activity of Pyganic is short in duration.	Sevin 80S, 1.25–2.5 lb, or 4F, 1–2 qt (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Coragen, 3.5–5.0 fl oz (1), ***or*** Pyganic EC 1.4 II, 1–4 pt (0)
HARVEST YEAR(S): POSTRENOVATION		
Diseases		
Leaf spot, leaf blight, and powdery mildew	See comments made at leaf emergence. Remember to alternate materials from different activity groups for resistance management.	Same materials available as at leaf emergence.
Leather rot	In the fall in fields where a problem. Apply to soil as a band application or through drip irrigation.	Ridomil Gold SL, 1 pt/treated A (—)
Insects		
Strawberry root weevil (adults)	When damage appears or adults are present. Adults feed at night.	Brigade WSP, 8–32 oz (0), ***or*** Actara, 4 oz (3), ***or*** Malathion 8F, 1.5–2 pt, or 57EC, 1.5–3.0 pt (3)
Strawberry root weevil (larvae)	Treat within one month after renovation when larvae are small and actively feeding.	Platinum, 12 fl oz (50)
Strawberry leafroller	See comments made for this insect at time flower buds in cluster separate.	Same materials available as when flower buds in cluster separate.
Aphids	See comments made at green fruit. Actara and Platinum have the same active ingredient.	Same materials available as at green fruit, ***or*** Platinum, 5.0–12.0 fl oz (50), ***or*** Admire Pro, 10.5–14.0 fl oz (14)
Strawberry rootworm	When feeding damage is detected. Insecticide applications made at night may enhance control.	Pyganic EC 1.4 II, 1–4 pt (0)
Whiteflies	As needed. Actara and Platinum have the same active ingredient.	Same materials available as at green fruit, ***or*** Platinum, 5.0–12.0 fl oz (50), ***or*** Admire Pro, 10.5–14.0 fl oz (14)
Leafhoppers	See comments made at pink fruit through harvest.	Same materials available as for pink fruit through harvest, ***or*** Platinum, 5.0–12.0 fl oz (50)
Japanese beetles	Treatment is only necessary if feeding damage becomes severe. Activity of Pyganic is short in duration.	Sevin 80S, 1.25–2.5 lb, or 4F, 1–2 qt (7), ***or*** Assail 70WP, 1.7–3.0 oz or 30SG, 4.0–6.9 oz (1), ***or*** Voliam Flexi, 4.0–5.0 oz (3), ***or*** Coragen, 3.5–5.0 fl oz (1), ***or*** Pyganic EC 1.4 II, 1–4 pt (0)
White grub complex	For treatment of grubs of Asiatic garden beetle, European and masked chafer, Japanese beetle, and Oriental beetle in perennial systems only. Apply during egg-laying period.	Admire Pro, 7.0–10.5 fl oz (14), ***or*** Platinum, 5.0–12.0 fl oz (50)

NOTE: (—) = days to harvest not specifically stated on label, though use pattern may otherwise define time frame for use.

a. Pristine may cause injury to foliage of Concord or related grape varieties such as Worden and Fredonia. Do not use Pristine on these varieties and use special care when applying to prevent contact with these sensitive varieties. Thoroughly rinse spray equipment, including the inside of the tank, hoses, and nozzles after and before using the same equipment on these sensitive grape varieties.

b. Do not allow Abound to drift to McIntosh, Gala, or related apple cultivars (Bancroft, Bromley, Cortland, Cox, Discover, Empire, Jonamac, Kent, McIntosh, Spartan, and Summared). Do not use the same spray equipment for other materials that will be applied to these cultivars, even if thoroughly cleaned.

Table 6.17. Additional restrictions on strawberry fungicides and insecticides.

Note: The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may be labeled for the same uses. Always consult the label before making pesticide applications. Information was current as of July 1, 2012.

Abound	Do not apply more than two sequential applications of Abound before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 6.14 for activity groups of fungicides labeled for use on strawberries. Do not allow to drift to McIntosh, Gala, or related apple cultivars (Bancroft, Bromley, Cortland, Cox, Discover, Empire, Jonamac, Kent, McIntosh, Spartan, and Summared). Do not use the same spray equipment for other materials that will be applied to these cultivars, even if thoroughly cleaned.
Acramite	Limited to two applications of Acramite per season. Applications must be at least 21 days apart.
Actara	Do not exceed 12 oz of Actara or 0.188 lb ai of thiamethoxam per acre per growing season. Minimum interval between applications is 10 days.
Admire Pro	Do not apply more than 10.5 fl oz (0.38 lb ai) of Admire Pro per acre per season. See additional notes in Provado restrictions concerning use of Admire and Provado in the same season.
Agri-Mek	Do not exceed 16 fl oz per acre per application or 64 fl oz per acre per season. Allow at least 21 days following second application before making another application.
Aliette	Do not exceed 30 lbs of product per acre per season.
Assail	Do not exceed a total of 0.26 lb ai per acre per growing season, make more than 2 applications per season, or apply more often than once every 7 days.
Athena	Do not make more than two consecutive applications or four total per season. Do not apply more than 68 fl oz of Athena, 0.075 lb of avermectin, or 0.5 lb of bifenthrin per season.
Brigade	Do not apply more than 0.5 lb ai (80 oz of product) per acre per season.
Cabrio	Do not apply more than two sequential applications of Cabrio before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 6.14 for activity groups of fungicides labeled for use on strawberries.
Captan	Do not apply more than 24 lb of 50WP or maximum specified of a different formulation per acre per season.
Captec	Do not apply more than 24 qt per acre per season.
Captevate	Do make more than two consecutive applications of Captevate. Do not apply more than 21.0 lb per acre per season.
Coragen	Do not make more than two applications per insect generation or apply more than 15.4 oz of Coragen per acre per crop. Rotate to an insecticide in a different chemical class for the subsequent generation of a targeted insect.
Courier	Do not make more than two applications per crop cycle.
Danitol	Do not make more than two applications of Danitol within 12 consecutive months.
Diazinon	Do not apply more than one foliar and one soil application per crop.
Dibrom 8E	Do not apply more than 5 pts per acre per season.
Elevate	Do not apply more than 6 lbs of Elevate per acre per year.
Esteem 0.86EC	Do not make more than two Esteem 0.86EC applications per growing season. Do not exceed 20 fl oz Esteem 0.86EC per acre per season. Do not apply earlier than 30 days after the last Esteem application.
Evito 480SC	Do not make more than two sequential applications of Evito without rotating to a fungicide with a different mode of application for at least one spray.
Flint	Do not apply more than 19.2 oz of Flint per acre per year. Do not exceed six applications of Flint or other strobilurin fungicides per year. Do not make more than two sequential applications of Flint or other Group 11 fungicides per year without rotating to fungicides in a different chemical class.
Kanemite	Do not apply more than a total of 62 fl oz of Kanemite 15SC per acre per season. Do not make more than two applications of Kanemite 15SC per year. Allow a minimum of 21 days between applications of Kanemite 15SC.

CONTINUED

Table 6.17. Additional restrictions on strawberry fungicides and insecticides, continued.

Lorsban	Do not make more than 2 foliar applications of Lorsban or another product containing chlorpyrifos per year. Do not make a second application of any product containing chlorpyrifos within 10 days of the first application.
Oberon	Do not use more than 16 fl oz of Oberon in a seven-day interval, more than 48 fl oz per crop season, or more than three applications per crop season.
Ph-D	Alternate with fungicides with a different mode of action. Do not make more than five applications of Ph-D per season.
Portal	Do not apply more than 4 pts per acre per season or make more than two applications per season. Allow at least 14 days between applications.
Pristine	Do not apply more than two sequential applications before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 6.14 for activity groups of fungicides labeled for use on strawberries. Pristine may cause injury to foliage of Concord or related grape varieties such as Worden and Fredonia. Do not use Pristine on these varieties and use special care when applying to prevent contact with these sensitive varieties. Thoroughly rinse spray equipment, including the inside of the tank, hoses, and nozzles after use and before using the same equipment on these sensitive grape varieties.
Procure	Do not exceed 32 oz of Procure 480SC per acre per season.
Provado	Allow at least 5 days between foliar applications of Provado. Do not apply more than 11.4 fluid ounces of Provado 1.6F per year. For resistance management purposes do not follow a soil application of Admire. Do not apply more than a total of 0.14 lb active ingredient of Provado per acre per season.
Quintec	Do not apply more than two consecutive applications of Quintec. See label for additional resistance management strategies.
Radiant	Do not make more than 2 consecutive applications of group 5 insecticides without rotating to another class of effective insecticides for at least 1 application. Do not make more than 5 applications per calendar year or apply more than 39 fl oz of Radiant SC per crop per year.
Rally	Apply no more than 30 oz of Rally per acre per year.
Ridomil Gold	Apply up to 3 times per crop. Do not apply more than 1.5 qt per acre per year.
Rimon	Do not apply more than 36 oz per acre per season.
Rovral	Do not make more than 1 application per season. Do not apply Rovral after the first fruiting flower.
Savey	Limited to one application of Savey per year. Do not use in strawberry nurseries.
Scala	Do not use a fungicide from Group 9 (anilinopyrimidine compounds) for more than 2 of 6 or 3 of 7 applications in any one season. When applying Scala alone, do not make more than two consecutive applications without alternating to an equal number of applications of a fungicide from a different resistance management group. Among fungicides labeled for use on strawberries, Switch and Scala are in the same resistance management group.
Sevin	Do not apply more than 5 times, or more often than once every 7 days.
Spintor, Entrust, Success	Do not apply more than a total of 0.45 lb ai of spinosad per acre per crop. Rotate to a different class of insect control products after two successive applications of Spintor, Entrust, or Success. Do not make more than 5 applications per year.
Switch	Do not exceed 56 oz of Switch per acre per year. Do not make more than 2 applications before using a fungicide in another resistance management group.
Synapse	Do not apply more than 15 oz per acre per crop season.
Thionex	Thionex use is being phased out. See label for details and other restrictions.
Tilt	Do not apply more than 16 fl oz per season.
Topsin M 70WSB	Do not apply more than 4 lb of product (2.3 lb ai) per acre per season.
Vendex 50WP	Make no more than 2 applications per season. Apply no more than 4 lb per acre per season.
Voliam Flexi	Do not apply more than 15 oz of Voliam Flexi, 0.188 lb of thiamethoxam, or 0.2 pounds of chlorantraniliprole per acre per season. Allow at least 10 days between applications.
Zeal	Do not make more than 1 application of Zeal per growing season. Do not apply more than 3 oz of Zeal per acre per season.

WEEDS

A general discussion of weed management options for small fruit plantings is presented in Chapter 4, and should be consulted for additional information. Topics covered include cultural practices such as site selection and preparation, mechanical management, and use of mulches (including plastic). Herbicides are discussed in detail as well. Weed management as it pertains specifically to strawberry plantings is discussed below.

SITE PREPARATION

Good weed control starts long before the field is planted. As discussed in Chapter 2, cover cropping with competitive crops for 1 to 2 years before planting reduces the number of weed species in a given field. This practice also increases organic matter if plowed in at the end of the year.

Weeds can also be controlled before planting by growing other row crops such as corn. This is especially desirable for a crop such as strawberries where few chemical options exist after the crop is planted. This particularly strategy is effective for getting yellow nutsedge under control in a prospective strawberry field since both the cultivation and the herbicides registered for corn can control this noxious weed. Because strawberry plants are poor competitors due to their low stature, they are especially weak competitors against yellow nutsedge.

Nonselective herbicides such as glyphosate or fumigants like metam-sodium (Vapam) can be applied during site preparation prior to planting. A major weed control objective in site preparation is to eliminate perennial broadleaf weeds. Once strawberries are planted, many perennial weed species, especially broadleaves, are impossible to control with herbicides due to few effective options, so controlling them before planting is the most viable option.

WEED CONTROL AFTER PLANTING

Many growers wish they could get season-long control with preemergence herbicides. However, this usually requires use of a relatively high herbicide rate, so with longer weed control comes a higher risk of stunting the crop plant. This may be especially problematic with strawberries since a large proportion of their shallow root system may be exposed to herbicides' effects. For this reason, cultivation is and will remain an important tool. Cultivation and hand-hoeing should begin as soon as weeds begin to germinate. Repeat as often as required to prevent the establishment of weeds not controlled with herbicides. Mechanical cultivation and hand-hoeing may again be necessary when herbicides lose their effectiveness, usually about two months after planting. Cultivation should be shallow and done carefully to avoid damaging established plants. The cultivator may be used to reposition runners and daughter plants early in their development. The cultivator should be set to throw soil shallowly into the row to anchor the runners and encourage rooting of the daughter plants. Consider applying a supplemental preemergence herbicide in midsummer after the desired number of daughter plants—usually four to five plants per square foot in matted-row production—have rooted. Use postemergence herbicides recommended for newly planted strawberries when susceptible weeds are observed. Hand-pull weeds in the row that escape the above measures.

As mentioned above, herbicides are classified as either preemergence or postemergence in reference to their time of application relative to whether the weed has emerged from the soil.

Preemergence herbicides are applied before weed emergence and thus prevent weeds from establishing. Labels often state that preemergence herbicides must be activated by rainfall, cultivation, or irrigation. Typically, the purpose of these activities is to solubilize the herbicide and move it into the zone of weed germination, as well as to prevent herbicide losses as a vapor. Of preemergence herbicides labeled for strawberries, DCPA (Dacthal) and napropamide (Devrinol) work by inhibiting cell division mainly in the roots, and terbacil (Sinbar) works by inhibiting photosynthesis. Sinbar, besides having this effect on germinating weeds, also kills recently emerged weeds (those just at the cotyledon stage). Chateau is a premergence herbicide that inhibits the manufacture of chlorophyll, and also has burndown activity, similar to that of Goal. When using preemergence herbicides, best results are obtained by

1. carefully matching the chemical with the weeds you need to control (see Table 4.1),
2. applying the rate appropriate for your soil type and organic matter content (see Table 6.18),
3. preparing soil properly,
4. incorporating herbicides that must be incorporated to be effective, and
5. having preemergence herbicides in place before weeds emerge.

Apply preemergence herbicides in spring before weed seeds germinate to control summer annual weeds—this means the herbicide should be in the soil when dogwoods are in full bloom. Applying preemergence herbicides in late summer will control winter annual weeds.

Postemergence herbicides, used for controlling weeds after they have emerged from the soil, fall into the categories of contact or translocated (systemic). Contact herbicides such as paraquat (Gramoxone), pelargonic acid (Scythe), carfentrazone (Aim), and acifluorfen (Ultra Blazer) kill only the foliage covered by the spray, so thorough coverage is important. Because these herbicides do not translocate (move within the plant), the roots survive. Hence, control of perennial weeds is only temporary since these plants will regrow from their root system. Translocated herbicides such as glyphosate (Roundup, others), 2,4-D, clopyralid (Stinger), fluazifop (Fusilade), sethoxydim (Poast), and clethodim (Select) move within the plant and kill portions with which they may or may not have come in contact, eventually killing the entire plant.

Postemergence herbicides also can be classified as selective or nonselective. Selective herbicides kill only certain classes of weeds, while nonselective herbicides kill all weeds. Scythe, Gramoxone, and glyphosate are nonselective herbicides and therefore kill or damage any plant with which they come in contact. Scythe and Gramoxone disrupt cell membranes. Glyphosate inhibits amino acid production and thus the production of protein in the

plant. Fusilade, Poast, and Select are translocated selective herbicides that work on grasses by inhibiting fatty acid synthesis, thus killing their growing points. The translocated herbicides 2,4-D and Stinger are growth regulators—they work through a variety of effects and are effective primarily on broadleaves. When using postemergence herbicides, best results are obtained by:

1. carefully matching the chemical with the weeds you need to control (see Table 4.1),
2. treating when weeds are actively growing and not under drought stress,
3. adding an appropriate surfactant or other adjuvant if the label calls for it,
4. applying contact herbicides when crop and weeds are within the recommended size and/or leaf stage,
5. applying under calm conditions to avoid spray drift,
6. verifying whether two postemergence herbicides can be combined without affecting crop tolerance or weed control when considering tank mixes.

To use herbicides effectively, there is no substitute for thorough knowledge of soil and herbicide characteristics. There may be some confusion about the proper rate of herbicides to use on the crop. Most recommendations are given as a range. What factors dictate proper application rates? Generally, heavier soils require more of an herbicide than lighter soils because the chemicals adsorb to clay particles and organic matter in heavier soils. In addition, the presence of undecomposed organic matter on the soil surface can lower herbicide effectiveness. Control may be more difficult if the herbicide is applied over mulching materials. Table 6.18 gives rate ranges for preemergent strawberry herbicides on different soil types, and Table 6.19 gives additional recommendations for weed control in strawberries by time of year.

Brief descriptions of herbicides available for use on strawberries follow. Do not use these materials without consulting Table 6.19 for recommended rates, timings, and restrictions.

Napropamide (Devrinol) is a soil-applied, selective, preemergence herbicide that controls many annual grasses and certain broadleaved weeds, including chickweed, at the germination stage. It will not control established weeds. Devrinol at half the maximum rate can be applied to weed-free soil immediately after transplanting strawberries. It can also be applied to new and established plantings in the late summer or early fall, but only after the desired number of daughter plants have established since Devrinol inhibits daughter plant rooting. In addition, Devrinol can be applied from late fall through early winter (not on frozen ground) or in early spring. Application in the fall just before winter mulching is especially useful since Devrinol will prevent growth of any small-grain seedlings emerging from the mulch and will provide control of spring-germinating weeds. While Devrinol is useful at several times, there is a limit of 4 pounds of ai (8 pounds of Devrinol 50DF) per acre per year. Devrinol is broken down by sunlight and therefore must be incorporated by rainfall, ½ inch of irrigation, or shallow cultivation within 24 hours after application. This moves the herbicide into the soil and prevents breakdown. Do not apply from bloom through harvest.

DCPA (Dacthal) is a soil-applied preemergence herbicide that can be applied before transplanting if shallowly incorporated or at any time after transplanting to weed-free soil. In established plantings, it can be applied to weed-free soil in the fall or spring but not after bloom. Dacthal primarily controls annual grasses and certain small-seeded broadleaf weeds such as field pansy, chickweed, lambsquarters, and purslane.

Flumioxazin (Chateau) is a soil-applied preemergence herbicide that also has burndown activity, similar to Goal. It must be applied to plants that are dormant and is labeled only for use on established plants during the fall and spring. Damage will occur to green tissue that comes in contact with the herbicide. Chateau can be difficult to clean out of a sprayer. Sprayers used for Chateau must be thoroughly cleaned according to label "Clean Out Instructions" if the tank or any part of the sprayer will be used for nondormant applications or on other crops. Otherwise, unexpected damage may occur during subsequent applications. Tank-mixing with 2,4-D when treating dormant matted-row strawberries in early spring improves the spectrum of weeds controlled, as does tank-mixing with Gramoxone when applying a shielded spray between the rows of strawberries grown on plastic mulch. Oil concentrate at 1 percent of the spray solution volume or nonionic surfactant at 0.25 percent of the spray solution volume may be added to improve control of emerged weeds but also may increase the risk of crop injury. Chateau provides control of wild pansy (Johnny-Jump-Up), chickweed, groundsel, and many other broadleaf weeds common in strawberry plantings.

Terbacil (Sinbar) is a preemergence herbicide that also is effective against susceptible weeds when newly germinated. Sinbar controls many annual broadleaf weeds but may be weak on pigweed species. During the establishment year, Sinbar can be used at low rates after transplanting but before new runner plants start to root. If strawberry transplants have developed new foliage prior to application, the spray must be followed immediately by ½ to 1 inch of irrigation or rainfall to wash the Sinbar off the strawberry foliage since unacceptable crop injury may result through foliar absorption. University data from Rutgers have shown that more consistent weed control and less crop injury occurs when Sinbar 80WP at 1 oz/acre is applied at 3-week intervals rather than higher rates. Applications should be begun 3 to 6 weeks after transplanting when the strawberries have three new full-size trifoliate leaves, but before weeds exceed 1 inch in height. Research at Penn State also shows that applying Sinbar in higher volumes of water may decrease negative effects by decreasing the concentration of Sinbar applied. During the establishment year, Sinbar can also be applied in late summer or early fall to control winter annual weeds, such as chickweed, following the application with irrigation or rainfall. In late fall, but before the ground is frozen, Sinbar can be applied to extend weed control through the following harvest season. In established plantings, Sinbar can be used at renovation after the old leaves have been removed but before

new growth begins. It can also be used in established plantings prior to mulching in late fall, though at higher rates than in the establishment year.

Growers should note that Sinbar 80WP may be applied at a maximum of 8 ounces per year. Lower rates are recommended for light, textured soils and soils with 1 to 2 percent organic matter. Sinbar should not be used on soils with less than ½ percent organic matter. Do not add surfactant, oil concentrate, or any other spray additive or tank mix with any other pesticide unless the mixture is approved on the Sinbar label.

Strawberry varieties vary in their sensitivity to Sinbar. Some varieties (e.g., Earliglow) are tolerant while others (e.g., Guardian) are known to be sensitive. When low rates (fewer than 4 ounces of product) are applied to unstressed plants, injury is unlikely on most varieties. When using maximum labeled rates in established plantings, consider treating a small area to determine whether the variety you are growing is sensitive.

Pendimethalin (Prowl H_2O) is a preemergence herbicide that controls many annual grasses and some small-seeded broadleaf weeds. As the formulation name implies, the material is water based, which offers certain advantages. However, large amounts rainfall or irrigation after application may result in reduced performance. In matted-row production during the establishment year, it can be used as a broadcast spray either before planting, or soon after planting before new foliage begins to grow. Applying later than this can result in stunting of plants. Once the plants have begun growing, it can be applied between the rows if a shielded sprayer is used. Other allowable timings for use are after the plants are dormant in the fall and after renovation. In plasticulture plantings, this material can be used between the rows.

2,4-D amine is a foliar-applied, selective, postemergence, translocated herbicide used to control established annual and perennial broadleaved weeds. It will not control grasses. It can be used in the spring when the strawberries are still dormant. Some growers find applying 2,4-D in the spring over the straw mulch before removal (when dandelions have emerged through the straw but before strawberries begin active growth) to be valuable. However, 2,4-D application is particularly useful at renovation to control dandelion and other established broadleaved weeds. Apply immediately after harvest and allow 5 to 7 days for maximum translocation before mowing. Previously issued labels allowed use in late fall when the plants were dormant. However, if applied before plants were fully dormant 2,4-D had the potential to damage developing flower buds. Labels currently issued do not include the late-fall timing. Some crops, such as tomatoes and grapes, are especially sensitive to 2,4-D. Follow label instructions to avoid drift to sensitive crops. Do not apply unless possible injury to the crop is acceptable.

Clopyralid (Stinger) can be used legally only in states with a "Special Local Needs" label (in the Mid-Atlantic region: Pennsylvania, New Jersey, Maryland, and Virginia).

Stinger is a foliar-applied, selective, postemergence, translocated herbicide. In new plantings, it can be used in late summer and early fall. In established plantings, it can be used in the spring at least 30 days prior to harvest, and after harvest through early fall. Stinger controls weeds in the composite and legume plant families. Common annuals controlled include galinsoga, ragweed species, common cocklebur, groundsel, pineappleweed, clover, and vetch. Perennials controlled include Canada thistle, goldenrod species, aster species, and mugwort (wild chrysanthemum). Spot treatment of Canada thistle colonies with Stinger is often all that is required since fields are rarely completely infested. Stinger will not control many common broadleaved weeds such as pigweed and lambsquarters. Stinger is very effective on weeds less than 2 to 4 inches tall, but it is less effective and takes longer to work when weeds are larger. Use 2 to 4 fluid ounces to control annual weeds less than 2 inches tall. Increase the rate to 4 to 8 fluid ounces to control larger annual weeds. Apply the maximum rate of 10½ fluid ounces (2/3 pint) in one application or split into two applications to suppress or control perennial weeds, but do not exceed 10½ fluid ounces in one year. When two applications are used to control susceptible hard-to-kill perennial weeds, spray the first application in the spring at least 30 days before harvest and the second application after harvest at renovation. Spray additives are not needed or required by the label and are not recommended.

Do *not* tank-mix Stinger with other herbicides registered for use in strawberries. Stinger has residual soil activity; therefore, observe restrictions concerning subsequent crops to avoid injury from herbicide carryover.

Clethodim (Select) and sethoxydim (Poast) are foliar-applied, postemergence, translocated herbicides for grass control. Both can be applied at any time after the planting is established when grasses are at the specified growth stages. For best results, treat annual grasses when they are actively growing and before tillers are present. Both Select and Poast control many annual and certain perennial grasses. Select controls annual bluegrass but will not consistently control goosegrass. Neither will control yellow nutsedge, wild onion, or broadleaf weeds. Control may be reduced if grasses are large or if hot, dry weather or drought conditions occur. Repeated applications may be needed to control certain perennial grasses. Crop oil concentrate should be added as 1 percent of the spray solution (1 gallon of oil per 100 gallons of spray solution). Using oil concentrate may increase the risk of crop injury when hot or humid conditions prevail. To reduce the risk of crop injury, omit additives or switch to a nonionic surfactant when grasses are small and soil moisture is adequate. Do not tank-mix with or apply within 2 to 3 days of any other pesticide unless labeled because the risk of crop injury may be increased or control of grasses may be reduced.

Paraquat (Gramoxone), pelargonic acid (Scythe), carfentrazone (Aim), and acifluorfen (Ultra Blazer) are foliar-applied, postemergence, contact (nontranslocated) herbicides sometimes referred to as "burn-down" materials. They only affect the parts of plants with which they contact, so incomplete coverage results in incomplete control. They are most useful for annual

weeds, especially when the weeds are small. They only burn the tops off of perennial weeds, which have the capacity to regrow from their roots. Scythe can be somewhat less effective than Gramoxone, and relatively large volumes of the herbicide are required. However, Scythe has the advantage of being safer to the applicator and can be used up until the day of harvest.

PLASTICULTURE WEED CONTROL

Fumigation or use of herbicides between the time that beds are raised and plastic is laid is essential to control weeds. Labeled residual herbicides cannot be used over the top of the plastic to provide adequate weed control around the plant hole. Several weed control options are listed below to control troublesome winter annuals and other weeds that grow around plant holes.

Option 1: Prepare soil, apply fertilizer, then apply fumigant. See Chapter 3 for additional information on fumigation. Wait 20 days to allow the fumigant to act and disperse. Then prepare raised beds as described above and apply 4 to 6 pounds per acre of Devrinol 50DF to the surface of the bed and the area between beds. Lay drip irrigation and plastic mulch.

~or~

Option 2: Apply fertilizer, prepare raised beds, and inject metam sodium (Vapam HL) at 56 to 75 gallons per acre or 37 gallons per mulched acre. Immediately reshape beds (if necessary to form a firm, crowned bed) and apply 4 to 6 pounds per acre of Devrinol 50DF to the surface of the bed and the area between beds, and lay drip irrigation and plastic mulch. Wait 20 days between fumigation and planting to allow the fumigant to act and disperse.

~or~

Option 3: Apply fertilizer and prepare raised beds as described above. Apply 4 to 6 pounds per acre of Devrinol 50DF to the surface of the bed. Apply drip irrigation and plastic mulch. Inject metam sodium (Vapam HL) through the drip system at 37 gallons per mulched acre. Wait 20 days between fumigation and planting to allow the fumigant to act and to disperse.

Weeds between the mulched beds can be controlled with standard herbicides. Band the treatment between the strips of plastic. New options for controlling weeds between rows are Chateau 51DF and Prowl H_2O. Chateau 51DF may be applied between the rows of plastic at 3 ounces per acre using a shielded sprayer as soon as possible after planting. Adding Devrinol 50DF at 4 pounds per acre will broaden the spectrum of weeds controlled. Prowl H_2O may be applied at 1.5 to 3.0 pints per acre, calculating the rate on only the area treated, not concentrating the entire per acre rate into the row middles. Grasses between the rows and around plant holes can also be controlled postemergence with applications of Poast 1.5EC. See recommendations for Poast 1.5EC in Table 6.19.

MATTED-ROW WEED CONTROL WITH HERBICIDES

Recommendations for use of herbicides at various stages of the crop's growth are described in detail in Table 6.19. Various herbicide options exist, but not all will be needed. In addition, other steps can be taken to minimize weed problems. A sample—and commonly used—weed control program for matted-row production is given below to aid in "putting everything together" into an integrated weed management program.

Sample Weed Control Program for Matted-Row Strawberries

Weed control is often cited as the largest challenge in matted-row production. However, you can achieve excellent weed control by following a weed control program using the following steps.

1. Eliminate perennial weeds before planting strawberries.
One or two years before strawberry planting, eliminate perennial weeds by growing rotational crops (corn, pumpkin, others) that compete with weeds and allow for the use of herbicides that control perennial weeds. For instance, Dual can be used in sweet corn to control yellow nutsedge. Stinger can be used in small grains and corn to suppress Canada thistle. In addition, rotational crops that get frequent cultivation are often perennial weed free.
In the late summer or fall the year before strawberry planting, apply Roundup, 2,4-D, or Stinger, if necessary, to clean up any perennial weeds. Spot treat perennial weeds even if only small patches exist.

During the fall that precedes planting, seed a rye cover crop that will overwinter and build soil organic matter; lime and fertilize according to soil test results to raise soil fertility levels.

2. Prevent establishment of weeds by using timely applications of preemergence herbicides and cultivation throughout the establishment year.
At planting in the spring, use 2 to 4 pounds of Devrinol 50WP (or other formulation) or 6 to 12 pints of Dacthal 6F per acre (for grasses) plus 1 to 2 ounces of Sinbar 80WP per acre (for broadleaves) immediately after planting. Be sure to see Sinbar precautions about organic matter and variety sensitivity. Irrigation or rainfall immediately after herbicide application is needed to incorporate the herbicide, and, in the case of Devrinol, avoid degradation by sunlight. Dacthal may be preplant incorporated. The Sinbar application can be delayed 3 to 4 weeks after planting. However, if applied after strawberries have produced new foliage, it must be irrigated off of foliage immediately after application.

In the summer of the planting year, the initial herbicide application will be effective for 6 to 8 weeks. Following this, cultivation is essential for good strawberry weed control. Frequent cultivation will control seedling weeds. Poast or Select will control grass weeds, and Stinger may be applied later in the summer to control certain broadleaved weeds that escape cultivation. These herbicides only control weeds that are present at the time of application.

In late summer and early fall of the planting year (late August or early September), cultivate and then apply 2 to 4 pounds Devrinol 50WP (or other formulation) plus 2 to 3 ounces of Sinbar. This application is important because it will prevent establishment of many fall germinating weeds. Be sure to irrigate or time applications to coincide with rainfall to incorporate the Devrinol and wash Sinbar off of strawberry foliage. In late fall after plants are dormant, inspect the planting. If many broadleaved weeds are present, note which types of weeds are present to be ready for spring applications of 2,4-D or Stinger.

Just before mulching apply 4 to 6 pounds of Devrinol 50WP (or other formulation) per acre. This is important to prevent germination of wheat or rye seed (and other weed seeds) in the mulch. Mulch immediately after Devrinol application or irrigate it in. The maximum rate of Devrinol 50WP per year is 8 pounds per acre, so subtract previous application rates from 8 and apply the balance. If the maximum seasonal rate of 8 ounces per acre of Sinbar has not been used, the balance (up to 4 ounces per acre) may also be applied prior to mulching.

Use plenty of clean rye or wheat straw mulch. Many growers grow their own rye straw, harvesting it before it forms heads. In any event, be sure that the straw used for mulch is not forming seed heads. Straw infested with weed seedheads, such as Canada thistle, should be avoided.

3. Use methods of weed control that are tailored to your weed species during the harvest years.

In the spring of the first bearing year, Poast may be applied within 7 days of harvest, but grass weeds are unlikely to be present. An application of 2,4-D can be made to emerging dandelions in late winter or early spring, and Stinger can be applied prior to 30 days from harvest. However, due to previous herbicide and straw mulch use, herbicides at this point should not be necessary.

During renovation after harvest, apply the full rate (1½ quarts) of 2,4-D amine (Formula 40 or Amine 4) or another postemergent herbicide (if a better match with your weeds) immediately after harvest and then wait 5 to 7 days so it can translocate within the weeds. Next, mow off strawberry foliage and fertilize and narrow rows. Then apply Sinbar at the maximum use rate for your soils and irrigate. Stinger may also be used at renovation and if Canada thistle is present.

In the summer, spot treat perennial weed patches (Canada thistle) with Stinger (if your state has a Special Local Needs label), if the maximum yearly rate (2/3 pint) hasn't already been reached. In the late summer or early fall, apply 2 to 4 pounds of Devrinol 50WP per acre.

See Step 2 for late-fall application, after plants are dormant. Be sure to apply the balance of your Devrinol (4 to 6 pounds) just prior to mulching or in late fall to control volunteer grain and other weed seed germination over winter. If the maximum seasonal rate of 8 ounces per acre of Sinbar has not been used, the balance (up to 4 ounces per acre) may also be applied prior to mulching.

Repeat the "bearing year" program in subsequent years.

4. Spot treat weeds that escape before they get out of hand.

Table 6.18. Per-acre rates per application for preemergence (residual) herbicides for common soil types for strawberries.

Rates for each active ingredient are followed by the corresponding rates of a commonly available product containing the active ingredient listed.

	Soil Type / % Organic Matter												
	Sand		*Loamy Sand*		*Sandy Loam*			*Loam*		*Silt Loam*		*Clay Loam*	
Herbicide	0–1	1–2	0–1	1–2	0–1	1–2	2–4	1–2	2–4	1–2	2–4	1–2	2–4
Flumioxazin (oz ai)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Chateau 51WDG (oz)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
DCPA (lb ai)	4.5–6	4.5–6	4.5–6	4.5–6	4.5–6	4.5–6	4.5–6	6–7.5	6–7.5	6–7.5	7.5–9	7.5–9	7.5–9
Dacthal 6F (pt)	6–8	6–8	6–8	6–8	6–8	6–8	6–8	8–10	8–10	8–10	10–12	10–12	10–12
Napropamide[a] (lb ai)	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Devrinol 50DF (lb)	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8
Terbacil[b] (oz ai)	—	1.6	—	1.6	—	2.4	2.4	2.4	3.2	3.2	3.2	3.2	3.2
Sinbar 80WDG (oz)	—	2	—	2	—	3	3	3	4	4	4	4	4
Pendimethalin (lb ai)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0	1.0	1.2	1.2	1.4
Prowl H_2O (pt)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0

— = Not labeled (do not use).

a. Use the lower recommended rate when tank-mixing with another preemergence herbicide, unless annual grass pressure is severe.

b. Use one-half the recommended rate when tank-mixing with another preemergence herbicide.

Table 6.19. Herbicides for matted-row strawberry weed control.

Note: See text for description of plasticulture weed control options. The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist that may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. See Table 3.2 for limits on states in which these cannot be used, use status (general versus restricted), days-to-harvest limitations, and reentry intervals, and Table 6.18 to more closely determine the rate for your soil type where necessary. Information was current as of July 1, 2012.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
TRANSPLANTING YEAR: NEW PLANTINGS—AT PLANTING OR POSTTRANSPLANT			
Preemergent			
Annual grasses, certain small-seeded broadleaf weeds	Apply preplant incorporated with shallow cultivation before transplanting, or apply anytime after transplanting to weed-free soil.	DCPA, 6–9 lb	Dacthal 6F, 8–12 pt (—)
Annual grasses, suppresses or controls certain annual broadleaf weeds	Apply to weed-free soil immediately after transplanting. Activate with one-half inch sprinkler irrigation within 24 hours after application. If left on the soil surface, napropamide (Devrinol) is broken down by sunlight. Irrigation moves the herbicide into the soil and prevents breakdown by the sun.	Napropamide, 1–2 lb	Devrinol 50DF, 2–4 lb (prebloom)
Controls many annual broadleaf weed species, but may be weak on pigweed species	Apply 1 to 2 dry ounces of Sinbar 80WDG per acre after transplanting but before new runner plants start to root. Do not add surfactant, oil concentrate, or any other spray additive, or tank-mix with any other pesticide unless the mixture is approved on the Sinbar 80WDG label. If strawberry transplants are allowed to develop new foliage prior to application, the spray must be followed immediately by 0.5 to 1.0 inches of irrigation or rainfall to wash the Sinbar 80WDG off the strawberry foliage, or unacceptable crop injury may result. University data has shown that more consistent weed control and less crop injury occurs when 0.05 lb/A, 1 dry ounce of Sinbar 80WDG is applied at 3 week intervals. Begin applications 3 to 6 weeks after transplanting, when the strawberries have 3 new full size trifoliate leaves, but before weeds exceed 1 inch in height. Applying Sinbar is higher volumes of water per acre may minimize injury by decreasing the concentration of Sinbar applied. Certain varieties differ in their sensitivity to Sinbar. Determine varietal tolerance before spraying field. Do not apply Sinbar 80WDG to soils with less than 0.5% organic matter. Do not use more than 8 ounces of Sinbar per acre per year.	Terbacil, 0.05–0.10 lb	Sinbar 80WDG[c], 1–2 oz (110)
Controls most annual grasses and certain small-seeded broadleaf weeds	This product may be applied pre- or posttransplant. However, most data as of this writing indicate that application of this material prior to transplanting is safer. May also be applied through sprinkler irrigation prior to transplanting if adequate measure are taken to prevent backflow. See label.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
NEW PLANTINGS—SUMMER THROUGH EARLY FALL			
Preemergent			
Controls many annual broadleaf weed species, but may be weak on pigweed species	Apply 2 to 6 dry ounces of Sinbar 80WDG per acre in late summer or early fall to control winter annual broadleaf weeds. Use lower rates on coarse textured sandy soils low in organic matter, and higher rates on fine textured silt and clay soils high in organic matter. Do not add surfactant, oil concentrate, or any other spray additive, or tank-mix with any other pesticide unless the mixture is approved on the Sinbar 80WDG label. If the crop is not dormant at the time of application, the spray must be followed immediately by 0.5 to 1.0 inches of irrigation or rainfall to wash the Sinbar 80WDG off the foliage, or unacceptable crop injury may result. Certain varieties differ in their sensitivity to Sinbar. Determine varietal tolerance before spraying field. Do not apply Sinbar 80WDG to soils with less than 0.5% organic matter. Do not use more than 8 ounces of Sinbar per acre per year. Applying Sinbar in higher volumes of water per acre may minimize injury by decreasing the concentration of Sinbar applied.	Terbacil, 0.10–0.3 lb	Sinbar 80WDG[c], 2–6 oz (110)
Controls most annual grasses and certain small-seeded broadleaf weeds	A second application of this material is allowed between the rows after the plants are established, but it must not be allowed to contact the plants. Reduce per acre rate to correspond to the area sprayed (i.e., do not concentrate the entire per acre amount into the row middles). Do not exceed 6 pints per acre per season.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)
Postemergent			
Emerged annual grasses and certain perennial grasses Clethodim (Select) controls annual bluegrass, but will not consistently control goosegrass	The use of oil concentrate may increase the risk of crop injury when hot or humid conditions prevail. To reduce the risk of crop injury, omit additives or switch to nonionic surfactant when grasses are small and soil moisture is adequate. Control may be reduced if grasses are large or if hot, dry weather or drought conditions occur. For best results, treat annual grasses when they are actively growing and before tillers are present. Repeated applications may be needed to control certain perennial grasses. Yellow nutsedge, wild onion, or broadleaf weeds will not be controlled. Do not tank-mix with or apply within 2 to 3 days of any other pesticide unless labeled as the risk of crop injury may be increased or reduced control of grasses may result.	Clethodim, 0.094–0.125 lb Sethoxydim, 0.2–0.4 lb	Select 2EC, 6–8 fl oz plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution) (4), ***or*** Selectmax 0.97EC, 12–16 fl oz plus nonionic surfactant at 0.25% of the spray solution volume (1 qt/100 gal of spray solution) (4), ***or*** Poast 1.5EC, 1–2 pt plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution); do not exceed 2.5 pints of Poast per acre per season (7)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Certain annual and perennial broadleaf weeds in the composite and legume plant families including Canada thistle	A Special Local Needs label [24(c)] has been approved for the use of Stinger to control weeds in strawberries in Maryland, New Jersey, Pennsylvania, and Virginia. If newly planted, do not make an application in spring directly after planting; instead, make a late summer application that year after plants are well established and, if needed, a spring application the following year. See comments in text and later in this table.	Clopyralid, 0.047–0.25 lb	Stinger[d], 2–10.5 fl oz (30)
ESTABLISHED STRAWBERRY BEDS: NEW PLANTINGS—LATE FALL DORMANT			
Preemergent			
Annual grasses, certain broadleaf weeds	Apply to weed-free soil in the fall and repeat in early spring, but do not apply after bloom.	DCPA, 6–9 lb	Dacthal 6F, 8–12 pt (—)
Annual grasses and certain broadleaf weeds including chickweed spp.	Apply in late fall through early winter (not on frozen ground) or in early spring. Do not apply from bloom through harvest. Rainfall or irrigation will increase effectiveness. Do not exceed 8 lb of Devrinol 50DF per year.	Napropamide, 2–4 lb	Devrinol 50DF, 4–8 lb (prebloom)
Controls many annual broadleaf weeds, but may be weak on pigweed species. Controls certain grasses	Apply just prior to mulching in late fall to extend weed control through harvest the following spring. Use lower rates on coarse textured sandy soils low in organic matter, and higher rates on fine textured silt and clay soils high in organic matter. Do not add surfactant, oil concentrate, or any other spray additive. Certain varieties differ in their sensitivity to Sinbar. Determine varietal tolerance before spraying field. Do not apply Sinbar 80WDG to soils with less than 0.5% organic matter. Do not use more than 8 ounces of Sinbar per acre per year.	Terbacil, 0.10–0.2 lb	Sinbar 80WDG[c], 2–4 oz (110)
Most annual grasses and certain small-seeded broadleaf weeds	Apply after plants are fully dormant in the fall or in early winter. Do not exceed 6 pints per acre per season.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)
Preemergent with some burndown activity			
Broadleaf weeds, such as wild or field pansy	May be applied only if field was planted in the spring (not the fall). A maximum of 3 oz per acre of Chateau may be applied per calendar year.	Flumioxazin, 1.5 oz	Chateau WDG, 3 oz (—)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergent			
Emerged annual grasses and certain perennial grasses Clethodim (Select) controls annual bluegrass, but will not consistently control goosegrass	See "New Plantings—Summer through Early Fall" for comments.	Clethodim, 0.094–0.125 lb	Select 2EC, 6–8 fl oz plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution) (4), ***or*** Selectmax 0.97EC, 12–16 fl oz plus nonionic surfactant at 0.25% of the spray solution volume (1 qt/100 gal of spray solution) (4), ***or***
		Sethoxydim, 0.2–0.4 lb	Poast 1.5EC, 1–2 pt plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution); do not exceed 2.5 pints of Poast per acre per season (7)
BEARING YEARS—LATE WINTER OR EARLY SPRING			
Preemergent			
Annual grasses, certain broadleaf weeds	Apply to weed-free soil in the early spring. Do not apply after bloom.	DCPA, 6–9 lb	Dacthal 6F, 8–12 pt (prebloom)
Many broadleaf weeds, and suppresses or controls wild pansy	Apply to established stands of strawberries in late winter or early spring when strawberries are dormant, or in a hooded shielded spray between the rows before fruit set. Tank-mix with 2,4-D to improve the spectrum of weeds controlled in matted-row production. Oil concentrate at 1% of the spray solution (1 gal per 100 gal of spray solution) or nonionic surfactant at 0.25% of the spray solution (1 qt per 100 gal of spray solution) may be added to improve the control of emerged weeds, but also may increase the risk of crop injury. A maximum of 3 oz per acre of Chateau may be applied per calendar year.	Flumioxazin, 1.5 oz	Chateau WDG, 3 oz (—)
Annual grasses and certain broadleaf weeds	In early spring, only if not already applied the previous late fall or early winter. Do not apply to frozen ground. Do not apply from bloom through harvest. Rainfall or irrigation will increase effectiveness. Do not exceed 8 lb of Devrinol 50DF per year.	Napropamide, 2–4 lb	Devrinol 50DF, 4–8 lb (prebloom)
Most annual grasses and certain small-seeded broadleaf weeds	Apply as an alternative to fall application. Do not apply if new growth has already begun to emerge from the crowns. Do not exceed 6 pints per acre per season.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)
Postemergent			
Many emerged broadleaf weeds including dandelion	Apply to established stands in late winter or early spring when the strawberries are dormant. Do not apply unless possible injury to the crop is acceptable. Do not apply 2,4-D between mid-August and winter dormancy, as it may negatively affect flower bud formation.	2,4-D, 1–1.5 lb	Formula 40, 1–1.5 qt (—)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Certain annual and perennial broadleaf weeds in the composite and legume plant families Common annuals including galinsoga, ragweed species, common cocklebur, groundsel, pineappleweed, clover, and vetch Perennials including Canada thistle, goldenrod species, aster species, and mugwort (wild chrysanthemum)	A Special Local Needs Label [24(c)] has been approved for the use of Stinger to control weeds in strawberries in Maryland, New Jersey, Pennsylvania, and Virginia. Apply in one or two applications. When two applications are used to control susceptible hard-to-kill perennial weeds, spray the first application in the spring at least 30 days before harvest and second application at renovation, after harvest (see below). Stinger is very effective on small seedling annual and emerging perennial weeds less than 2 to 4 inches tall, but is less effective and takes longer to work when weeds are larger. Use 2 to 4 fluid ounces to control annual weeds less than 2 inches tall. Increase the rate to 4 to 8 fluid ounces to control larger annual weeds. Apply the maximum rate of 10.5 fluid ounces, in one or split into two applications to suppress or control perennial weeds, but do not exceed 10.5 fluid ounces in one year. Spray additives are not needed or required by the label, and are not recommended. Do not tank-mix Stinger with other herbicides registered for use in strawberries. Stinger is a postemergence herbicide with residual soil activity. Observe restrictions on crops that follow use of Stinger, or injury may occur from herbicide carryover.	Clopyralid, 0.047–0.25 lb	Stinger[d], 2–10.5 fl oz (30)
Emerged annual grasses and certain perennial grasses Clethodim (Select) controls annual bluegrass, but will not consistently control goosegrass.	See "New Plantings—Summer through Early Fall" for comments.	Clethodim, 0.094–0.125 lb	Select 2EC, 6–8 fl oz plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution) (4), ***or*** Selectmax 0.97EC, 12–16 fl oz plus nonionic surfactant at 0.25% of the spray solution volume (1 qt/100 gal of spray solution) (4), ***or***
		Sethoxydim, 0.2–0.4 lb	Poast 1.5EC, 1–2 pt plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution); do not exceed 2.5 pints of Poast per acre per season (7)
BEARING YEARS—RENOVATION THROUGH SUMMER			
Postemergent			
Many emerged broadleaf weeds including dandelion	Apply to established stands immediately after the last picking. Do not apply between mid-August and winter dormancy due to negative effects on flower bud formation.	2,4-D, 1–1.5 lb	Formula 40, 1–1.5 qt (—)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Preemergent			
Primarily broadleaf weeds but not pigweed species Certain grasses	Apply at postharvest renovation after old leaves have been removed but before new growth begins. If using Sinbar, another product may also be needed to control annual grasses. Use lower rates on coarse textured sandy soils low in organic matter, and higher rates on fine textured silt and clay soils high in organic matter. Do not add surfactant, oil concentrate, or any other spray additive. Certain varieties differ in their sensitivity to Sinbar. Determine varietal tolerance before spraying field. Do not apply Sinbar 80DG to soils with less than 0.5% organic matter. Do not use more than 8 ounces of Sinbar per acre per year.	Terbacil, 0.2–0.4 lb	Sinbar 80WDG[c], 4–8 oz (110)
Annual grasses and certain small-seeded broadleaf weeds	Apply after mowing, but prior to emergence of new growth. Do not exceed 6 pints per acre per season.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)
Annual grasses, certain broadleaf weeds	Apply to weed-free soil.	DCPA, 6–9 lb	Dacthal 6F, 8–12 pt (—)
Postemergent			
Certain annual and perennial broadleaf weeds in the composite and legume plant families Common annuals controlled include galinsoga, ragweed species, common cocklebur, groundsel, pineappleweed, clover, and vetch Perennials controlled include Canada thistle, goldenrod species, aster species, and mugwort (wild chrysanthemum)	A Special Local-Needs Label [24(c)] has been approved for the use of Stinger to control weeds in strawberries in Maryland, New Jersey, Pennsylvania, and Virginia. Apply in one or two applications. When two applications are used to control susceptible hard-to-kill perennial weeds, spray the first application in the spring at least 30 days before harvest and second application at renovation, after harvest (see below). Stinger is very effective on small seedling annual and emerging perennial weeds less than 2 to 4 inches tall, but is less effective and takes longer to work when weeds are larger. Use 2 to 4 fluid ounces to control annual weeds less than 2 inches tall. Increase the rate to 4 to 8 fluid ounces to control larger annual weeds. Apply the maximum rate of 10.5 fluid ounces, in one or split into two applications to suppress or control perennial weeds, but do not exceed 10.5 fluid ounces in one year. Spray additives are not needed or required by the label, and are not recommended. Do not tank-mix Stinger with other herbicides registered for use in strawberries. Stinger is a postemergence herbicide with residual soil activity. Observe restrictions on crops that follow use of Stinger, or injury may occur from herbicide carryover. For control of Canada thistle from after harvest to early fall, apply Stinger after the majority of basal leaves have emerged but prior to bud stage.	Clopyralid, 0.047–0.25 lb	Stinger[d], 2–10.5 fl oz (30)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Emerged annual weeds between rows, variable suppression of perennial weeds	Apply as a directed shields spray to control emerged weeds between the rows after crop establishment. Do not allow spray or spray drift to contact the crop or injury may result. Use shields to prevent spray contact with the crop plants. Do not exceed a spray pressure of 30 psi. Do not apply more than 3 times per season. See the label for additional information and warnings.	Paraquat, 0.5 lb	Gramoxone Inteon 2SC, 2 pt, plus nonionic surfactant at 0.25% of the spray solution volume (1 qt per 100 gal of spray solution) (21)
Postemergent			
Emerged annual grasses and certain perennial grasses Clethodim (Select) controls annual bluegrass, but will not consistently control goosegrass.	See "New Plantings—Summer through Early Fall" for comments.	Clethodim, 0.094–0.125 lb	Select 2EC, 6–8 fl oz plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution) (4), ***or*** Selectmax 0.97EC, 12–16 fl oz plus nonionic surfactant at 0.25% of the spray solution volume (1 qt/100 gal of spray solution) (4), ***or***
		Sethoxydim, 0.2–0.4 lb	Poast 1.5EC, 1–2 pt plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution); do not exceed 2.5 pints of Poast per acre per season (7)
ESTABLISHED PLANTINGS—LATE FALL DORMANT			
Preemergent			
Annual grasses, certain broadleaf weeds	Apply to weed-free soil in the fall and repeat in early spring. Do not apply after bloom.	DCPA, 6–9 lb	Dacthal 6F, 8–12 pt (—)
Annual grasses and certain broadleaf weeds including chickweed spp.	Apply in late fall through early winter (not on frozen ground) or in early spring. Do not apply from bloom through harvest. Rainfall or irrigation will increase effectiveness. Do not exceed 8 lb of Devrinol 50DF per year.	Napropamide, 2–4 lb	Devrinol 50DF, 4–8 lb (prebloom)
Many annual broadleaf weeds, but not pigweed species Certain grasses	Apply just prior to mulching in late fall to extend weed control through harvest the following spring. Use lower rates on coarse textured sandy soils low in organic matter, and higher rates on fine textured silt and clay soils high in organic matter. Do not add surfactant, oil concentrate, or any other spray additive. Certain varieties differ in their sensitivity to Sinbar. Determine varietal tolerance before spraying field. Do not apply Sinbar 80WDG to soils with less than 0.5% organic matter. Do not use more than 8 ounces of Sinbar per acre per year.	Terbacil, 0.2–0.4 lb	Sinbar 80WDG[c], 4–8 oz (110)
Most annual grasses and certain small-seeded broadleaf weeds	Apply after plants are fully dormant in the fall or in early winter.	Pendimethalin, 0.7–1.4 lb	Prowl H_2O, 1.5–3.0 pt (35)

CONTINUED

Table 6.19. Herbicides for matted-row strawberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergent			
Emerged annual grasses and certain perennial grasses Clethodim (Select) controls annual bluegrass, but will not consistently control goosegrass.	See "New Plantings—Summer through Early Fall" for comments.	Clethodim, 0.094–0.125 lb	Select 2EC, 6–8 fl oz plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution) (4), ***or***
			Selectmax 0.97EC, 12–16 fl oz plus nonionic surfactant at 0.25% of the spray solution volume (1 qt/100 gal of spray solution) (4), ***or***
		Sethoxydim, 0.2–0.4 lb	Poast 1.5EC, 1–2 pt plus oil concentrate at 1% of the spray solution volume (1 gal per 100 gal of spray solution); do not exceed 2.5 pints of Poast per acre per season (7)

a. Adding a surfactant to these herbicides may improve their effectiveness (see labels).

b. (—) indicates that days-to-harvest limitations are not specified on the label; however, use directions may limit timing to certain periods of the year or growth stages.

c. Limited to a total of 8 ounces of Sinbar applied per growing season.

d. One to two applications per year not to exceed 0.67 pint per acre per year. Make only one application in the spring.

ADDITIONAL NOTES

- All the rates in this table are given on a full-acre basis. If the material is to be banded along or over the row, use the following formula to calculate the banding rate:
  rate/A banded = rate/A broadcast x (band width in inches ÷ row spacing in inches).
- With all chemicals, follow label instructions and warnings carefully.
- Use pesticides safely. Consult label for restrictions.
- It is unlawful to use recommended chemicals for crops not covered on the label or to use chemicals not cleared for such use on strawberry plantings.
- Formulations, other than those listed, with the same active ingredient, may be labeled for the same uses.

C H A P T E R 7

Blueberries

CONTENTS

Introduction 115
Types of Plants 115
The Blueberry Plant 115
Anatomy and Morphology 115
Cold-Hardiness and Chilling Requirements 115
Pollination 116
General Considerations in Choosing a Site 116
Topography 116
Previous Crops and Field Borders 117
Soil Characteristics 117
Irrigation Availability 117
Culture 117
Soils and Soil Preparation 117
Obtaining Plants 118
Varieties 118
Planting and Establishment 122
Fertility 123
Mulching 123
Irrigation 124
Frost Protection 124
Pruning 124
Harvest and Postharvest Handling 125
Economics 126
Pests 131
Fungal and Bacterial Diseases 131
Viruses and Phytoplasmas 133
Nematodes 134
Insect and Mite Pests 134
Vertebrate Pests 154
Weeds 154
Weed Identification 154
Practices for Minimizing Weeds Between the Rows 154
Practices for Minimizing Weeds in the Rows 155
Herbicides 155
Problem Perennial Weeds 159

INTRODUCTION

Blueberries are grown throughout the Mid-Atlantic region. A large, well-organized blueberry industry is located in New Jersey where "berryland soils," a type of soil made up primarily of sand and a small amount of organic matter, are found. Other areas of the region with well-drained, low-pH soils, where native indicator plants such as wild blueberries, rhododendrons, and mountain laurel grow, are also well suited to blueberry production. Blueberries are cultivated by many growers on heavier soils with a high native pH, but special well-planned measures must be taken if production is to be successful. When the soil type is too heavy (clays or clay loams) and/or the soil is of a limestone parent material, yields will likely be low and struggles with nutrient availability and plant vigor are likely to be continual.

Blueberries are long-lived plants. The commercial life of a blueberry planting can be 50 years or longer, making it worthwhile to take the time during establishment to make sure that plant needs are being met.

TYPES OF PLANTS

Several species of blueberries are indigenous to the United States. These include the lowbush blueberry *(Vaccinium angustifolium)*, commercially important primarily in Maine and Canada; the rabbiteye blueberry *(V. ashei)*, grown commercially in the southern United States; and the highbush blueberry *(V. corymbosum)*, the commercially most widely grown blueberry in the Mid-Atlantic, the Pacific Northwest, and the Midwestern United States. The information given here pertains primarily to highbush blueberry production.

While the highbush blueberry plant is indigenous to North America, it has been grown as a domesticated commercial fruit crop for only 80 years. The original breeding work and research was conducted by Miss Elizabeth White of Whitesbog, New Jersey, and Dr. Frederick Coville, USDA botanist, shortly after the turn of the century.

THE BLUEBERRY PLANT

The highbush blueberry originated in areas with acidic soils containing high levels of organic matter and with water abundantly available from a water table only 24 inches down. This caused the blueberry to develop features that make it well adapted to this type of environment, rather than to agricultural soils.

ANATOMY AND MORPHOLOGY

The blueberry plant is a perennial, consisting of a shallow root system and woody canes that originate from the crown. The root system is very fibrous with many fine feeder roots but no root hairs. Root hairs, which most crop plants have, increase the root's surface area for water and nutrient uptake. The absence of root hairs on blueberry plants makes them very sensitive to changing soil-water conditions. In nature, blueberry plant roots are colonized by a fungal symbiont that forms mycorrhizae ("fungus roots"). This symbiotic relationship allows the plant to better absorb nutrients, particularly nitrogen, and occurs to a lesser extent when blueberry plants are conventionally cultivated. Whether this relationship occurs more frequently in organic culture is not known.

A mature cultivated blueberry bush usually has 15 to 18 canes. Growth habit varies among cultivars—some bushes grow very upright, while others have a more spreading growth habit. Fruit is borne on buds formed the previous growing season.

COLD-HARDINESS AND CHILLING REQUIREMENTS

Blueberries generally tolerate temperatures to -20°F, although some cultivar variation exists. Most highbush cultivars require 750 to 800 hours of chilling below 45°F as a prerequisite for breaking dormancy. In the Mid-Atlantic region, this requirement is usually met no later than early February. After the chilling requirement is met and temperatures begin to warm, water begins to move into plant tissues as a precursor to bud expansion. This increased water content makes the plants more susceptible to damage at low temperatures. Other types of blueberry plants such as rabbiteye and southern highbush types

have lower chilling requirements and can therefore come out of dormancy too early in the year when planted in northern areas. Blueberries, like most fruit crops, will bloom in the early spring, so choosing a site that is free of frost is important.

POLLINATION

A blueberry bush is capable of setting 100 percent of its flowers; a 70 to 80 percent set represents a commercially viable yield. Highbush varieties are moderately to highly self-fertile. However, most will benefit from cross-pollination, which can increase the number of seeds per berry, fruit size, and weight and hasten berry ripening, all of which improve yield. Therefore, abundant insect pollinators (bees) are needed to achieve optimal pollination, even in solid-block plantings of highly self-fertile varieties. Interplanting two or more highbush cultivars will often benefit fruiting characteristics.

No concrete data exist that indicate what the best arrangement of cultivars is for optimum pollination; however, alternating blocks of four rows of each cultivar is commonly suggested as a good middle ground for both pollination and cultural care considerations. Two cultivars that bloom at the same time are needed. Although cultivar-ripening periods vary, there is sufficient overlap of bloom periods to allow most cultivars to serve as pollen sources for each other.

Individual cultivars can bloom for a period of 7 to more than 20 days, depending on environmental conditions. Plants of early blooming cultivars tend to have a longer flowering period than later-blooming cultivars. The top four cultivars grown in the Mid-Atlantic region bloom in the following sequence: Weymouth (early season), Duke (early midseason), Bluecrop (midseason), and Elliott (late season). Pick-your-own farms, in particular, tend to have several cultivars to extend the blueberry-picking season.

Blueberry flowers have several characteristics that encourage cross-pollination. Inverted flowers with narrow corolla openings protect the reproductive structures from wind and rain, preventing excessive self-pollination. The heavy, sticky pollen grains cannot be wind blown, and fragrant nectar is secreted explicitly to attract insect pollinators to the open blossoms. Individual blueberry flowers remain receptive to pollen for only a few days, and adequate pollination must occur in this time for proper fruit set to occur.

Blueberry pollen is most effectively dislodged from anthers by bees that have sonicating ("buzz-pollinating") foraging behavior. These bees vibrate their wing muscles, which shakes the pollen free from the anther structures. Bumble bees (*Bombus* spp.) and the southeastern blueberry bee *(Habropoda laboriosa),* both of which are present in the Mid-Atlantic region, have this foraging behavior, while honey bees *(Apis mellifera)* do not.

Although honey bees are less efficient at pollinating blueberry flowers, they make up for this by having larger populations than non-Apis bees, whose populations fluctuate by year and are often inadequate for large plantings. As such, wild bees should not be relied upon as the sole source of pollination. Regardless of species, one rule of thumb is to have four to eight bees foraging on each blueberry plant at any given time during the warmest part of the day.

Some growers are interested in using commercial bumble bee colonies for blueberry pollination. However, not enough data are compiled to recommend this practice since commercial bumble bee colonies are currently more expensive to rent than honey bee colonies and have much smaller population sizes (fewer than 300 adults per colony).

Providing one or two strong honey bee colonies (i.e., those having 30,000 or more adult bees and six or more frames of brood) per acre of blueberries is usually sufficient. Beehives should be distributed throughout large fields to ensure adequate flower visitation. Hives should be introduced when about 5 percent of the flowers have opened, but no later than when 25 percent are at full bloom. If introduced too early, honey bees will find alternative plant sources and may prefer them over blueberry flowers until the competitive plants stop blooming. Eliminating blooming weed species in the field will help focus bee activity on blueberry plants. Pesticide use during bloom should be avoided to prevent killing bees. Once petal drop has occurred, honey bee colonies should be removed from the field.

The use of bee attractants to increase the efficacy of honey bee pollination has been given minor attention. In one study, spraying a synthetic honey bee queen mandibular pheromone increased the yield of Bluecrop by at least 6 percent and farm gate revenue by $364 per acre. Plant hormone sprays, such as gibberellic acid, have also been shown to increase fruit set in poorly pollinated blueberry fields; however, this hormone induces parthenocarpic fruit set (seedless berries), resulting in small, later maturing berries.

A bumble bee look alike, the carpenter bee *(Xylocopa* spp.), is not a good blueberry pollinator. These bees rarely visit blueberry flowers legitimately and instead pierce the flower base with their tongues to steal nectar. Such illegitimate floral visits provide little or no pollination. Compounding this problem is the fact that honey bees learn to utilize the holes made by carpenter bees, and research has shown that 80 to 90 percent of foraging honey bees may switch to flower-robbing behavior if enough carpenter bee damage to blueberry flowers has occurred. No recommendations exist for ridding a blueberry field of carpenter bees since any chemical measures taken would likely have negative impacts on legitimate pollinators as well. While actual yield loss due to carpenter bee damage has not been documented, excessive carpenter bee activity could interfere with optimal fruit set. Providing enough honey bee colonies to overcome this potential problem would be the best solution to ensure profitable blueberry yields.

GENERAL CONSIDERATIONS IN CHOOSING A SITE

Consult considerations for crops as discussed in introductory chapters. Additional points that apply specifically to blueberries are given below.

TOPOGRAPHY

Blueberries, like most fruit crops, will bloom in the early spring, so choosing a site that is free of frost, or being prepared to provide frost protection, is important. When blueberries are in full bloom, the flowers can be injured by temperatures

slightly below freezing (28°F). The earliest flowering varieties are most susceptible to frost injury, so avoid planting these on frost-prone sites.

PREVIOUS CROPS AND FIELD BORDERS

As with small fruit crops in general, avoid planting following sod since white grubs can be especially injurious to young roots. Green manure crops grown for one or two years before planting are extremely valuable for new blueberry plantings, which require a high organic matter content (5 percent is preferred). Buckwheat is a good cover crop to precede blueberries because of its ability to tolerate a low soil pH.

Frequently, wild blueberries may be found in surrounding woods or uncultivated areas. These plants can be sources of viruses and other diseases, so keep new plantings at least 500 feet from wild plants.

See Chapter 1 and later information on specific blueberry pests for more information on these subjects.

SOIL CHARACTERISTICS

Blueberry roots will not tolerate extremely dry or excessively wet soils. Blueberries will thrive in light soils that are high in organic matter and have a relatively low native pH. Blueberries fall into the category of plants known as "calcifuges," which means "lime-fleeing." While heavy (clay or clay loam) soils can be amended with organic matter to improve aeration, and high pH soils can be amended with sulfur to lower the soil pH, nutritional problems are likely to be a continual concern and plant productivity is likely to be lower than in soils that are better suited for blueberry production. When a soil too high in calcium is used for blueberry production, magnesium deficiency is a recurring problem due to competition of the nutrients for uptake. When lowering the pH of a high-pH soil, the same chemical processes that change desirable nutrients, such as iron and zinc, into plant-available forms also change elements that can be toxic, such as aluminum and manganese, into more available forms as well. In addition, blueberries are extremely sensitive to high salt concentrations. The NRAES *Highbush Blueberry Production Guide* has an excellent in-depth discussion on calcium levels and suitability of soils for blueberry production and should be consulted for further information (see Appendix E for ordering information).

IRRIGATION AVAILABILITY

Blueberries are very sensitive to fluctuating soil moisture levels due to their shallow root systems and fine roots. Long-term damage to the plants' fine root system is possible when roots die off during dry spells. Therefore, installing trickle irrigation is highly recommended in plantings. While overhead irrigation for frost protection is not needed in every year, having it available is prudent.

CULTURE

SOILS AND SOIL PREPARATION

When choosing a site for blueberry production, begin soil testing and soil preparation one to two years before you plan to plant (see Appendix B for a listing of laboratories in the region). Few areas in the Mid-Atlantic region can support blueberries without a considerable amount of soil amending prior to planting. The best soils for blueberries are sandy loams that are moist, porous, and acidic. Soil pH should be between 4.5 and 5.0. A lower soil pH can result in manganese or aluminum toxicity; a higher pH results in the unavailability of certain nutrients, most notably iron. In southern New Jersey where highbush blueberries originally grew, soils are usually sandy loams, the water table is shallow, organic matter is high, and the soil pH is naturally between 4.3 and 5.0. Most areas outside of southern New Jersey do not have these soil characteristics, so soil must be amended and plantings must be mulched and irrigated. Even the best of soils will often have no more than 2 percent organic matter and common limestone and clay soils tend to be more alkaline than is needed for blueberries. Because most blueberry cultivars are not well adapted to heavy upland soils, most soils will require considerable amendment with organic matter if plants are to thrive. Organic matter content can be increased by growing cover crops for two or more successive years prior to planting the blueberries on the site intended. Crops such as sudangrass, hairy vetch, and rapeseed will all contribute needed organic matter if plowed under when green. For a complete discussion of preplant cover crops, see Chapter 2. Manure can be applied, but it should be composted or applied well ahead of planting to allow time for salts to be leached.

Added sulfur is generally recommended to lower soil pH, but sulfur needs to be incorporated thoroughly to be effective throughout the rooting zone. The amount of time required to lower the soil pH varies with the acidifying material used. The reaction of elemental sulfur (also known as ground or powdered sulfur) with the soil is dependent on soil microorganisms, which are not active unless soil temperatures are warm. Thus, elemental sulfur applied in the fall may have little effect in lowering the soil pH until the following year, and the full effects may not be realized for at least 6 months. The time required for the soil pH to be lowered, along with the benefits of building organic matter for one or two years, is why early site selection prior to planting is important. Reactions with sulfate forms such as iron sulfate take place regardless of soil temperature as microorganisms are not needed for soil reactions to take place.

See Table 7.1 for the amount of sulfur required to adjust your soil pH levels. Sulfur is most frequently available in a powdered form, but it is difficult to work with in this state, so some growers apply it as a slurry. Pelletized sulfur is relatively easy to manage. Because sulfur does not move through the soil readily, surface sulfur applications after the plants are in place are relatively ineffective for lowering the pH. Lowering the soil pH only in the plant row is also unadvisable because soil interactions with the high-pH soil in the row middles will make maintaining the proper pH within the row difficult. Thus, incorporating sulfur throughout the blueberry field is recommended. Iron sulfate may also be used at four to six times the rate in the table for elemental sulfur. Do not use aluminum sulfate to lower the soil pH because aluminum is toxic to blueberries and is already present in many soils in the region in quantities that can

negatively impact blueberry plants once the pH is lowered.

For organic production, select a site that has a soil pH as close to the ideal range (between 4.5 and 5.0) as possible. Fewer options may exist for lowering the soil pH as compared to conventional production. Options may include peat moss, pine bark, organic cottonseed meal, and sulfur. Working closely with your certifying agency when considering options is best to ensure organic certification is not compromised.

At least one year before planting, eliminate all noxious weeds (see "Controlling Weeds"). Phosphorus (if needed) should be added the fall before planting. Potassium can be added either in the fall or spring.

OBTAINING PLANTS

Blueberries may be purchased as one-year-old cuttings, as two- or three-year-old bare-root plants, or as potted plants. Generally, two-year-old plants are the best buy. One-year-old cuttings require very close management or mortality will be high, and the larger size of the three-year-old plants is often not worth the extra cost. Potted plants are often more expensive as well, but many growers find that the plants establish much more quickly. As long as plants are not pot bound and effort is made to ensure good root-soil contact at planting, potted plants are a reasonable though expensive alternative. If the plant is pot bound, the root ball must be cut so that the roots will branch once the plant is placed in the hole. Remove the pot and place the plant on its side. Then, cut through the perimeter of the root mass four to six times, rotating the root ball between each cut. Cuts should be evenly spaced around the perimeter of the root mass.

For organic production, planting stock does not need to be organically produced since blueberries are perennial crops. However, the planting must be managed organically on a certified organic area for one year before harvested berries can be marketed as organic. Since harvesting newly planted blueberries the first year after planting is not recommended, this generally does not affect marketing.

The number of plants required per acre at various spacings is given in Table 7.2. For a list of nurseries from which to order blueberry plants, consult Appendix C.

Table 7.1. Amount of sulfur required to lower the soil pH.*

	Target pH of Soil					
	4.5			5.0		
Present pH of Soil	Sand	Loam (lbs/acre)	Clay	Sand	Loam (lbs/acre)	Clay
4.5	0	0	0	—	—	—
5.0	175	520	610	0	0	0
5.5	350	1,050	1,130	175	520	610
6.0	520	1,520	1,610	350	1,050	1,130
6.5	650	2,000	2,090	520	1,520	1,610
7.0	830	2,530	2,610	650	2,000	2,090
7.5	1,000	3,010	3,090	830	2,530	2,610

*Iron sulfate may be used at four to six times the above rates (see text).

Table 7.2. Number of blueberry plants required per acre at various spacings.

	Between Rows				
In Rows	8 feet	9 feet	10 feet	11 feet	12 feet
4 feet	1,361	1,210	1,089	990	908
5 feet	1,089	968	870	792	726
6 feet	908	807	726	660	605

Example: At a spacing of 5 feet x 10 feet, 870 plants are needed per acre.

VARIETIES

Appropriate cultivar selection is crucial for any perennial crop. Blueberry cultivars can be selected so they can be harvested from July through mid-September, if so desired. Cultivars are discussed below in order of ripening and are subgrouped as "standard cultivars" and "recent cultivars." Standard cultivars are those on which long-term data on production are available. "Recent" cultivars may have been available for many years, but because of the longevity of blueberry plantings and the time it takes to evaluate new cultivars or plant availability, there still is not much information on their performance. However, some truly are recent—released in the last few years as of this writing. All of the cultivars in the "recent" category are currently recommended for trial only.

Early Season

Standard Cultivars

BLUETTA

- Bush is compact, low growing, and of medium vigor.
- Fruit is medium sized, soft, and blue-black with fair flavor.
- Stem scars tend to be broad; fruit can hang for a long time.
- Consistent production may be a problem.
- Winters well and does not break dormancy too early.
- Moderately resistant to mummy berry disease; highly susceptible to anthracnose and red ringspot virus.

CHANTICLEER

- Released in 1997.
- Very early, but the early bloom time can increase susceptibility to spring frosts.
- Yields tend to be biennial.
- Very good flavor.
- Early plantings not deemed successful by growers.
- Needs a well-drained soil.
- Slightly susceptible to anthracnose.
- Average resistance to both phases of mummy berry.

EARLIBLUE

- Bush is vigorous, upright.
- Fruit is large, firm, and light blue with fair flavor.

- Not recommended commercially in many areas because of erratic fruit set.
- Fruit does not drop easily when ripe.
- Plants have some resistance to powdery mildew.
- Especially susceptible to phomopsis twig blight and fusicoccum canker.
- Relatively susceptible to anthracnose.
- Average resistance to mummy berry blight; relatively susceptible to mummy berry fruit infection.

POLARIS

- A cold-hardy half-high release from Minnesota (1996).
- Moderate productivity and average berry size, but has very good flavor and aroma.
- Not self-pollinating.
- Susceptible to anthracnose.
- Average resistance to both phases of mummy berry.

WEYMOUTH

- Old variety (from 1936) that has been widely grown.
- Fruit is relatively dark, a bit soft, of average size, and has a mild, sweet flavor.
- Resistant to many diseases, except phomopsis.
- Relatively resistant to anthracnose.
- Average resistance to mummy berry blight; relatively susceptible to mummy berry fruit infection.

Recent Releases

HANNAH'S CHOICE

- Vigorous, upright bush.
- Released in 2000.
- Fruit has superior firmness, sweetness, and flavor with peachy overtones.
- Large first-pick berries, with some size decrease in later picks.
- Relatively resistant to anthracnose.
- Average resistance to both phases of mummy berry.
- Less productive in some areas than others.

Early Midseason

Standard Cultivars

BLUEHAVEN

- Bush is upright and productive but not sufficiently hardy for northern areas.
- Berry is large, light blue, and exceptionally flavorful.
- Scar is small and dry.
- Relatively resistant to anthracnose.
- Highly susceptible to mummy berry blight; average resistance to mummy berry fruit infection.

BLUEJAY

- Bush is vigorous, upright, and open.
- Berries are long stemmed and hang in loose clusters; they hold on to the bush without losing their quality and until most are ripe.
- Fruit is of medium size.
- Berries are firm and light blue with a small stem scar.
- Wood and buds are resistant to low winter temperatures.
- Flowers are less resistant to frost than Bluecrop.
- Average resistance to anthracnose.
- Resistant to both phases of mummy berry.
- Field resistant to shoestring virus.
- Production is sometimes erratic.

BLUERAY

- Plant is vigorous and propagates easily.
- Fruit is borne on small, tight clusters and canes tend to bend over, making it difficult to harvest mechanically; tight clusters can cause berries to drop, especially in hot weather.
- Berries are large, dark blue, and firm with medium scar and excellent flavor.
- Consistently productive, but may overproduce if not pruned properly.
- Upright habit; very hardy.
- Highly susceptible to mummy berry disease and anthracnose; also susceptible to red ringspot virus.

COLLINS

- Ripens about 5 to 7 days after Earliblue.
- Susceptible to winter injury.
- Bush is vigorous and upright with some spreading canes.
- May not sucker freely.
- Fruit is large, firm, light blue, and has very good flavor and a small scar.
- Has narrow soil adaptation and produces only moderately.

DUKE

- A vigorous, upright bush bearing medium-sized, light-blue, firm fruit with a small dry scar.
- Blooms late, avoiding early frosts, but ripens relatively early, slightly after Bluetta.
- Plant has numerous canes that are stocky and moderately branched.
- Buds and wood tolerate fluctuating winter temperatures well.
- Harvest can be completed in two or three pickings.
- Flavor is mild but is said to improve in storage.
- Moderately resistant to anthracnose.
- Good resistance to mummy blight (primary shoot infection); moderately susceptible to mummy berry fruit infection.
- Stem blight problems have been documented.

IVANHOE

- Vigorous, upright bush with numerous stocky, moderately branched canes.
- Medium-sized light-blue fruit with good to excellent flavor.
- Buds and wood tolerate fluctuating winter temperatures well.
- Moderately resistant to anthracnose; good resistance to mummy blight (primary shoot infection); moderately susceptible to mummy berry fruit infection.
- Consistent yields in small-scale New Jersey test plot.

NUI

- Produces a very high-quality, large berry.
- Winter hardiness is questionable and growth is slow.
- Relatively susceptible to anthracnose.
- Resistant to mummy berry blight; relatively resistant to mummy berry fruit infection.

PATRIOT

- Plant is upright and vigorous, though only medium in height.
- Fruit is large and firm with a small dry scar and excellent flavor.
- Developed in Maine and has excellent cold hardiness, but blooms early and is subject to frost.
- Resistant to root rot.
- Average resistance to anthracnose.

- Average resistance to mummy berry blight; relatively resistant to mummy berry fruit infection.

REKA

- An introduction from New Zealand.
- Upright, very vigorous habit that has been very productive where grown.
- Trial results in PA indicate potential for high yields.
- Berries are small with a spicy flavor.
- This cultivar's outstanding characteristic is that it appears to be very adaptable to a wide range of soil types.
- Average resistance to anthracnose.
- Relatively resistant to both phases of mummy berry.

SPARTAN

- Plants are vigorous, upright, and open.
- Fruits are large, firm, light blue, and highly flavored.
- Plant performs poorly on amended upland soils.
- Blooms late, but harvests relatively early; late bloom date helps prevent frost injury.
- Relatively susceptible to anthracnose.
- Average resistance to both phases of mummy berry.

SUNRISE

- Moderately vigorous bush with taller, easily managed structure.
- Fruit is similar to that of Bluetta in size and color, but scar and firmness are superior.
- Very good flavor.
- Preliminary data from PA trial indicate potential.
- Suitable for commercial packing and pick-your-own.
- Average resistance to anthracnose.
- Average resistance to both phases of mummy berry.
- Resistant to red ringspot virus.

Recent Releases

DRAPER

- Released in 2004 from the breeding program at Michigan State.
- Ripens with Duke, but with better flavor.
- Relatively susceptible to mummy berry blight.

PINK CHAMPAGNE

- A specialty selection, not intended for mainstream production.
- Fruit is dark-pink and slightly smaller than that of Bluecrop.
- Good flavor and firmness.
- Sporadic yields in New Jersey related to marginal flower bud hardiness.
- May be better adapted to southerly areas.
- Fall foliage color and winter twig color have ornamental value.

SWEETHEART

- Characteristic of note is excellent flavor.
- Holds up well in storage.
- Released in 2010.
- Harvest is concentrated; do not allow to hang on bush as it develops overripe flavors.
- Tends to overcrop; cross-pollinate and prune hard to maintain size.
- Has some southern ancestry; hardiness not yet known.
- Reflowers to small degree in mild autumn, but not enough to produce a significant crop.

Midseason

Standard Cultivars

BLUECROP

- Best midseason variety presently available.
- Bush is vigorous and upright, but canes tend to be slender and whippy, which may make fruit difficult to harvest mechanically.
- Is slow to send up new canes on upland soils.
- Fruit is medium and numerous, firm, with small scars, good flavor, and is resistant to cracking.
- Consistently high production and good winter hardiness; season tends to be prolonged, requiring several harvests.
- Berries appear to be ripe (completely blue) well before full sweetness is achieved, so they need to be picked 5 to 7 days after the full blue color is present.
- Field resistant to shoestring and red ringspot virus; moderately resistant to mummy berry and powdery mildew; susceptible to anthracnose.

BLUEGOLD

- Very productive and cold hardy within the region.
- Has a very vigorous, bushy growth habit.
- Ripening is concentrated.
- Below-average to very good flavor, depending on location.
- Primary downside to cultivar is that the stem sometimes remains, or when removed the skin tears.
- Entire clusters may come off at one time.
- New growth is a golden color.
- Average resistance to anthracnose.
- Highly susceptible to mummy berry blight; relatively resistant to mummy berry fruit infection.

CHIPPEWA

- A cold-hardy half-high release from Minnesota (1996).
- Compact bushes with medium to large, light blue, firm, sweet fruit.
- For trial in areas where cold tolerance is needed.
- Relatively susceptible to anthracnose.
- Resistant to both phases of mummy berry.

ELIZABETH

- Extremely flavorful, with medium to large berries.
- No longer commercially important because of inconsistent productivity, but of interest to home gardeners because of excellent flavor.
- Resistant to anthracnose.
- Relatively resistant to mummy berry blight, relatively susceptible to mummy berry fruit infection.

LEGACY

- Has some *V. darrowi* (an evergreen blueberry native to Florida) in its background and holds its leaves through much of the winter, so its winter hardiness is suspect.
- Outstanding characteristic is extremely high yields due to a long harvest season while maintaining superior flavor and quality.
- Medium to large fruit.
- For trial only in milder or protected locations.
- Resistant to anthracnose.
- Average resistance to both phases of mummy berry.

NORTHLAND

- Fruit is of average quality and soft, so it tends not to store well.
- Plants are bushy.
- Consistently productive.
- Resistant to mummy berry.
- Relatively resistant to anthracnose.
- Average resistance to mummy berry blight; relatively resistant to mummy berry fruit infection.

PURU

- Purported to have excellent flavor and fruit quality.
- Upright, moderately vigorous bushes with light-blue, medium to large fruit.
- Winter hardiness is uncertain.
- Average resistance to anthracnose.
- Average resistance to a both phases of mummy berry.

TORO

- Vigorous, upright bush that is consistently productive.
- Fruit is large with small, dry scars and good color and flavor.
- Begins ripening with Bluecrop but has a concentrated ripening, and harvest can be completed in two pickings.
- Tolerates fluctuating winter temperatures well.
- Not very self-fertile, so should be planted with another cultivar.
- Average resistance to anthracnose.
- Relatively resistant to mummy berry blight; average resistance to mummy berry fruit infection.

Recent Releases

CARA'S CHOICE

- Released in 2000 as a specialty cultivar for exceptional fruit quality.
- Low- to moderate-sized spreading plants.
- Exceptionally firm, sweet, and flavorful.
- Medium-sized fruit.
- Moderate yield; about half that of Bluecrop.
- Moderately susceptible to anthracnose; resistant to mummy berry blight; average for mummy berry blight fruit infection.

RAZZ

- Released in 2011 as a specialty cultivar with unique raspberry flavor.
- Untested outside of NJ, where yields are approximately 75 percent of Bluecrop.
- Average in firmness, fruit continues to soften after harvest.
- Similar fruit size to Bluecrop.
- Robust upright plants.
- Relatively susceptible to anthacnose.
- Resistant to mummy berry shoot blight, average resistance to mummy berry fruit infection.
- Intended for niche markets rather than wide usage.

Mid- to Late Season

Standard Cultivars

BERKELEY

- Bush is tall, open, and spreading but tends to drop fruit, affecting the efficiency of mechanical harvesting.
- Berries are very large, light blue, firm, and store well in spite of a large stem scar.
- Flavor is only fair but sweet.
- Clusters tend to be hidden by heavy foliage, which slows hand-picking.
- Ships poorly unless picked early in ripening period.
- Production can be inconsistent.
- Winter hardiness is limited.
- Canes are very stout, sometimes making pruning difficult.
- Slow to produce new canes.
- Tends to be susceptible to fungal diseases during wet seasons; also especially susceptible to some viral diseases.
- Average resistance to anthracnose.
- Relatively susceptible to both phases of mummy berry.

BONUS

- Large fruited.
- Very little testing has been done on this cultivar.
- Average resistance to anthracnose.
- Average resistance to mummy berry blight, relatively susceptible to mummy berry fruit infection.

BRIGITTA BLUE

- Upright, vigorous, cold-hardy bush with moderate productivity.
- Fruit is large, very light blue, and firm with a small dry scar.
- Plant with other cultivars to ensure good pollination.
- Clusters are loose and ripening is concentrated.
- Excellent fruit quality and shelf life.
- Slow to "shut down" in the fall, so don't fertilize after early season.
- Resistant to anthracnose.
- Resistant to both phases of mummy berry.

CHANDLER

- Extremely large fruit ripens over a long harvest season, so this cultivar has good potential, especially for pick-your-own operations.
- Winter hardy in northeastern PA, so far.
- Very good "true blueberry" flavor.
- Average resistance to both phases of mummy berry.

DARROW

- Very large fruit on vigorous, upright plants.
- Fruit is firm with excellent flavor and can be slightly acidic.
- Average resistance to anthracnose.
- Relatively resistant to mummy berry blight, relatively susceptible to mummy berry fruit infection.

NELSON

- A vigorous, upright bush.
- Fruit is large, of size similar to Spartan, firm, and light blue with very good flavor.
- Initial tests show it to tolerate cold temperatures well.
- Test-plot yields in New Jersey and Michigan have been high.
- Average resistance to anthracnose.
- Average resistance to both phases of mummy berry.

OZARKBLUE

- Very late flowering.
- Slow to produce new canes.
- Quality is similar to that of Bluecrop.
- Average resistance to anthracnose.
- Average resistance to both phases of mummy berry.

RUBEL

- A wild selection with small, firm fruit.
- Bush is erect and very productive.
- Flavor is fair.
- Fruit retains stems during drought or if harvest is delayed.
- Has higher concentrations of antioxidants than larger-fruited cultivars.
- Susceptible to stunt and resistant to red ringspot virus.
- Relatively resistant to anthracnose.
- Relatively resistant to mummy berry blight, average resistance to mummy berry fruit infection.

SIERRA

- A vigorous, upright, productive bush.
- Fruit is medium sized with a small dry scar, good color, and excellent flavor and firmness.
- Because Sierra is an interspecific hybrid of four species, its cold hardiness is unknown.
- Average resistance to anthracnose.
- Relatively susceptible to both phases of mummy berry.

Recent Releases

SUPERIOR

- A cold-hardy release from Minnesota.
- For trial in areas where cold tolerance is needed.
- Compact plants.
- Medium-sized berries with sweet to tart flavor and good firmness.
- Untrialed in the Mid-Atlantic region.

PINK LEMONADE

- A specialty selection, not intended for mainstream production.
- Fruit is bright pink and medium in size.
- Fruit has mild flavor and good firmness.
- Hardiness in colder areas unknown.
- Moderate yields, but blooms early resulting in spring frost susceptibility.
- May need to be planted with a rabbiteye cultivar for good cross-pollination.

Late Season

Standard Cultivars

COVILLE

- Bush has very vigorous spreading habit.
- Has open fruit clusters; excellent for machine harvest.
- Needs high bee concentration for best pollination.
- Berry is large, medium blue, highly aromatic, and rated highly for strong blueberry flavor.
- Does not set fruit well on occasion, which can limit its productivity.
- Narrow soil adaptation and produces only moderately.
- Fruit is relatively susceptible to anthracnose.
- Has average resistance to both phases of mummy berry.

ELLIOTT

- Almong the last to fruit of all standard cultivars.
- Bush is vigorous and upright; plants very productive and hardy.
- Berry size is small and berries are light blue with firm flesh and only fair flavor.
- Fruit can be tart and berry can be fully blue when not fully ripe, so fruit should be allowed to remain on bush after coloring.
- Interplanting with another late-blooming variety has provided cross-pollination and improved size and flavor.
- Stores well.
- Resistant to anthracnose.
- Resistant to mummy berry blight; relatively susceptible to mummy berry fruit infection.

JERSEY

- Bush is vigorous and erect with open fruit clusters and is very good for machine harvesting.
- Medium-sized, firm fruit with good color and good flavor.
- May have fruit set problems; tends to set fruit without undergoing pollination, so fruit does not size.
- Considered by some to have the sweetest flavor.
- Susceptible to fusicoccum canker.
- Relatively resistant to anthracnose.
- Resistant to mummy berry blight; average resistance to mummy berry fruit infection.

LATEBLUE

- Bush is erect, vigorous, and very productive.
- Berries are firm, light blue in color, have small stem scars, and are fine flavored but tart.
- High temperature during harvest may lead to excessive stemminess.
- Average resistance to anthracnose.
- Average resistance to mummy berry blight; relatively susceptible to mummy berry fruit infection.

Recent Releases

AURORA

- Released in 2004 from the breeding program at Michigan State.
- Ripens very late; slightly later than Elliott.
- Huge berries with excellent flavor.
- Likely to have good resistance to anthracnose and both phases of mummy berry based on parentage.

LIBERTY

- Released in 2004 from the breeding program at Michigan State.
- In PA trial, is producing more foliage than fruit.
- Berries are nice size.
- Ripens with Elliott, but with better flavor than Elliott.
- Likely to have good resistance to anthracnose and both phases of mummy berry based on parentage.

PLANTING AND ESTABLISHMENT

Plants are typically planted in the spring as soon as soil can be worked. Traditionally, moistened peat moss is added at the rate of one gallon per plant to each planting hole; however, the high cost of peat moss has resulted in the use of alternative sources of organic matter. Composted sawdust, cranberry leaves, or woodchips can also be worked into the planting hole, replacing about one-half of the original soil with the organic material. *Note:* Do not use mushroom compost because the pH of this compost is not conducive to blueberry plant growth.

Plants should be watered immediately after planting. Newly set plants will leaf out and will show a second flush of growth approximately 2 weeks later. This is an indication that the root system has begun to take up water and nutrients from the soil. The first application of fertilizer should be made at this time. Plants should be fertilized with 10 pounds of actual nitrogen per acre in the form of ammonium sulfate at 48 pounds per acre. Soils that are not naturally within the pH range of 4.5 to 5.0 should use ammonium sulfate as the first application and for the life of the planting because it helps to maintain the correct pH range and provides needed nitrogen. After this first application of fertilizer, plants should be heavily mulched along the length of the row with about 4 inches of composted sawdust or other organic matter. Avoid using fresh sawdust since it may burn the tender green stems and because it competes with the plants for nitrogen. The second application of fertilizer should be made in mid-June to supply an additional 5 to 10 pounds per

acre of actual nitrogen to the planting. Ammonium sulfate can once again be used as the nitrogen source.

Immediately after planting, prune back 25 percent of the wood and rub off all the flower buds. Also, completely remove the flowers from plants during their second year so plants become well-established. Sacrificing this small amount of fruit is well worth the dividend of establishing a planting that will fruit for 50 years or more if well-maintained. Some of the crop should also be removed the third year, again encouraging sound establishment.

Fall planting (mid- to late October) may also be done if growers wish to plant at a less busy time of the year. Success will vary depending on fall temperatures, and growers may find that some plants become heaved out of the ground. Mulching once plants are in minimizes this problem. Nitrogen fertilization should not take place until the following spring, using the rates for first and second applications given above, applied at bud break and 6 weeks later. Otherwise, follow recommendations below for care during the establishment year.

Establishing permanent sod middles between the blueberry rows is a standard recommendation. However, note that sod middles increase the incidence of disease and insect problems. Many plantings are clean cultivated to avoid these problems. Characteristics of various permanent cover crops are listed in Table 7.3 and seeding rates and nutrient and pH requirements are listed in Table 7.4. Experimentation at Penn State has shown that hard fescues perform extremely well as permanent sod covers, being slow growing, relatively noncompetitive, and tough enough to withstand traffic. Planting in the fall rather than the spring has aided in establishment. Additional tips for successfully establishing sod middles are covered under "Practices for Minimizing Weeds Between the Rows" in the weed control section.

FERTILITY

Urea and ammonium sulfate are the recommended nitrogen fertilizers. Urea can be used when the soil pH is in the target range of 4.5 to 5.0, while ammonium sulfate should be used when the pH needs to be lowered or in locations where the soil pH tends to rise. Research has shown that blueberry plants prefer the ammonium form of nitrogen. Also, blueberry plants are sensitive to nitrates, which can cause root damage at high levels. Fertilization practices recommended for the planting year are outlined in the "Planting and Establishment" section. As a rule of thumb, nonbearing plants require 20 pounds of nitrogen per acre per year, which should be split into 2 applications of 10 pounds each. Depending on soil type and growing conditions, this requirement may be as much as 30 pounds of nitrogen per season. After the plants begin bearing, tissue analysis should be used for nutrient recommendations. Fully bearing mature plants, depending on soil type and plant condition, will need about 65 pounds of nitrogen per acre. The prior season's tissue analysis (see Appendix B for a listing of labs and interpretation levels) is the best method to fine-tune your blueberry fertility program. Table 7.5 shows recommended starting points for nitrogen application rates for a blueberry planting. After the first year, nitrogen should be applied annually using half of the recommended amount per acre during bloom and the other half approximately 6 weeks later. Split application encourages efficient uptake of nutrients and produces equivalent growth to that of higher rates applied at one time early in the season. Dormant applications of fertilizer to blueberries are not recommended since very little fertilizer is taken up into the plant before the leaves are present—a greater proportion of fertilizer is more likely to be leached into the groundwater.

MULCHING

Because the blueberry plant is very sensitive to fluctuating soil moisture, mulching is essential for a healthy planting and consistent yields. Hardwood bark mulch (such as that used for landscaping), rotted sawdust, and chopped corncobs are good mulches. Mixtures of sawdust and bark mulch have been used successfully, providing better infiltration of rain than sawdust alone. Apply mulches to a depth of 4 inches and replenish whenever necessary. As previously mentioned, avoid mulches with a high pH, such as mushroom compost. Also avoid uncomposted leaves, which may be high in natural toxins. Applying uncomposted sawdust or woodchips may tie up nitrogen as the mulch decomposes. Increased amounts of nitrogen fertilizer will be required to compensate; however, predicting how much is impossible due to differences in soil type, microorganism activity, temperature, and other variables. Only leaf analysis accurately depicts nitrogen status.

Table 7.3. Relevant characteristics of various cover crops for row middles.

Cover Crop	Water Use[a]	Establishment[b]	Vigor	Durability[c]
Creeping red fescue	M	VG	L	VG
Chewings fescues	M	G	L	VG
Hard fescues	M	F	L	E
White (ladino) clover	H	F	M	F
Tall fescue	MH	G	H	E
Sudangrass hybrids	H	VG	VH	P
Kentucky bluegrass	M	G	M	G
Perennial ryegrass	M	G	M	G
Annual ryegrass	M	G	M	P
Rye (*Secale cereale*)	H	VG	H	P
Buckwheat	H	VG	H	P
Oats	H	VG	H	P

a. VH = very high; H = high; MH = moderately high; M = moderate; L = low.
b. E = excellent; VG = very good; G = good; F = fair; P = poor.
c. Tolerance to foot traffic or equipment operations.

IRRIGATION

Blueberry plants need at least 1 inch of water per week. Although either overhead or trickle irrigation can be used on blueberries, trickle both conserves moisture and supplies the plant with adequate water while avoiding an increase in foliar disease. The trickle line can be placed under the mulch so it is out of the way and, in some cases, semi-permanent. Because the small emitter holes in trickle irrigation components clog easily, the water source must be very clean (such as municipal water or clean spring), or water should be passed through a sand filter. Overhead irrigation has the advantage of cooling plants and berries when temperatures are very high. In addition, overhead irrigation can be used for frost protection.

FROST PROTECTION

Damage due to freezes and frost increases after bud break in the spring until flowering or fruit set. When blueberries are in full bloom, temperatures slightly below freezing (28°F) can injure the flowers. The exact temperature that damages flowers depends on the rate of temperature change, wind speed, humidity, sugar content of nectar, flower orientation, and so forth. Under certain conditions, open blueberry flowers can tolerate temperatures as low as 23°F. The earliest flowering varieties are most susceptible to frost injury, so avoid planting these on frost-prone sites. See Appendix A for additional general information on frost protection.

Table 7.4. Seeding rates and requirements for various seasonal and permanent cover crops for row middles.

Cover Crop	Seeding Rate (lb/A)	Seeding Time (mo)	Nutrient and pH Required[a] (N-P-K lbs/A) & pH
Creeping red fescues	70	Apr–May or Aug–Sept	60-80-40 & 6–7
Chewings fescues	75	Apr–May or Aug–Sept	60-80-40 & 6–7
Hard fescues	80	Apr–May or Aug–Sept	60-80-40 & 6-7
White (ladino) clover	15	Apr–May	10-80-60 & 6–7
Tall fescue	75	Apr–May or Aug–Sept	50-60-40 & 5–7
Sudangrass hybrids	80	June–Aug	80-40-40 & 5–7
Kentucky bluegrass	75	Apr–May or Aug–Sept	60-80-40 & 6–7
Perennial ryegrass	85	Apr–May or Aug–Sept	60-80-40 & 6–7
Annual ryegrass	60	Apr–May or Aug–Sept	60-80-40 & 6–7
Rye *(Secale cereale)*	110	May–Sept	30-60-30 & 5–7
Buckwheat	75	May–Aug	30-40-30 & 5–7
Oats	100	April or Aug	30-60-30 & 6–7

a. Nutrient requirements may be satisfied by some soils without amendments. Consult a soil test before applying fertilizers and avoid balanced fertilizers high in chloride.

Table 7.5. Postplant nitrogen recommendations for blueberries.

Age of Planting	Actual Nitrogen/A (lbs)	A.S./A[a] (lbs)	Urea/A (lbs)	A.S./plant[b] (grams)	Urea/plant[b] (grams)	A.S./plant[b] (oz)	Urea/plant[b] (oz)
0 (planting year)	see text	see text	see text	see text	see text	see text	see text
1	20	100	45	50	20	1.5	0.75
2	30	150	65	70	30	2.5	1.0
3	40	200	85	90	40	3.0	1.5
4	50	250	110	110	50	4.0	1.8
5	60	300	130	140	60	5.0	2.2
6+	65	325	140	150	65	5.5	2.5

a. A.S. = ammonium sulfate. If pH is equal to or higher than 5.0, ammonium sulfate should be used. If pH is lower than 5.0, urea can be used.

b. Assumes 5 x 9 foot spacing (968 plants per acre).

PRUNING

Understanding how a blueberry plant grows is important in order to prune correctly. Each year, canes are initiated from the base of the plant. Each succeeding year, a cane produces laterals, which produce laterals the next year and so on. Each year the lateral production on any individual cane decreases in diameter—in other words, the wood becomes progressively twiggy. As the wood becomes smaller, fruit size decreases. This is why we detail prune (remove small twiggy growth) to increase fruit size. In addition, pruning controls crop load, thus increasing fruit quality. It also invigorates plants, forcing essential new growth from the plant's base. The philosophy behind pruning is to constantly renew the older, decreasingly productive canes by cutting them out and forcing new canes. Plants are continually replacing old canes with new canes while most canes are in a productive, intermediate stage.

Pruning is best done toward the end of the dormant season, usually sometime in March. Fall pruning is not recommended because it can force plants to produce new shoots that will be killed by winter cold. In March, flower buds are easily recognizable because they are plumper than vegetative buds (Figure 7.1). For the first two growing seasons, remove all flower buds to force vegetative growth in the plant.

Keep these five basic steps in mind when approaching a bush to be pruned:

1. Assess the plant's overall vigor. Is the cane production adequate? Mature plants should produce at least three to five new canes per year. If they are not, check your fertilizer program, the pH, or for soil insects or diseases.
2. Prune out all dead wood.
3. Keep the three best one-year-old canes and remove the rest.
4. Locate the oldest canes and prune out one of every six canes, starting with the oldest. For example, if the plant has 12 canes, remove two of the oldest.
5. Prune out all low branches that will never be picked and are a source of disease.
6. Detail prune (i.e., remove as much twiggy wood as time allows).

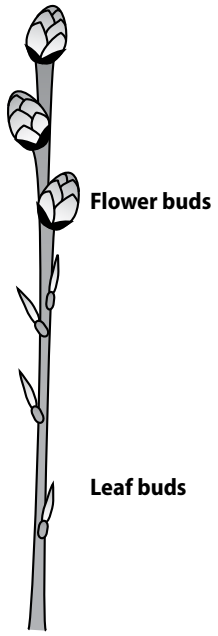


Figure 7.1. Types of buds on blueberry.

Figure 7.2 shows a mature blueberry plant before and after pruning. New shoot production is somewhat cultivar dependent, and some cultivars may not respond as well as others. Pruning with this method will produce a plant that has two to three canes each of one-, two-, three-, four-, and five-year-old canes, or ten to fifteen canes. As in any biological system, this is an optimal range and many plants will deviate from this ideal. Which canes are pruned will also need to be adjusted depending on the growth habit of the plant.

Spreading or Open Growth Habit

Most pruning of plants in this category should be directed to the outer edge of the bush. Keeping the growth habit pruned to a more erect form makes cultural operations and harvesting easier. Plants with this growth habit include Berkeley, Bluetta, Coville, Patriot, and Weymouth.

Upright or Erect Habit

Plants in this category become dense in the center. The denseness causes shading, which reduces both shoot formation and flower bud initiation. Remove the older central canes to produce a better growth situation. Bluecrop, Blueray, Collins, Darrow, Earliblue, Elliott, Herbert, Jersey, and Lateblue fall into this category.

Vigorous Varieties

These varieties yield better when "thinned out" rather than "detail" pruned (removing twiggy, one-year growth). Entirely removing older canes (six years and older) is beneficial for yield and growth, especially in Blueray, Collins, Coville, Earliblue, and Herbert.

Weak or Slow-Growing Varieties

These varieties usually produce many short, weak shoots that lack productivity. Detail pruning improves overall berry quality on remaining shoots. Systematically removing thin shoots (less than 1/8 inch in diameter) and those less than 6 inches long improves fruit quality. This is of special importance when pruning Bluetta and Weymouth.

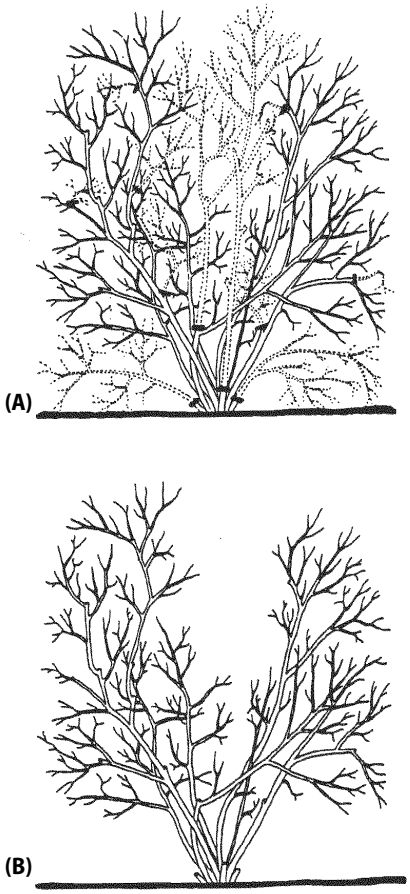


Figure 7.2. Blueberry bush before and after pruning.

(A) = mature bush showing typical annual pruning cuts (solid bars) and wood to be removed.
(B) = mature bush after pruning.
Courtesy Virginia Polytechnic Institute and State University

Special Case: Neglected Plantings

If plants have not been pruned for many years, they can be rejuvenated by cutting back all of the canes and allowing regrowth, or by cutting back half the canes in one year and half the following year. Commercial growers may prefer the latter method since it prevents a lapse in cropping.

HARVEST AND POSTHARVEST HANDLING

A well-managed mature blueberry plant can produce 6 to 10 pounds (7 to 10 pints) of fruit per year. Harvest begins in June with cultivars such as Duke, Earliblue, and Weymouth, and may continue through mid September with Lateblue. Berries turn blue 3 to 4 days before attaining maximum sweetness and flavor. Pick every 7 to 10 days. Do not pick berries with a reddish tinge because they are underripe.

Blueberries, like other fruits, should be picked in the morning after the dew has evaporated. If picked in the afternoon, the berries will more likely contain field heat, which needs to be removed in cooling. Field heat is not only expensive to remove, but the berry's heated condition makes it more susceptible to postharvest breakdown. In addition, berries should not be harvested when they are wet since the incidence of fungal problems drastically increases. After harvest, store at 32°F in 90 to 95 percent relative humidity. Under these conditions blueberries will keep for about 14 days.

ECONOMICS

The blueberry budgets given here were prepared to provide general information and do not apply to any specific operation. Use them, with appropriate modifications, as guides for preparing budgets for individual situations. Budgets can be used:

- for general farm business planning purposes
- as a basis for obtaining credit
- to project cash flows
- to assess profitability

Using these sample budgets as guides should help ensure that all costs and receipts are included in budgets you prepare for your farm. Costs are often difficult to estimate in budget preparation because they are numerous and variable. Therefore, you should think of these budgets as a first approximation and then make appropriate adjustments using the "Your Farm" column to add, delete, and adjust items to reflect your specific growing conditions and resource situation.

The sample cost-of-production budgets were developed using a computerized budget generator. Input data reflect recommended production practices and current input costs. Major subheadings in the budgets are variable costs, fixed costs, and total specified costs. They are defined as follows:

Variable costs are costs that vary depending on the level of production. These include such inputs as fertilizer, herbicides, insecticides, fungicides, and labor.

Fixed costs are costs that do not vary by level of production and are incurred by virtue of owning assets such as machinery and land. Depreciation and taxes are examples.

Total specified costs are the sum of variable and fixed costs. Most land-preparation activities are assumed to be custom hired in these budgets because the small acreages for many berry farms do not justify the ownership of these implements. If you use your own tillage equipment, the variable costs for custom hire should be subtracted from the budgets and your labor variable costs and machinery fixed costs should be substituted.

Cost-of-production budgets are presented for the year of land preparation (Table 7.6), year of planting (Table 7.7), year after planting (Table 7.8) and for a mature planting (Table 7.9).

Returns to risk and management is the estimated profit attributable to the acceptance of risk and the contribution of management expertise by the grower (Table 7.10). The table estimates the return to the grower for a range of prices and yields. Because yields, grades, and prices are so variable, growers should use representative values for their operation. It is important to account for cash flows over the life of the investment when assessing the overall profitability of the enterprise, so prorated land preparation and planting costs are subtracted from the estimates. Breakeven prices and yields are shown in the tables. Breakeven price is an estimate of the unit price required to cover all costs at a given yield; it is also the average cost per unit of production. Breakeven yield is an estimate of the yield required to cover all costs at a given price.

Berry production involves large initial investments and can be very risky; weather and animal related crop losses are common and crop prices can be highly variable. Use of whole-farm risk management tools such as AGR-Lite crop insurance can help you reduce these risks.

A land charge of $200/acre has been included in the budgets, but this charge can vary greatly from location to location. If you own the land, you could include your principal, interest payments, and property taxes as a fixed cost. If you lease the land, then the annual rental cost could be included as a variable cost.

Production assumptions used in generating the budgets include the following:

- Fumigation is not used.
- Trickle irrigation is used and water is applied to 5 acres.
- Fungicides are rotated to reduce the likelihood of disease resistance.
- The numbers of pesticide and irrigation applications are average. In any given year or location, growers will need to adjust these for their particular set of circumstances.
- Both green manure and cover crops are used to increase organic matter.
- Plants are spaced at 5 feet within the row and 10 feet between rows (870 plants per acre).
- Two-year-old (12- to 18-inch) bare-root plants are used for establishment.
- Sawdust is used as a mulch.
- Hard fescue is planted in the aisles to reduce the need for mowing.
- Berries are hand-harvested and sold retail as ready-picked berries in one-pint clamshells.

Table 7.6. Summary of estimated costs per acre, 2011: year of land preparation for blueberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Soil test	acre	10.00	1.00	10.00	
Chisel plowing	acre	16.90	1.00	16.90	
Grain drilling	acre	17.50	1.00	17.50	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	3.00	53.70	
Spread dry fertilizer	acre	9.85	2.00	19.70	
Broadcast seeding	acre	11.20	1.00	35.80	
Fertilizer					
Urea	lb	0.25	150.00	37.50	
Sulfur 90%	ton	650.00	2.00	325.00	
Seed					
Oat seed	bu	8.20	3.00	24.60	
Annual ryegrass seed	lb	0.35	30.00	10.50	
Labor	hour	12.00	0.50	6.00	
Interest on Operating Capital				6.01	
Total Variable Cost				560.61	
FIXED COST					
Total fixed cost				0.00	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				760.61	

* Fixed costs are zero in this budget because it is assumed that all field operations for land preparation are done by custom operators. Ownership of tillage equipment, grain drills, and grass seeders is not economically justified for growers engaged solely in small fruit production.

Table 7.7. Summary of estimated costs per acre, 2011: planting year for blueberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	2.00	19.70	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	1.00	17.90	
Grass seeding	acre	11.20	0.60	6.72	
Fertilizer					
Ammonium sulfate	lb	0.19	100.00	19.00	
Herbicides					
Devrinol W	lb	12.35	4.00	49.40	
Princep 90DF	lb	5.70	2.20	12.54	
Solicam 80DF	lb	27.01	2.50	67.53	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Blueberry plants	each	5.94	870.00	5,167.80	
Hard fescue seed	lb	4.30	18.00	77.40	
Sawdust mulch	acre	250.00	1.00	250.00	
Drip tape	ft	0.03	4,400.00	132.00	
Labor					
Seasonal	hour	12.00	73.28	880.50	
Operator	hour	15.00	2.17	32.50	
Diesel Fuel	gal	3.50	37.25	130.36	
Repairs and Maintenance					
Tractors	acre	26.74	1.00	26.74	
Implements and irrigation	acre	79.52	1.00	79.52	
Interest on Operating Capital				271.18	
Total Variable Cost				7,300.76	
FIXED COST					
Tractors	acre	56.10	1.00	56.10	
Implements and irrigation	acre	209.33	1.00	209.33	
Total Fixed Cost				265.43	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COST				7,766.19	

Table 7.8. Summary of estimated costs per acre, 2011: year after planting for blueberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Ammonium sulfate	lb	0.19	100.00	19.00	
Fungicides					
Lime sulfur	gal	17.86	5.00	89.30	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Poast	oz	0.84	32.00	26.88	
Princep 90DF	lb	5.70	4.40	25.08	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Blueberry plants	each	5.94	20.00	118.80	
Plant analysis kit	acre	25.00	1.00	25.00	
Labor					
Seasonal	hour	12.00	26.88	322.50	
Operator	hour	15.00	4.00	60.00	
Diesel Fuel	gal	3.50	43.26	151.40	
Repairs and Maintenance					
Tractors	acre	32.58	1.00	32.58	
Implements and irrigation	acre	86.29	1.00	86.29	
Interest on Operating Capital				35.39	
Total Variable Cost				1,173.87	
FIXED COST					
Tractors	acre	68.17	1.00	68.17	
Implements and irrigation	acre	220.93	1.00	220.93	
Total Fixed Cost				289.10	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COST				1,662.97	

Table 7.9. Summary of estimated costs per acre, 2011: mature planting of blueberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Bee rental	acre	75.00	1.00	75.00	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Ammonium sulfate	lb	0.19	325.00	61.75	
Fungicides					
Captan 80W	lb	6.99	3.00	20.97	
Indar 2F	oz	1.98	6.00	11.88	
Lime sulfur	gal	17.86	5.00	89.30	
Pristine 38WDG	oz	3.11	40.00	124.40	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Princep 90DF	lb	5.70	2.20	12.54	
Sinbar WDG	lb	48.66	2.00	97.32	
Surflan AS	gal	48.10	0.50	24.05	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Imidan 70WSP	lb	9.75	1.30	12.68	
Intrepid 2F	oz	1.71	16.00	27.36	
Malathion 8F	gal	37.50	0.63	23.44	
Other					
Plant analysis kit	acre	25.00	1.00	25.00	
Clamshell, 1 pint	each	0.14	6,000.00	840.00	
Flats, 1 pint	each	0.85	500.00	425.00	
Labor					
Seasonal	hour	12.00	44.88	538.50	
Operator	hour	15.00	7.27	109.02	
Blueberry harvest	pt	0.85	6,000.00	5,100.00	
Diesel Fuel	gal	3.50	51.69	180.90	
Repairs and Maintenance					
Tractors	acre	41.21	1.00	41.21	
Implements and irrigation	acre	92.89	1.00	92.89	
Interest on Operating Capital				206.70	
Total Variable Cost				8,314.09	
FIXED COST					
Tractors	acre	86.00	1.00	86.00	
Implements and irrigation	acre	235.38	1.00	235.38	
Total Fixed Cost				321.38	
Land Charge	acre	200.00	1.00	200.00	
Total Specified Costs				8,835.47	

Table 7.10. Returns to risk and management for blueberries, 2011.

	Yield (pt/A)					
Price ($/pint)	4,000	5,000	6,000	7,000	8,000	Breakeven yield
$2.00	$945	$1,884	$2,824	$3,763	$4,702	2,994
$2.50	$2,945	$4,384	$5,824	$7,263	$8,702	1,954
$3.00	$4,945	$6,884	$8,824	$10,763	$12,702	1,450
$3.50	$6,945	$9,384	$11,824	$14,263	$16,702	1,153
$4.00	$8,945	$11,884	$14,824	$17,763	$20,702	957
Breakeven price	$1.76	$1.62	$1.53	$1.46	$1.41	

Prorated land preparation and planting costs included based on a productive life of 25 years.
A one-pint clamshell of blueberries weighs 17 ounces.

PESTS

Pest control involves many aspects of production, and pesticide application is only one. All available practices to reduce the potential for disease and insect problems should be used. Consider site selection, crop rotation, variety selection, soil treatment, and planting stock in relation to disease and insect control before you plant.

Information on individual diseases and insects is presented below, with cultural controls discussed. Pesticide information including activity groups, efficacy, labeled uses, and restrictions are presented in tables that follow. Because avoiding buildup of resistant strains of fungi and insects is important, activity groups (for rotational use to avoid buildup of resistant strains) of fungicides and their efficacy on common diseases are presented in Table 7.11, and activity groups and efficacy of insecticides are listed in Table 7.12. Fungicides, insecticides, and miticides that can be used to assist in management are given in Table 7.13, arranged by various growth stages during the year for the crop. Pests are listed at the stages where they are most likely to be problematic or when treatment is most effective. Information in Table 7.13 should be supplemented with the reading below. Table 7.14 presents additional restrictions beyond preharvest intervals and reentry intervals that appear on the label.

FUNGAL AND BACTERIAL DISEASES

Alternaria Leaf Spot and Fruit Rot

Symptoms: Light-brown to gray spots surrounded by a reddish margin primarily on lower leaves of the plant unless infection is severe. Spots may enlarge up to 3/16 inch in diameter under conditions of high humidity. On the fruit, black or dark-green moldy growth on the blossom end of the berry appears shortly before harvest. Fruit stored at room temperature may become leaky.

Causal Agent: The fungus *Alternaria tenuissima*.

Epidemiology: The fungus overwinters on twigs and in debris on the ground. Its growth is favored by wet or humid conditions. Leaf infection is more severe during springs with prolonged periods of cool wet weather and may result in a high incidence of fruit infection. Development of fruit infections is poorly understood, but it is presumed that overripe and injured berries are particularly susceptible to decay.

Controls: Do not allow fruit to become overripe. Harvest at regular intervals (7 to 10 days). No specific control programs are recommended for this disease although a regular fungicide program using a broad-spectrum material will help. Rapidly cooling the fruit after harvest is recommended.

Anthracnose Fruit Rot

Symptoms: A slightly sunken area on the fruit surface where orange to salmon-colored ooze, which contains spores, develops. These are the most diagnostic signs of an anthracnose infection. During wet or very humid conditions, spores are dispersed in water droplets to nearby surfaces. Fruit infections often do not become apparent until after harvest and may result in rejection or greatly reduced quality and shelf life at the marketplace. The disease organism may rarely cause a blossom blight as well as brown to black leaf and stem lesions of various sizes and shapes.

Causal Agent: The fungus *Colletotrichum acutatum.*

Epidemiology: Anthracnose overwinters primarily under bud sales. Spores are produced during wet periods throughout the growing season and are distributed by splashing rains. Fruit are susceptible to infection at any time during their development. Infections that occur are not immediately apparent but remain dormant until the fruit begins to ripen.

Controls: Fungicide sprays are needed during bloom and also prior to periods of wet, warm weather from bloom until harvest. The varieties Berkeley, Bluecrop, and Coville are the most susceptible, but the disease can occur on any cultivar when conditions are favorable. Use of overhead irrigation should be minimized. Heavy nitrogen fertilization and failure to harvest ripe fruit promptly may also increase the incidence of anthracnose.

Botryosphaeria Stem Blight

Symptoms: Sudden yellowing and reddening of leaves followed by death of individual canes and eventually entire plants. Cutting a cross-section through the cane or cutting away the bark below the area with outward symptoms reveals brown dead tissue, often on just one side of the cane for as little as an inch or two, or possibly along the entire cane. Young plants are much more susceptible than older, more mature plants. In new plantings, the first symptoms include scattered plants with dead symptomatic branches. The disease is most serious in young plantings where widespread infection can kill many plants if infection takes place near the crown.

Causal Agent: The fungus *Botryosphaeria dothidea.*

Epidemiology: Infection takes place through wounds, which may be made mechanically, by injury from burndown herbicides, or by another disease organism. Symptoms begin showing 4 to 6 weeks after infection. Inoculum is spread mainly by rainfall, with most infections taking place in late spring and early summer, though inoculum is present anytime. Young tissue and plants are most susceptible.

Controls: Plants that are fertilized in August are likely to be more susceptible to winter injury as a result of not hardening off properly. This condition will lead to higher infection levels during the following growing season. Unlike phomopsis, fungicides are generally ineffective against botryosphaeria diseases, making the prompt removal of infected branches and, sometimes, whole plants the best approach. Most cultivars are susceptible; however, within the region, this disease has been observed primarily on Duke.

Botryosphaeria Stem Canker

Symptoms: Small, red lesions on green stems in the late spring that slowly grow into swollen lesions over the next 6 months. After 2 to 3 years, lesions are large, swollen, and have deep cracks. Entire stems or plants may be killed. On less susceptible cultivars, swelling may not occur and lesions are restricted in size and to the epidermis of the stem. On susceptible cultivars, cankers can girdle and kill stems as tissue is invaded.

Causal Agent: At least eight races of the fungus *Botryosphaeria corticis*, which affect different cultivars to different degrees.

Epidemiology: Only current season's growth can be infected, though progression of the disease continues within the tissue. The initial infection takes place in late spring with warm temperatures optimum for fungal growth and sporulation. Inoculum is released during wet weather and spread by wind.

Controls: Clean planting stock, isolation from infected plantings, and removal of cankers during pruning are necessary. Fungicides have not been effective in control.

Botrytis Blight

Symptoms: Green tissue, blossoms, fruit, and leaves can become infected. Tips of shoots die back and turn brown to black, eventually bleaching to a lighter tan or gray, which can be confused with winter injury. Infected blossoms appear water soaked and turn brown. This blossom blight causes the most loss. Infected immature fruits shrivel and turn bluish purple, whereas ripe, mature fruits become tan. In damp weather, all infected plant parts become covered with this fungus's characteristic "gray mold."

Causal Agent: The fungus *Botrytis cinerea.*

Epidemiology: *Botrytis cinerea* overwinters on infected plants and plant debris and is favored by cool, humid weather. Fungal spores are disseminated primarily by wind. The disease does not occur every year, instead occurring in years when conditions are favorable.

Controls: Any practice that minimizes leaf wetness such as keeping plantings pruned and weeded, and using trickle instead of overhead irrigation, will help. Refer to Table 7.13 for fungicide recommendations.

Leaf Rust

Symptoms: Yellow spots appear on the upper leaf surface in early summer that turn reddish brown. Yellow orange pustules develop on the leaf undersides in midsummer directly under these spots.

Causal Agent: The fungus *Naohidemyces vaccinii,* formerly referred to as *Pucciniastrum vaccinii.*

Epidemiology: This disease requires the presence of hemlock as an alternate host in order to complete its life cycle in northern locations. Evergreen blueberries in the South also serve in this role. Spores released from hemlocks infect blueberry leaves in late spring or early summer. Additional infections of other blueberry leaves take place within the planting during the summer. The disease survives the winter on infected blueberry leaves on the ground. Spores released from these leaves infect hemlocks in early spring, which then release the spores that infect the blueberries.

Controls: Controls are not typically needed, as yields are not reduced unless defoliation is severe. Any practices that minimizes leaf wetness such as using trickle irrigation rather than overhead and keeping plantings well pruned and weed free will help. In small plantings, removal and destruction of leaves soon after they fall may help as long if the planting is isolated from other blueberries. If only a few hemlocks are nearby, their removal may be a viable option. The current recommended distance from hemlocks for protection is 1/3 mile. Indar, Quash, and Pristine (when blueberries appear on the label; see Table 7.13 notes) are labeled for control of blueberry rust, but efficacy is unknown and timing of application for effective control could be problematic.

Mummy Berry

Symptoms: In the spring, brown, cup-shaped structures (mummy cups), ¼ inch in diameter can be found on the soil surface. About 2 weeks later, new shoots and leaves suddenly wilt. Brown discoloration develops along the upper surface of the wilted shoots and along midribs and veins of affected leaves (referred to as "strikes"). Flower buds can also be affected. All affected parts become covered with a powdery mass of fungal spores and eventually fall off of the plant. No other symptoms are apparent until the berries begin to ripen, when infected berries lighten in color and at first become soft, then shrivel, dry, and drop from the plant, usually before harvest.

Causal Agent: The fungus *Monilinia vaccinii-corymbosi*

Epidemiology: The fungus overwinters on shriveled, infected berries called "mummies." In the spring, cup-shaped fruiting bodies are produced on the mummies and release spores that infect new growth, causing a shoot blight. Spores from blighted shoots are carried by insects to open flowers along with the pollen. The fungus colonizes the developing fruit by growing into and colonizing flower ovaries. Mummy berry is most serious and widespread in the north after moist spring weather.

Controls: Several practices may help control mummy berry. Remove and dispose of fallen leaves and old berries. Cover old berries with at least 2 inches of soil by disking between rows or adding 2 inches of new mulch. An application of urea fertilizer, or a shallow cultivation of the ground between rows and beneath infected bushes before bud break, kills the exposed mushroom-like apothecia (mummy cups). See cultivar descriptions for resistance information.

Susceptible varieties include Berkeley, Bluecrop, Blueray, Earliblue, Jersey, and Weymouth. Wet sites are especially problematic. Fungicide applications made at bud break and followed up at 7- to 10-day intervals through bloom will control the disease effectively. Once the flowers have been pollinated, no further infection can take place.

Phomopsis Twig Blight and Canker

Symptoms: Usually consist of a tip dieback of about 2 to 6 inches on current-year wood and are very similar to those of winter injury. This disease can also cause cankers on stems or in the crown area that girdle and kill stems with the infection site appearing as an elongated flattened area, usually near the base of the cane. The pith appears discolored. Small, black dots, the spore-containing bodies (pycnidia) of the phomopsis fungus, can sometimes be seen within this flattened area and also on blighted twigs. As in other canker diseases, the most conspicuous symptom is "flagging" or wilting and death of individual stems during the summer with leaves turning reddish and remaining attached. Under severe disease conditions, several individual canes may be affected on a single bush. The disease also can cause a fruit rot, turning infected tissue reddish brown and soft.

Causal Agent: The fungus *Phomopsis vaccinii.*

Epidemiology: *Phomopsis vaccini* overwinters in infected plant parts. Pycnidia produce spores that are released during rainy periods and spread primarily by splashing rain. The disease infects opening buds and grows into the twigs, enters canes through wounds, or penetrates directly into the fruit. Infection can take place anytime from blossom bud swell through late summer.

Controls: Remove and burn all blighted or discolored wood during dormant pruning and whenever blighted tips appear in the summer; cut shoots back to the point that pith appears normal. Avoid planting sites that are prone to spring frosts and use fertilization, irrigation, and weed control practices that discourage late-season growth and that promote early hardening off. Certain sprays for mummy berry and botrytis may help, particularly during flowering. Fungicides active against mummy berry and botrytis may not be active against phomopsis canker and vice versa. Consult Table 7.11 for efficacy ratings.

Phytophthora Root Rot

See discussion in Chapter 8: Brambles. Causes and management are similar.

VIRUSES AND PHYTOPLASMAS

There is no cure for plants infected with viral and phytoplasma diseases. Viruses and phytoplasmas are quite different, but they are often grouped together in discussions of plant pathogens. Viruses consist only of protein and genetic material (DNA or RNA) and cannot replicate (reproduce) on their own, instead needing to infect living cells to complete the process. Phytoplasmas are essentially a type of bacteria without cell walls. Both become systemic throughout the plant. Controls can only prevent or delay the movement of viruses and phytoplasmas into the planting and will slow further spread of the disease in infected plantings.

Blueberry Scorch Virus (BBScV)

Symptoms: This virus can cause severe flower and leaf necrosis in highbush blueberry. Symptoms first appear during bloom and consist primarily of a blossom blight with necrotic leaves near blighted flower clusters. Blighted clusters fail to develop into fruit and remain on the bush through the summer. Only one or a few branches are initially affected. Bushes appear to recover as the season progresses; however, yield is reduced or eliminated. Symptoms reappear in following years with more branches affected. Plants can be killed in 3 to 6 years with all plants eventually infected. Tolerant cultivars may not show symptoms but still serve as sources of inoculum.

Epidemiology: This disease is spread by aphids; transmission from infected to uninfected plants takes place quickly (in a matter of minutes or hours). Aphid control is the best method available to stop the infection of the entire field. Virus spreads outward from the first plants infected.

Controls: Only virus-free stock should be utilized when setting out new plantings. Affected plants should be removed and burned. Aphids should be controlled to prevent spread. Bluetta, Blueray, Chanticleer, Duke, Elliott, and Weymouth are susceptible; Jersey is tolerant; and Bluecrop is intermediate.

Blueberry Shock Virus

Symptoms: Symptoms do not appear until one to two years after plants have become infected. Symptoms consist of death of blossoms and vegetative shoots just prior to bloom, first on one or two canes and then on a greater portion of the plant. A second flush of growth occurs on blighted portions of the plant. Plants exhibit symptoms for one to four years before recovering and becoming symptomless. Recovered plants resume fruiting but can continue to infect others.

Epidemiology: This virus is pollen transmitted and thus cannot be contained through vector management. This virus is endemic in production fields on the West Coast.

Controls: Locations in which shock exists in the Mid-Atlantic region have not yet been well characterized. Because infected bushes may be asymptomatic, using planting stock that has been tested and certified free of shock is the only way to be sure planting stock is clean. Removal of suspicious bushes prior to pollination is critical to prevent the virus from spreading.

Blueberry Stunt

Symptoms: Overall dwarfing of the bush is the primary symptom. Leaves are small, cupped downward, and often chlorotic. Stem internodes become shortened and growth of normally dormant buds causes twiggy branching. Infected bushes appear dense and bushy. The leaves of stunted bushes turn a bright red in early fall before normal plants begin to turn color. Fruit set is decreased. Symptoms are most noticeable after the initial flush of vegetative growth in early summer and when plants begin to turn color in the fall.

Epidemiology: This disease is caused by a phytoplasma rather than a virus, but it is often grouped under viruses. Stunt is spread by sharp-nosed leafhopper nymphs or adults. Once the leafhopper acquires the phytoplasma, the insect retains it for its entire life.

Controls: Using phytoplasma-free stock, controlling leafhoppers, and removing infected bushes are critical to control stunt. Treat bushes to be removed with an insecticide before removal. Otherwise, leafhoppers on infected bushes will only migrate to other bushes when disturbed, spreading infection further.

Red Ringspot Virus

Symptoms: Reddish-brown spots with green centers on leaves and stems. The spots, ⅛ to ¼ inch in diameter, are found on the upper surface of the leaf. Plants with this disease exhibit a loss of crop—the amount varies with variety. Powdery mildew fungus can cause similar symptoms that appear on both sides of the leaf.

Epidemiology: Unknown; however, mealybugs may be involved in transmitting this virus.

Controls: The primary form of control is to use virus-free stock and remove infected bushes. Blueray and Bluetta are especially susceptible.

Shoestring Virus

Symptoms: Elongated, reddish streaks about ⅛ by ½ to ¾ inch on current-year and one-year-old stems, especially on the side exposed to the sun. During blossoming, the flowers on infected bushes will exhibit pinkish to reddish petals. Infected leaves are often straplike, hence the name shoestring. Many leaves on a bush may appear this way, although in some cases just a few clumps near the crown will show this symptom.

Epidemiology: Shoestring is spread by the blueberry aphid. A latent period of four years occurs between infection of the plant and expression of symptoms.

Controls: Aphid control is critical to prevent the spread of shoestring. The long latent period makes identifying infected bushes before they serve as sources of inoculum impossible, so roguing is not feasible or effective. Clean planting stock is critical. Bluecrop shows resistance.

Tomato Ringspot Virus

Symptoms: Leaves are often malformed and have circular chlorotic spots on them, 1⁄16 to ⅛ inch in diameter. In addition, stems, twigs, and branches may exhibit circular, brownish necrotic spots of similar size. Younger terminal leaves tend to be strap shaped and have a mottled pattern. Fruit production may be reduced, and infected plants may eventually die.

Epidemiology: The vector for tomato ringspot virus is the dagger nematode. This virus can infect many different species of plants, including other fruit crops such as apples, peaches, and raspberries and weeds such as chickweed and dandelion. Infection spreads slowly.

Controls: The best control for this virus is to test the soil for this nematode before planting, eliminating the nematodes through chemical fumigation or biofumigation if present, and avoiding following fruit crops. Weeds should be controlled.

NEMATODES

Numerous species of nematodes have been found in association with blueberry plantings, but yield reductions in mature plantings have not been well documented. Highbush blueberries appear to have some resistance to root-lesion nematodes *(Pratylenchus penetrans)*. As vectors of the tomato ringspot and tobacco ringspot viruses, dagger nematodes *(Xiphinema* spp.) merit watching. Two years of a grass crop with excellent weed control before blueberries are planted will decrease virus inocula so that nematodes, if present, are more likely to be virus free.

INSECT AND MITE PESTS

More than 300 species of insects and mites can attack blueberries, but only a few are commercially important in the Mid-Atlantic area. Pests may be divided into two groups: those affecting the fruit (direct pests) and those affecting parts of the plant other than the fruit (indirect pests). Direct pests must be kept at very low populations because even a few can cost the grower a great deal of return on the crop. Indirect pests, on the other hand, can be tolerated to some degree because a healthy plant can withstand some feeding damage and the fruit is not directly damaged.

Managing blueberry insects and mites can be keyed to the various growth stages of the plants because insect life cycles respond to many of the same environmental cues as the plants.

In this section, blueberry insects and mites are discussed as members of either the direct or the indirect pest group. Management is discussed in terms of plant growth stages or phenology.

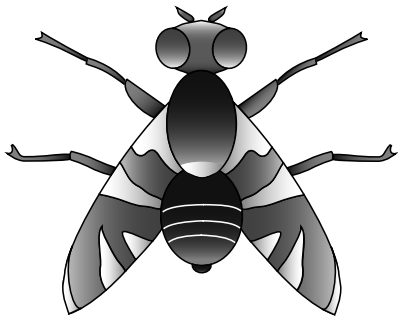
Direct Pests

Blueberry Maggot, Rhagoletis mendax *(Diptera: Tephritidae)*

Symptoms of Damage: The blueberry maggot is the major blueberry pest in the northeast and Mid-Atlantic area, but populations may vary a great deal from farm to farm. Small upland areas may not be as susceptible to injury as are those in southern New Jersey. The presence of infested fruit at harvest can bring about the condemnation of whole fields of harvested fruit. Attacked fruit is soft and mushy with a maggot inside.

Identification: The female fly is about 3⁄16 inch long, just slightly smaller than a housefly (Figure 7.3). It has a black body and one pair of clear wings marked with heavy black bands in the shape of an upside-down W. Its abdomen is black with white cross bands. Several other species of fruit flies can be confused with blueberry maggots if not inspected carefully. The larvae (maggot) is legless, has no head capsule, and starts out transparent but becomes white as it grows, reaching a length of 6 to 7 millimeters (¼ inch). The puparia in which they overwinter are ovoid, light brown, and about 3 millimeters (⅛ inch) in length.

Life Cycle: Overwintering as pupae buried in the top inch of the soil below bushes, flies first emerge from the soil in



Actual length:

(3/16 inch)

Figure 7.3. Blueberry maggot adult.

early to mid-June and continue through July and the first half of August. After emerging, adult females take about 10 days to sexually mature but live for about 30 days. During the time just after emergence, they feed on nectar, dew, and honeydew. Toward the end of this period, mating takes place and females seek large, ripened berries in which to lay eggs. The female pierces the skin of fruit with her egg-laying apparatus and deposits a single egg in each berry. Each fly may lay up to 100 eggs in a 2- to 3-week period. Upon leaving the berry, the female deposits a chemical that deters other flies from laying eggs in that berry. The eggs hatch in 2 to 7 days, and the legless larva burrows into the berry and feeds on the pulp for about 2 weeks. The mature larva then drops to the soil where it pupates and overwinters. Only one generation occurs per year, but a few pupae may remain in the soil for 2 or 3 years.

Monitoring and Controls: The potential for infestations of blueberry maggots can be assessed by trapping adults before their numbers reach damaging levels. Traps are yellow, sticky boards placed in the field and hung in the top 6 inches of the bush canopy. Traps should be hung from poles, folded, and hung in a "V" position with the yellow surface facing down. Traps should be placed at least a week before the first flies are expected to emerge (early June) and be placed at a density of 3 traps per 5 acres, though this depends on the size of the farm. For larger plantings, 1 trap per 9 to 10 acres may be sufficient. Boards are baited with a feeding attractant, either ammonium acetate or protein hydrolysates (see Appendix D for sources). Since most maggot flies will come from wild hosts outside the field, traps should be placed on field borders near wooded areas, with a few traps in the field interior. Continue trapping through harvest, replacing traps every 3 weeks or when they become clogged with insects. Each week count the flies on each trap and then remove them. Several other fly species will be trapped on the boards, along with other insects. Make sure only blueberry maggot flies are counted. If identifying species is difficult, consult an extension educator. If control is necessary, use a relatively nontoxic, short residual insecticide that does not interfere with harvest. Always check the preharvest interval for the pesticide being used. If ripe berries are present, harvest before the spray is applied. Sprays should be initiated within 10 days after the first adult catch. If using a calendar approach, continue with an application every 7 to 10 days until all unharvested fruit has dropped. Alternatively, if you use yellow sticky boards throughout the season, continue on a 7- to 10-day schedule only as long as at least one fly is caught in any trap per week. Planting early maturing cultivars that may escape blueberry maggot attack may help to minimize damage, especially for organic producers.

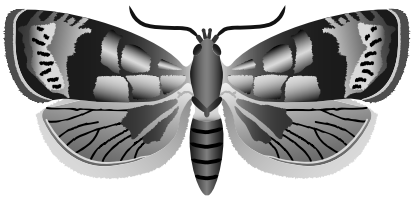
Brown Marmorated Stink Bug,* Halyomorpha halys (Stal) *(Hemiptera: Pentatomidae)

Symptoms of Damage: Direct feeding on fruit by adults and all stages of nymphs. This pest has a very wide host range. On tree fruit, fruit becomes dimpled and corky or gummy under the feeding site; on blueberries, there is little experience with this pest.

Identification: Adults are mottled brown, about ¾ inch long, and nearly as wide. They are similar in shape to other stink bugs exhibiting a shield shape. Adults can be differentiated from common brown stink bugs by alternating brown and white bands on their antennae and along the edges of their abdomens. Nymphs are smaller and, like adults, they exhibit white bands on brown antennae. Their coloration varies with instar, but each has some yellow or red coloration, and their eyes are red. Eggs are yellowish green, oval, and laid in clusters that are attached side by side on leaf undersides.

Life Cycle: One generation per year is expected in this region, but at least two can occur with warmer temperatures. Adults overwinter in protected locations and emerge in spring. They lay eggs from May through August. Nymphs progress through five instars.

Monitoring and Controls: Direct observation; other monitoring techniques are in development. Pyrethroids are the most effective chemical class. Nymphs should be targeted during pesticide applications as they cannot fly away; a direct hit of nymphs or adults is necessary for efficacy. Natural enemies are present but have a wide host range and thus currently provide insufficient control.



Actual wing span: (3/8 inch)

Figure 7.4. Cherry fruitworm adult.

Cherry Fruitworm,* Grapholita packardi *(Lepidoptera: Tortricidae)

Symptoms of Damage: Unlike cranberry fruitworms (see below), cherry fruitworms seal entrance holes with silk so that frass is not visible outside the berries. An infestation is only evidenced by prematurely blue, shrunken berries that drop to the ground. Berries are not webbed together.

Identification: Eggs are greenish white, flat, and are laid on the undersurfaces of leaves or on fruit starting in late spring. Newly hatched larvae are white with black heads, become pink with brown heads when mature, and reach ¼ inch in length. Adult moths have a wingspan of ⅜ inch and are dark gray with brown-banded wings (Figure 7.4).

Life Cycle: Cherry fruitworms overwinter as mature larvae in old pruning stubs on the bush. The moths emerge in late spring. After hatching, the larvae enter the berries. The larvae usually feed on one berry at a time and then penetrate and feed on another. Larvae require one to three berries to complete development. When feeding is complete, the larvae leave the berry to seek hibernation quarters. One generation occurs per year.

Monitoring and Controls: See cranberry fruitworm—monitoring and controls are similar, except that since webbing is not present, ascertaining presence of the pest is more difficult. Cherry fruitworm is usually less of a problem since fewer berries are required to complete development.

Cranberry Fruitworm,* Acrobasis vaccinii *(Lepidoptera: Pyralidae)

Symptoms of Damage: Characterized by berries tied together with webbing and masses of brown frass (excrement). Larvae can be found feeding in berries through late June or early July.

Identification: Adults are ½-inch-long moths with grayish-brown wings with white, triangular patches on each wing (Figure 7.5). Newly emerged moths have two white spots on each forewing. Eggs are raised and white when deposited, laid singly inside the calyx cup on the end of the berry. The larva, ½ inch long when mature, has a green body with a reddish tinge on its back and a yellowish to light-brown head.

Life Cycle: This pest overwinters as a fully grown larva in a cocoon under litter within the top ½ inch of soil under bushes. The adult moths emerge at bloom and begin laying eggs along the rim of the calyx cup. After hatching, the larva bores into the fruit at the stem end and eventually webs together several berries with silk, moving between and feeding inside as many as four berries. One generation occurs per year.

Monitoring and Controls: Because this pest is widespread in native blueberry populations, symptoms of damage are more common on rows near woods. Cranberry fruitworm infestations may be difficult to detect early. Look for a pin-sized entry hole near the stem of any small, shrunken berries that have turned blue and open adjacent berries to find the larva. The distinctive frass and webbing do not appear until later in the larva's lifetime when it begins to move between berries. In small plantings, one method of control for this pest is to pick and destroy infested berry clusters showing evidence of webbing. Repeated disking to eliminate weeds and trash also helps in control. Both cranberry and cherry fruitworms can be controlled with one to two insecticide sprays. Use pheromone traps to monitor adult emergence and place the traps when berries first come into bloom. Insecticides can be applied just after the flight peak. Another spray should be made about 10 days later if needed.

Actual wing span: (5/8 inch)

Figure 7.5. Cranberry fruitworm adult.

Cranberry Weevil, also known as the Blueberry Blossom Weevil,* Anthonomus musculus (Say) *(Coleoptera: Curculionidae)

Symptoms of Damage: Adults feed on developing leaf and flower buds. Feeding signs include the chewing of expanding buds and holes chewed in the sides of flowers. Infested flowers turn purplish, fail to open, and eventually fall to the ground.

Identification: Adults are 1/16 inch long and brown with a few white markings on the wing. The snout is about one-third as long as the body. Grubs are small, C-shaped, and have brown heads.

Life Cycle: Overwintering adults disperse into fields from wooded areas, hedgerows, weedy areas, or debris early in the spring. Like plum curculio, the cranberry weevil is active on warm, sunny days. Females lay eggs singly through the feeding holes into the developing flower somewhere along the style or anther filaments. The grubs feed throughout their growth within the flower bud in which they hatched. Pupation occurs within infested flowers and adults begin to emerge again in late May to June. The cranberry weevil has one generation per year in most of New Jersey, but a partial second generation in parts of southern New Jersey also occurs.

Monitoring and Controls: Most feeding and egg-laying activity occurs near field edges that are bordered by woodlands. Therefore, monitoring should concentrate on fields that border wooded areas. If weevils or weevil injury is found on field edges, sampling should continue into the interior of the field to define the area of weevil activity. Monitoring should start at bud swell and continue through bloom, particularly on warm, sunny days. If monitoring on a cloudy day, concentrate on weevil injury. If the day is warm and sunny, look for both injury and adult weevils. Bud injury or the presence of adults prior to bloom is particularly important to catch since insecticides cannot be applied during bloom. Treatment can be initiated anytime weevils reach a threshold of five adults per bush. Monitor with a 1 square yard beating tray and knock the bush three times; examine the tray; knock the bush three times from the other side and examine the tray again. A more reliable threshold is to scan the number of blossom clusters showing damage. Use a treatment threshold of 20 percent of blossom clusters showing damage.

Japanese Beetle,* Popillia japonica Newman *(Coleoptera: Scarabaeidae)

Symptoms of Damage: Adults will feed on leaves and fruit. A well-known pest of fruits and ornamentals, Japanese beetles feed on more than 275 host plants. Adults can also fall into picking buckets and can be found as nuisance insects in the sold product. Larvae cause damage to roots as part of the white grub complex (see "Oriental Beetle").

Identification: Adults are just under ½ inch long and metallic green to bronze with some coppery red color on the wings. Larvae are C-shaped, white grubs that feed on the root system.

Life Cycle: One generation occurs per year. Grubs that overwinter in the soil pupate in late May with adults emerging from mid-June through mid-July. Adults will live for 30 to 45 days and can be found throughout the summer. Females lay approximately 50 eggs in the soil, which hatch after 2 weeks. Larvae feed on roots until the soil temperatures cool and then remain dormant until spring.

Monitoring and Controls: When numerous, adults can be controlled with the use of broad-spectrum insecticides. Eliminating row-middle sods is helpful, especially in large plantings. Entomopathogenic nematodes are effective for larvae, but they have a limited shelf life and must be applied strictly according to directions.

Obliquebanded Leafroller,* Choristoneura rosaceana (Harris) *(Lepidoptera: Tortricidae)

Symptoms of Damage: Overwintered larvae feed on developing buds, leaves, and berry clusters. Summer larvae feed on both foliage and fruit.

Identification: Larvae are easily recognized. They are up to ⅞ inch long and robust with a green body and dark-brown to black head capsule, legs, and prothoracic shield (just behind the head capsule). Obliquebanded leafroller adults are larger than redbanded leafoller adults and are tan with a darker band of tan to brown on each front wing.

Life Cycle: Half-grown larvae overwinter under bark scales, around the crown, and in other protected places. Larvae feed for several weeks before pupating at the feeding site. Two generations occur per year. The first adults usually start to emerge by mid- to late May but may appear by late April. Eggs are laid on the foliage and hatch after 1 to 2 weeks, depending on the temperature. Summer larvae are usually found from late June through July. Second-flight adults start to appear in late July to mid-August, with larvae feeding briefly before finding overwintering sites.

Monitoring and Controls: Where first-hatch larvae are numerous, an insecticide application of a *Bacillus thuringiensis* (Bt) product, Intrepid, or Confirm may be applied during mid-bloom since these products do not have activity against bees. No other insecticides should be used at this time. Treatments are justified only when the combined number of lepidopteran pests (worms) exceeds 1 larva per 100 blossom clusters.

Plum Curculio,* Conotrachelus nenuphar (Herbst) *(Coleoptera: Curculionidae)

Symptoms of Damage: Detected by examining berries for crescent-shaped scars, starting when the berries are green. The scar develops and remains for the life of the fruit. Most infested fruit will drop off of the bush before they are harvested. However, because early season varieties like Bluetta and Weymouth are ready to harvest before the grubs are fully mature, these varieties may be picked while still infested with grubs.

Identification: The adult weevil (a type of beetle) is dark brown, ¼ inch long, and has four humps on its back and a wrinkled surface with black and white flecks. It has a long snout (one-third the body length) that projects forward and downward from its head. The larva is a legless white grub, ¼ inch long when mature, with a distinct brown head capsule.

Life Cycle: Beetles overwinter as adults under debris in woods or field margins and disperse into fields around petal fall. They disperse more heavily when temperatures exceed 70°F and slow significantly when the weather is damp and cool (below 70°F). Plum curculios are usually more prevalent on plants adjacent to woods, fence rows, and trashy fields. The females gouge out crescent-shaped depressions with their snouts when the berries are green and oviposit one egg per berry. Upon hatching, larvae burrow into the fruit where they feed on the pulp for about 2 weeks, often causing the fruit to drop. Fully grown larvae leave the fruit, burrow into the soil, and pupate within an earthen chamber. The adult emerges about 4 weeks later, from midsummer to fall. Most adults enter diapause after several weeks of feeding, but if green berries are still present, a few will mate and produce a second generation in southern regions of the Mid-Atlantic area.

Monitoring and Controls: Adult curculios are cryptic and may be difficult to see, but they can be found early in the morning or late in the evening by shaking the branches of a bush over a white cloth placed on the ground. Adults disturbed in this manner drop onto the sheet and feign death—they fold their legs tightly against the body and then remain motionless. They can easily be mistaken for debris. Because the weevil spends much of its life cycle on the ground under the bushes, frequent cultivation can aid in control. Infestations are more common in weedy fields. Some monitoring can be accomplished by using tedder traps, which are pyramid-shaped, wooden traps that attract the adult plum curculio beetle. The most reliable method of monitoring, however, is to sample newly set berries for the presence of egg scars. Early season varieties, especially if planted near wooded areas, should be monitored starting at the end of bloom. Effective control is reached through postpollination applications of insecticides. Make sure flowers have dropped in treated blocks so bees are not killed. Bluetta, Duke, Earliblue, and Weymouth are among varieties heavily attacked.

Redbanded Leafroller,* Argyrotaenia velutinana Walker *(Lepidoptera: Tortricidae)

Symptoms of Damage: First-generation larvae feed on leaves and the surfaces of young berries. Like other leafrollers, redbanded leafroller larvae produce a shelter made of leaf pieces spun together. During the early part of the season, these may be found on the tips of growing shoots and around developing blossoms or fruit clusters.

Identification: Adults have a wingspan of about ½ inch and have silver, gray, and orange markings with a prominent cinnamon-colored band across each wing. Larvae are green with a green head and prothoracic shield and are about ⅝ inch long when mature.

Life Cycle: Redbanded leafroller pupae overwinter in leaf litter and trash. Adults emerge during the early spring before flowering and deposit egg masses on bark and leaf surfaces. Three generations occur per year. The first flight can start in early April, with a second flight starting in mid-June and peaking by the end of June to early July. The third flight usually peaks by early to mid-August. Egg-laying periods occur at roughly the same times as peak trap catches.

Monitoring and Controls: Where first-hatch larvae are numerous, an insecticide application of a Bt product, Intrepid, or Confirm may be applied during mid-bloom since these products do not have activity against bees. No other insecticides should be used at this time. Treatments are justified only when the combined number of lepidopteran pests (worms) exceeds 1 larva per 100 blossom clusters.

Spotted Wing Drosophila,* Drosophila suzukii Matsumura *(Diptera: Drosophilidae)

Symptoms of Damage: Tiny white larvae found in otherwise marketable fruit. Tiny holes surrounded by sunken tissue may be found where oviposition

wounds were made. Flies may lay eggs in fruit as soon as it begins to ripen.

Identification: This pest is similar in appearance to other vinegar flies or fruit flies. Most adult males have one large black spot on each wing forward of the tip. Some other species of vinegar flies have a spot on their wings, but the spot is smaller and either at the tip or farther forward. The truly differentiating feature from other species is two black bands (sex combs) on each front leg. Adult females lack wing spots but have a large sawlike ovipositor. Larvae are 2–3 millimeters long, white, and have no obvious head.

Life Cycle: Due to this pest's recent arrival, its local life cycle is still uncharacterized. It is likely that a small number of adults will survive the winter. The pest can also be transported into the region in fruit at any time. Each female can lay between 200 and 600 eggs. Eggs hatch in 1 to 3 days depending on temperature, after which larvae feed in the fruit for 5 to 11 days. Pupation lasts for 4 to 15 days. Eight to nine generations per growing season are likely.

Monitoring and Controls: Vinegar traps can be bought or made and are used to monitor for pest presence, but they are not a method of control. Traps containing vinegar should be hung in the crop as the fruit begins to color. Pyrethroids and spinosads are efficacious on the adults; neonicotinoids and some other broad-spectrum materials are less so. See Tables 7.12 and 7.13 for more information on specific materials. Natural enemies are being found in the region, but little is known about them so far.

Indirect Pests

Aphids, Illinoia pepperi, Ericaphis *spp.,* Myzus persicae *(Sulzer) and Others*

Symptoms of Damage: Aphids suck sap out of tender new growth and plants are devitalized. Honeydew is secreted as a waste product, which acts as a substrate for sooty mold. However, it takes heavy populations to create a honeydew film and resulting sooty mold. Six species of aphids are found in New Jersey blueberries. Of primary importance is the fact that three species are known to act as vectors for blueberry scorch virus (BBScV). One aphid (*Illinoia pepperi*) can also transmit shoestring virus.

Since aphids may serve as a disease vector, they should not be tolerated in any significant numbers where BBScV is known to occur. Virus transmission under field conditions can occur from early May to mid-August when aphid populations are common.

Identification: Aphids are slow-moving insects, usually 1 to 2 millimeters long, that are usually similar in color to that of the foliage on which they feed. They have sucking mouthparts and cornicles (tubes) extending backward from their posterior. Winged forms are found in the fall.

Life Cycle: Aphids overwinter as eggs deposited on stems, small shoots, and bud scales. After the eggs hatch in the spring, females find new growth and mature into "stem mothers," giving live birth to more females. Males and egg-laying females are produced in the fall and mate. Females then lay overwintering eggs.

Monitoring and Controls: Scouting should begin during bloom and continue through the remainder of the season. Recording the percent of new growth infested with aphid colonies is one way to track aphid populations. In scorch-infested areas, only one to two aphids should define an infested leaf or terminal, and sampling should be heavily biased toward new growth. New terminal growth should be scouted as soon as bees are removed. If significant populations of aphids are present, control can be initiated with Provado at 3 to 4 ounces per acre. Treating fields with Admire for Oriental beetle will also give several weeks of aphid control. Lannate can also be used for aphid control, but it is effective only at a full 1 pound per acre, which is higher than the labeled rate for aphids. Other materials that can keep low populations in check or be used as aphid suppressants include Asana, Diazinon, and Malathion. Controlling aphids combined with removing and destroying infected bushes over a 2- to 3-year period can reduce the spread of the virus.

Blueberry Bud Mite, Acalitus vaccinni (Keifer) (Acari: Eriophyidae)

Symptoms of Damage: Heavily infested buds become reddish and roughened with bumps on the outer scales. In severe cases, buds become desiccated and fail to open. In less severe cases, fruit may be set, but berries are ruined by roughening and blistering of the skin.

Identification: The white mites are extremely small (1/125 inch) with four legs bunched toward the "head end." They are carrot shaped with the head end being the wider portion. They are confined to the buds and blossoms and are difficult to see except with a dissecting scope. Symptoms of injury are noticed first.

Life Cycle: This mite is a sporadic pest; however, it may be more likely to be a problem following mild winters. Mites spend the winter under bud scales. All stages of the life cycle are present throughout the year.

Monitoring and Controls: Pruning out old canes helps to reduce mite populations. An insecticide and/or oil application will give control. A high water volume (400 gallons per acre) and high pressure (200 pounds per acre) are needed during application.

Blueberry Gall Midge, also called the Cranberry Tipworm, Dasineura oxycoccana *(Johnson) (Diptera: Cecidomyiidae)*

Symptoms of Damage: Small holes and feeding areas around the terminal bud and developing leaves are evident when larvae are feeding. As the larvae mature, infested bud and leaf tissue will dry up, leaving a very small and blackened terminal shoot.

Identification: This is a small fly in the gall midge (Cecidomyiidae) family. The adult is just over 1½ millimeters long with a wingspread of about 3 millimeters. Larvae are tapered at both ends and legless. They mature from clear to white to yellow orange. Fully grown larvae are only 1.6 millimeters (1/16 inch) long.

Life Cycle: The insect overwinters as a pupa and emerges as an adult in early May. Eggs are laid on swelling buds and developing leaf petioles. Larvae feed deep within the terminal growth in developing terminal buds and leaf

tissue. Three larval instars occur, which can mature in as little as 9 days. A generation takes from 2 to 4 weeks to mature, depending on temperature. Therefore, four to five or more generations may occur per year in the Mid-Atlantic area.

Monitoring and Controls: Suspected damage and buds can be collected in plastic bags and watched for emerging larvae. Larvae, if present, will emerge in about 2 days. Most organophosphate materials have some effect on this insect. Recommendations for best timing of application are under investigation.

Blueberry Stem Borer,* Oberea *sp. (Coleoptera: Cerambicidae)

Symptoms of Damage: The main symptom of this beetle's damage is wilting at the tip of the shoots. As the grub bores down into the cane, the whole cane may be affected, with leaves turning red, dropping off, and then the entire cane dying.

Identification: The blueberry stem borer adult is a slender, elongated, light brown beetle. Inspection of a damaged cane may show pinholes down its length with light-yellow frass extruding from the holes. A yellowish grub will be found if the stem is split at the end of its long tunnel.

Life Cycle: This beetle deposits eggs in current season's growth near the shoot tip in June or July. The girdling of the shoot is associated with egg laying and causes the tips to wilt. The grub bores down through the shoot toward the crown of the plant, then moves to adjacent stems and continues feeding. Larvae complete their development by the spring of the third year.

Monitoring and Controls: Remove and destroy wilted tips as soon as they appear.

Blueberry Stem Gall Wasp,* Hemadas nubilipennis *(Hymenoptera: Pteromalidae)

Symptoms of Damage: A pithy gall about an inch long that forms on the stem. Galls are greenish and spongy on young shoots but become reddish-brown and hardened later. Exit holes may be present where the adults emerged from the galls.

Identification: The adult is a tiny (less than ⅛ inch long), black, shiny wasp. Larvae are grublike.

Life Cycle: This wasp deposits eggs in the current season's tender growth. Larvae develop inside the gall, exuding a growth hormone that causes the plant tissue to grow into a protective gall. Pupation occurs within the gall, after which the adult emerges.

Monitoring and Controls: Remove and destroy galls when noticed or during normal pruning.

Blueberry Tip Borer,* Hendecaneura shawiana (Kft.) *(Lepidoptera: Tortricidae)

Symptoms of Damage: Feeding results in shoot dieback and often resembles a primary infection of mummy berry.

Identification: These tiny moths emerge in early June and deposit eggs on the undersides of tip leaves. The larvae hatch and bore several inches into the soft tissue of terminal blueberry shoots.

Life Cycle: The blueberry tip borer overwinters as mature larvae inside stems.

Monitoring and Controls: The insecticides applied against fruitworms usually also control this pest.

Gypsy Moth,* Lymantria dispar *(Lepidoptera: Erebidae)

Symptoms of Damage: Caterpillars feed on tender spring foliage and can defoliate plants.

Identification: Adults are moths. Females are light colored and do not fly. Males are smaller with bands of various brown shades on the wings. Eggs masses are buff colored, oval, ½ to 1½ inches long, and velvety in appearance. Young larvae are hairy and black. Later instars are gray and hairy and have five pairs of blue dots, six pairs of red spots, and a yellow lengthwise stripe on their back. The head capsule is solid black on the first three instars and mottled on later instars.

Life Cycle: Egg masses are the overwintering stage and may contain between 100 and 1,000 eggs depending on the size. Larvae emerge in the spring and disperse on silken strands. They progress through five instars and pupate in early summer. Pupae are reddish brown and about an inch long. Pupation lasts about two weeks; adults live only long enough to mate and for the females to lay eggs.

Monitoring and Controls: Observation of overwintering egg mass size and number provides an indication of likely populations. Insecticides that target lepidopteran larvae (Bt, Confirm, etc.) are safe to predators and pollinators and are very effective if applied to instars when the head capsule is still black. Diseases and predators may decimate larval populations naturally in some years.

Oriental Beetle,* Exomala (Anomla) orientalis (Waterhouse) *(Coleoptera: Scarabaeidae)

As part of the white grub complex along with Japanese beetles, the Asiatic garden beetle, and several June beetles, the Oriental beetle is the most important as a pest in New Jersey and the Mid-Atlantic area.

Symptoms of Damage: Grubs feed on roots. Large populations will retard growth and contribute to plant death. Damage is more severe on young plantings.

Identification: Oriental beetle adults are straw colored with black markings to varying extents, though completely black or completely straw-colored beetles are also found.

Life Cycle: Oriental beetles overwinter as grubs deep enough in the soil to avoid freezing. As soil temperatures warm in the spring, the grubs move upward and resume feeding on roots. Pupation occurs in May, and adults begin emerging in early June. Peak emergence is near the end of June. Female adults lay an average of 25 eggs each. Eggs hatch into larvae (grubs) from early July though mid-August, which feed on the roots, then move downward for winter. The Oriental beetle, Asiatic garden beetle, and Japanese beetle all have one-year life cycles.

Monitoring and Controls: Beetle populations should be monitored with Japanese beetle "can traps," which are placed on the soil surface and baited with the Oriental beetle pheromone. In infested areas, traps will fill up in only a few days. Root systems that are excavated in infested areas may yield up to a dozen or more grubs per plant. Admire is currently the only insecticide that gives adequate control. Since Admire works only on first- and second-instar grubs, the applications must be made shortly after the eggs are laid and grubs are close to the soil surface. This means

that applications should be made by late June to early July for mid- to late-season varieties and immediately after harvest for early season varieties. Additional controls currently being worked on include the use of pheromone-based mating disruption and entomopathogenic nematodes.

Scales Including Putnam Scale,* Aspidiotus ancylus *(Homoptera: Diaspididae), and Terrapin Scale,* Lecanium nigrofasciatum *(Homoptera: Coccidae)

Symptoms of Damage: Decreased vigor and yields and plant decline if in high numbers. The scale insects feed on sap and secrete honeydew on which black sooty mold develops. Infested berries are undersized and unmarketable.

Identification: These insects may be common in blueberry plantings if pruning has been neglected for several years and older canes are not removed, especially if the scales' parasites and predators have been destroyed by insecticide sprays. They spend most of their lives as legless, sedentary individuals. Putnam scales, which are the scale most commonly attacking blueberry, appear as gray, waxy dots about 1⁄16 inch in diameter. Most are under loose bark on older canes, but they can also be found on leaves and fruit. An immobile yellow insect can be seen if the scale covering is removed. Terrapin scales are brown or reddish brown, are shaped like a half-sphere about 1⁄7 inch in diameter, and are marked with black bands like the shell of a turtle. They are present primarily on the canes.

Life Cycle: Depending on location, there may be one or two generations of Putnam scale per year with varying life cycles for other species. In general, eggs are laid in the spring. Crawlers emerge in spring to early summer, thereby helping the insects disperse.

Monitoring and Controls: Good scale control is accomplished first by good pruning practices. Removing and destroying old wood during pruning often does much to reduce scale populations. The second approach is to use dormant oils to smother the overwintering scales. Oil should be applied early in spring after the bud scales start to expand but before the first leaf stands out from the cluster. Cover sprays during the growing season are usually ineffective because the scales are protected by their secreted "shell." However, sprays timed to coincide with crawler emergence can be effective. Crawlers can be detected by wrapping black electricians' tape covered by double-sided sticky tape around twigs. Use a hand lens to see the active crawlers on the edge of the sticky tape.

Sharp-Nosed Leafhoppers (three species),* Scaphytopius magdalensis, Scaphytopius frontalis, *and* Scaphytopius acutus *(Homoptera: Cicadellidae)

Symptoms of Damage: All three species of sharp-nosed leafhopper, while causing little outright injury to blueberry plants, are important in blueberry culture because they can transmit the phytoplasma that causes blueberry stunt disease, for which there is no control.

Identification: The adults are brownish gray, wedge shaped, and approximately 3⁄16 inch long with a distinctly sloped and pointed extension of the head in both the nymphal and adult stages. Both *S. frontalis* and *S. acutus* have a yellowish white marking on the front of the head. This marking is missing from *S. magdalensis.* The nymphs are 1⁄16 inch long and brownish black with a white or cream hourglass-shaped mark on their backs. Leafhoppers acquire the stunt pathogen by feeding on infected plants. Only the motile adults transmit the disease to healthy plants by subsequent feeding activity. Once leafhoppers have acquired the virus, they have it for life.

Life Cycle: The leafhopper overwinters as an egg inside fallen leaves. Eggs hatch in mid- to late spring, with first-generation adults appearing by late May to early June. In the northeast and Mid-Atlantic area, two generations occur per year. Large populations often emerge in abandoned blueberry fields and in wooded habitats where blueberries and huckleberries are common in the ground cover. Adults can fly long distances and tend to disperse from the woods during the spring generation and back into the woods during the fall generation. The stunt pathogen is probably carried back and forth between commercial fields and wild reservoirs by the annual cycle of leafhopper dispersal.

Monitoring and Controls: Control of first-generation leafhoppers is usually accomplished by a petal fall cover spray for plum curculio and fruitworms. Blueberry maggot traps can be used to monitor leafhoppers and to help time an insecticide spray, if necessary. Traps should be hung vertically, yellow side out, with the bottom about 18 inches above the ground. The yellow sticky traps used for leafhoppers do not have to be baited as they are for blueberry maggot. Apply an insecticide if the leafhopper population increases sharply between one week and the next. Make sure to apply at least one insecticide for the second generation just prior to flight peak. This will normally occur shortly after the last berries have been picked, or mid to late August to early September.

Thrips,* Frankliniella *spp.

Symptoms of Damage: Thrips can significantly damage blossoms, affect fruit set, and cause curling and malformation of leaves.

Identification: Very small, cigar-shaped insects. The adults are slender, winged, about 1⁄25 inch long, and orange or yellow. Young thrips are smaller, wingless, yellowish, and active.

Life Cycle: Several species of thrips are present in blueberries. The biology and damage potential is not well understood. The flower thrips has been the most common over the last several years.

Monitoring and Controls: Thrips can be monitored with a small beating tray just prior to, during, and shortly after bloom. If treatment is justified, then Spintor (spinosad) is the material of choice. Provado will also control thrips. Lannate and Diazinon will control thrips to a much lesser extent. Of these choices, only Spintor may be used during bloom, but it is highly toxic to bees exposed to the spray before it has dried.Do not apply within 3 hours of bee activity, and if used during bloom, then apply the product in the evening after bees have stopped foraging for the day.

(Text continued on p. 154)

Table 7.11. Activity groups and effectiveness of fungicides for blueberry disease control.

Not all fungicides listed below are labeled for all the diseases listed. This table is intended to provide information on effectiveness for diseases that appear on the label and additional diseases that may be controlled from application. See Table 7.13 for labeled uses.

Fungicide	Activity Group[a]	Anthracnose Fruit Rot	Mummy Berry	Alternaria Fruit Rot	Botrytis Blight	Phomopsis Twig Blight	Phytophthora Root Rot
Abound	11	+++[b]	+++	++	++	0	0
Aliette	33	++[c]	0	0	0	0	+++
Bravo	M	++	+	+	++	0	0
Captan	M	+++	+	+	++	0	0
Captevate	17, M	+++	+	+	+++	0	0
Elevate	17	0	0	0	+++	0	0
Indar	3	0	+++	++	++	+++	0
Lime sulfur	M	++	++	++	++	++	0
Omega	29	+++	0	+++	+++	++	0
Orbit, Tilt	3	0	+++	0	0	+++	0
Phosphorous acid[d]	33	++[c]	0	0	0	0	+++
Pristine	7, 11	+++	+++	++	++	0	0
Quash	3	++	+++	++	---	+++	0
Ridomil Gold	4	0	0	0	0	0	+++
Sulforix	M	++	+	++	0	++	0
Switch	9, 12	+++	+++	0	+++	0	0
Ziram	M	+++	0	+	++	0	0

a. Chemistry of fungicides by activity groups: 3 = demethylation inhibitors (includes triazoles); 4 = acylalanines; 7 = carboxamides; 9 = anilinopyrimidines; 11 = strobilurins; 12 = phenylpyrroles; 17 = hydroxyanilides; 29 = activity group not named, chemical group = 2,6-dinitroanilines; 33 = unknown (phosphonates); M = chemical groups with multisite activity. Fungicides with two activity groups listed contain active ingredients from two activity groups.

b. 0 = not effective; + = slight effectiveness; ++ = moderate effectiveness; +++ = very effective; — = insufficient data.

c. Aliette and the phosphorous acid fungicides are not effective for prevention of anthracnose fruit rot; however, they can be used to improve storage.

d. Phosphorous acid fungicides have the same active ingredient as Aliette. These include Phostrol, Prophyte, and Rampart.

Table 7.12. Activity groups and effectiveness of insecticides and miticides on blueberry pests.

Not all insecticides listed below are labeled for all the insects listed. This table is intended to provide information on effectiveness for insects that appear on the label plus additional insects that may be controlled from application. See Table 7.13 for labeled uses. Products that are mixes of two active ingredients are not listed; activity would be expected to be similar to a tank mix.

	Activity[a] Group	Aphids	Blueberry Maggot	Bud Mite	Cranberry Weevil	Fruit-worms	Japanese Beetle Adults	Leaf-hoppers	Leaf-rollers	Plum Curculio	Scales	Spotted Wing Drosophil[b]	Thrips	White Grubs
Actara	4A	+++ [b]	+	0	+++	0	++	+++	—	+	—	—	0	—
Admire	4A	+++	+	0	—	0	+	++	—	—	—	—	0	+++
Altacor	28	—	—	0	0	+++	0	0	+++	0	0	—	0	0
Asana	3	++	++	0	+++	++	++	++	+	++	—	—	—	—
Assail	4A	+++	+++	—	—	++	++	+++	—	—	—	—	++	—
Avaunt	22	—	—	—	—	++	—	—	—	++	—	—	—	—
Aza-Direct	un	—	+	—	—	—	+	—	—	—	—	—	—	—
Brigade	3	++	++	—	—	++	—	++	++	++	++	+++	—	—
Bt Products	11	0	0	—	0	—	0	0	++	0	0	—	0	0
Confirm	18	0	0	—	0	++	0	0	+++	0	0	—	0	0
Danitol	3	—	—	—	—	+++	+++	—	+++	++	—	+++	—	—
Delegate	5	—	—	—	—	+++	—	0	+++	—	—	—	++	0
Diazinon	1B	++	++	0	++	++	0	+++	++	+++	+++	+++	+	—
Esteem	7	0	0	0	0	++	0	0	—	0	+++	—	0	0
Guthion (NJ only)	1B	—	+++	0	+++	+++	++	+++	+++	+++	++	—	—	—
Imidan	1B	—	+++	—	+++	+++	++	+++	+++	+++	++	—	—	—
Intrepid	18	0	0	0	0	+++	0	0	+++	0	0	—	0	0
Lannate	1A	++	++	—	++	+++	—	++	++	+	—	+++	+	0
Malathion	1B	+	+++	—	+	+	+	+	+	++	—	+++	++	0
M-Pede	—	++	—	—	—	—	—	+	—	—	—	—	—	—
Mustang Max	3	—	—	—	—	—	—	—	++	—	—	—	—	—
Platinum	4A	+++	—	0	—	0	—	++	—	—	—	—	0	—
Provado	4A	+++	+++	—	—	—	+++	+++	—	—	—	—	+++	—
Pyganic	3	+	+	—	—	—	+	—	—	—	—	++	—	—
Rimon	15	—	—	—	—	—	—	—	+++	—	—	—	—	—
Sevin	1A	—	+	—	+	+	+++	++	+	+	—	+	—	—
Spintor, Success, Entrust	5	—	+++	0	—	+++	0	—	+++	0	0	+++	+++	—
Superior Oil	—	++[c]	0	+	0	0	0	0	0	0	+++	—	0	0
Surround	—	—	+	—	—	—	—	—	—	++	—	—	—	—
Thionex	2A	+	0	+++	—	+	—	0	—	+	0	+	—	—

a. Chemistry of insecticides by activity groups: 1A = carbamates; 1B = organophosphates; 2A = chlorinated cyclodienes; 3= pyrethrins and synthetic pyrethroids; 4A =neonicotinoids; 5 = spinosyns; 7 = juvenile hormone mimics; 11 = Bt microbials; 15 = benzoylureas;18 = ecdysone agonists/molting disruptors; 22 = voltage-dependent sodium channel blocker; 28 = diamides

b. Dormant to delayed dormant only; effective on eggs.

c. — indicates insufficient data; +++ = good control; ++ = moderate control; + = some control; 0 = little or no control.

Table 7.13. Pesticides for blueberry disease and insect control.

Note: The recommendations below are correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. If control cannot be achieved with a particular material, it is possible that resistant populations exist. Use a material in a different activity group, which will have a different mode of action. See Table 3.2 for use status, chemical names of active ingredients, and reentry intervals. See Table 3.1 for toxicity to nontarget organisms, and Tables 7.11 and 7.12 for activity groups and efficacy ratings to help determine products that best suit your situation. See Table 7.14 for other use restrictions such as quantity allowable per season, etc. Information was current as of July 1, 2012.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
DORMANT TO DELAYED DORMANT		
Note: The severity of many diseases such as botrytis blight, phomopsis twig blight, and anthracnose and some insects such as scale and bud mite can be decreased by thoroughly pruning out old canes and/or diseased twiggy growth. Avoid excessive nitrogen fertilization, which results in succulent growth that is more subject to infection.		
Diseases		
Phytophthora root rot	Before plants begin active growth, apply to soil in a 3-foot-wide band. Make either this application, or a soil application at green tip to pink bud stage (see Budbreak through Prebloom). Ridomil is at risk for resistance development, so have an accurate diagnosis made of the need for this treatment before applying.	Ridomil Gold SL, 3.6 pt (0)
Phomopsis twig blight[b]	When dormant, prune out diseased canes and burn. Continue to remove and burn blighted wood during the season. Apply lime sulfur at sufficient volume to achieve coverage of the canes. Do not use within 14 days of an oil spray or when temperature is above 75°F. Do not mix with other insecticides or fungicides. Will also aid in control of scale insects.	Lime sulfur, 5–6 gal in 100–150 gal of diluted spray/A (—)
Mummy berry	Bury old mummies by disking before mummy cup formation. Burial of mummies (infected berries) a least 1 inch deep, and 2 inches preferably, will greatly reduce germination of mummy cups.	
Insects		
Scale	Apply oil only if scales are present and there is no danger of freezing temperatures for 2 days. Apply when buds have swollen but no green tissue is present. Good coverage is essential. Lime sulfur applied in the dormant stage for phomopsis will also aid in control of scale insects. Do not use oil within 14 days of a lime sulfur application. Pruning out old canes prevents heavy infestations.	Superior oil, 3.0 gal. Apply 250–300 gal water/A at a pressure of 300–400 psi, or follow manufacturer's recommendations for water volume and pressure to be used. Esteem 35WP at 5 oz/A may be added to the oil for increased scale control.
BUD BREAK THROUGH PREBLOOM		
Diseases		
Phytophthora root rot	Make the first soil application of Ridomil now, unless used when dormant in spring (see above). Ridomil is at risk for resistance development, so have an accurate diagnosis made of the need for this treatment before applying.	Ridomil Gold SL, 3.6 pt (0), ***or***
	Phosphorous acid products (Aliette, Phostrol, Prophyte, and Rampart) can be used as a soil application at this time, or as a foliar application if leaves are developed.	Phosphorous acid, see individual product labels

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
Mummy berry (primary infection)	Rake, sweep, or hoe under plants to disturb mummy cups through blossom period. Limited success has been achieved by applying 200 lb of 50% urea mix as a ground application as first mummy cups are formed (burns only open cups). Apply a fungicide when leaf buds show green, repeating once in 10 days. Abound, Quash, and one of the active ingredients in Pristine are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Indar, Orbit, and Tilt are in the same fungicide group (group 3) and cannot be rotated with each other for resistance management.	Indar 75WSP, 2.0 oz or 2F, 6 fl oz (30), ***or*** Orbit, 6 fl oz (30), ***or*** Tilt, 6 fl oz (30), ***or*** Pristine, 18.5–23.0 oz (0), ***or*** Quash, 2.5 oz (7), ***or*** Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Switch 62.5 WDG, 11–14 oz (0)
Anthracnose	Make this application immediately before bloom. Apply in sufficient water to cover emerging flowers and bud scales, in which anthracnose inoculum overwinters.	Omega 500F, 1.25 pt (30)
Phomopsis twig blight	When flower buds are visible but flowers are still tightly closed.	Indar 75WSP, 2.0 oz or 2F, 6 fl oz (30), ***or*** Omega 500F, 1.25 pt (30)
Insects		
Cranberry weevil	When leaf buds show green and blossom buds show white and are separating in the cluster. Do not apply within 7 days of pollination, as Asana repels bees.	Asana XL, 4.8–9.6 fl oz (14)
Leafrollers	Confirm is a selective insecticide effective against most caterpillar pests (larvae only). Confirm, Bt products, Delegate, Intrepid, and Altacor should be targeted toward early instars.	Confirm 2F, 16.0 fl oz (14), ***or*** Bt products, var. kurstaki (0), ***or*** Intrepid 2F, 16 oz (7), ***or*** Altacor, 3.0–4.5 (1)
Spanworms	These products are most effective against early instars of larvae. Rimon also affects eggs if they are laid on Rimon residues.	Confirm 2F, 16.0 fl oz (14), ***or*** Intrepid 2F, 16 oz (7)
Gypsy moth	These products are effective against larvae only. Apply these products to early instars.	Confirm 2F, 4.0–8.0 fl oz (14), ***or*** Dipel DF, 0.5–2.0 lb (0), ***or*** Intrepid 2F, 4–8 oz (7)
Ants	Ants building mounds around blueberry bushes may be a sign of mealybugs on the roots or scale insects or aphids on the bushes that produce honeydew. Make applications in early spring or summer and repeat according to label directions, if needed. Esteem is a slow-acting material that affects only the larvae.	Esteem Ant Bait, 2–4 level Tbsp per mound (1)
Plum curculio	Apply pre-bloom to newly expanded foliage.	Rimon 0.83EC, 20–30 fl oz (8)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
BLOOM		
Diseases		
Mummy berry (secondary infection)	At 7- to 10-day intervals through petal fall. This spray is designed to prevent flower infections and is necessary if primary mummy berry (shoot blight) infections were not controlled previously. Abound, Quash, and one of the active ingredients in Pristine are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Likewise, Indar, Orbit, and Tilt are in the same fungicide group (group 3) and cannot be rotated with each other for resistance management.	Indar 75WSP, 2 oz or 2F, 6 fl oz (30), ***or*** Orbit, 6 fl oz (30), ***or*** Tilt, 6 fl oz (30), ***or*** Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Quash, 2.5 oz (7), ***or*** Pristine, 18.5–23.0 oz (0), ***or*** Switch 62.5WG, 11.0–14.0 oz (0)
Botrytis	Begin application at early bloom. Combine treatments with anthracnose controls. Spray at 7- to 10-day intervals through petal fall. As of this writing, new Pristine product labels excluded use on blueberries. Growers may use old product that has blueberries on the label; new product labels are expected to be issued that once again include blueberries. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Note that although captan has a 0-day PHI, it has a longer REI for blueberries, and Captevate has a 48-hour REI.	Pristine, 18.5–23.0 oz (0), ***or*** Elevate, 1.5 lb (0), ***or*** Captevate 68WDG, 3.5–4.7 lb (0), ***or*** Switch 62.5WG, 11.0–14.0 oz (0), ***or*** Omega 500F, 1.25 pt (30), ***or*** Captan 50W, 5 lb or 80WDG, 3.125 lb (0), ***or*** Captec 4L, 2.5 qt
Anthracnose	Apply at early bloom and repeat every 7 to 10 days through immediate postbloom. Abound, Quash, and one of the active ingredients in Pristine are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Captevate has a 48-hr REI.	Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Quash, 2.5 oz (7), ***or*** Pristine, 18.5–23 oz (0), ***or*** Switch 62.5WG, 11.0–14.0 oz (0), ***or*** Omega 500F, 1.25 pt (30), ***or*** Ziram 76DF, 3 lb (—)—see special local needs label (24C) allowing 4 lb/acre rate and 14-day PHI in NJ
Insects		
Leafrollers, fruitworms	Only insecticides nonharmful to bees (e.g., Bt, Confirm, Intrepid, Altacor) can be applied during bloom. These products affect only larvae, except for Altacor, which also affects eggs.	Confirm 2F, 16 oz (14), ***or*** Dipel DF, 0.5–1.0 lb (0), ***or*** Intrepid 2F, 16 oz (7), ***or*** Altacor, 3.0–4.5 (1)
Gypsy moths	Only insecticides nonharmful to bees (e.g., Bt, Confirm, Intrepid) can be applied during bloom. These products are effective against larvae only. Apply products to early instars.	Confirm 2F, 4.0–8.0 fl oz (14), ***or*** Dipel DF, 0.5–2.0 lb (0), ***or*** Intrepid 2F, 4–8 oz (7)
Thrips	Spintor, Success, and Entrust have the same active ingredient; Entrust is labeled for organic production. All of the products listed to the right are in the same chemical class and are toxic to bees exposed to the spray before it has dried. Apply in the evening after bees have stopped foraging for the day.	Spintor 2SC or Success, 4.0–6.0 fl oz (3), ***or*** Entrust, 1.25–2.0 oz (3), ***or*** Delegate WG, 3–6 oz (3)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
AT PETAL FALL		
Diseases		
Anthracnose	This is intended to be the follow-up spray for the one applied at mid-bloom. Abound, Quash, and one of the active ingredients in Pristine are strobulirin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Captevate has a 48-hr REI.	Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Quash, 2.5 oz (7), ***or*** Captevate 68WDG, 4.7 lb (0), ***or*** Pristine, 18.5–23.0 oz (0), ***or*** Switch 62.5 WG, 11.0–14.0 oz (0), ***or*** Omega 500F, 1.25 pt (30), ***or*** Ziram 76DF, 3 lb (—)—see special local needs label (24C) allowing 4 lb/acre rate and 14-day PHI in NJ
Insects		
Cranberry or cherry fruitworm	At petal fall (May 25 to June 7 in NJ) and again 10 days later. Sprays for insects at this time will also give control of spanworms and gypsy moth. Intrepid, Delegate, Confirm, Esteem, Altacor, and Rimon are most effective against early instars of larvae. Do not use an adjuvant with Avaunt. Growers using Guthion should be aware of restrictions on use and long re-entry intervals for the general public. Guthion use on blueberries is prohibited after Sept. 30, 2012. A yearly maximum amount of 0.75 lb ai/a applies for 2012.	Intrepid 2F, 16 oz (7), ***or*** Delegate WG, 3–6 oz (3), ***or*** Confirm 2F, 16 oz (14), ***or*** Esteem 35WP, 5 oz (7), ***or*** Altacor, 3.0–4.5 (1), ***or*** Rimon, 20–30 fl oz (8), ***or*** Diazinon 50W, 1 lb or AG500, 1 pt (7), ***or*** Malathion 57EC, 1.6 pt or 8F, 1.25 pt (1), ***or*** Imidan 70W, 1.33 lb (3), ***or*** Asana XL, 4.8–9.6 fl oz (14), ***or*** Lannate SP, 0.5–1.0 lb or LV, 1.5–3.0 pt (3), ***or*** Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Avaunt, 3.5–6.0 oz (7), ***or*** Danitol 2.4EC, 10.67–16 fl oz (3), ***or*** Brigade WSB, 5.3–16.0 oz (1)
Leafrollers	Confirm, Dipel, Intrepid, Spintor, Delegate, and Altacor are most effective against early instars of larvae at petal fall (May 25 to June 7 in NJ). Danitol is labeled for obliquebanded leafroller only. In NJ, leafroller resistance to malathion has been noted.	Confirm 2F, 16 oz (14), ***or*** Dipel DF, 0.5–1.0 lb (0), ***or*** Intrepid 2F, 16 oz (7), ***or*** Spintor 2SC, 4.0–6.0 fl oz (3), ***or*** Delegate WG, 3–6 oz (3), ***or*** Altacor, 3.0–4.5 (1), ***or*** Imidan 70W, 1.33 lb (3), ***or*** Lannate SP, 1 lb or LV, 3 pt (3), ***or*** Malathion 8F, 1.25 pt (1), ***or*** Danitol 2.4EC, 10.67–16 fl oz (3), ***or*** Mustang, 4.3 oz (1), ***or*** Mustang Max, 4.0 oz (1), ***or*** Brigade WSB, 5.3–16.0 oz (1)
Plum curculio	At petal fall (May 25 to June 7 in NJ). Apply if there is a history of this pest or oviposition scars are seen on earliest forming green berries. Growers using Guthion should be aware of restrictions on use and long reentry intervals for the general public. Guthion use on blueberries is prohibited after Sept. 30, 2012. A yearly maximum amount of 0.75 lb ai/a applies for 2012.	Malathion 57EC, 2 pt or 8F, 1.25 pt (1), ***or*** Imidan 70W, 1.33 lb (3), ***or*** Surround 95WP, 25.0–50.0 lb (0), ***or*** Danitol, 10.67–16 fl oz (3), ***or*** Brigade WSB, 5.3–16.0 oz (1), ***or*** Hero, 4.0–10.3 (1)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
Thrips	Spintor, Success, and Entrust have the same active ingredient; Entrust is labeled for organic production. Spintor, Success, Entrust, and Delegate are in the same chemical class.	Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Provado 1.6F, 6.0–8.0 fl oz (3), ***or*** Spintor 2SC or Success, 4.0–6.0 fl oz (3), ***or*** Entrust, 1.25–2.0 oz (3), ***or*** Delegate WG, 3–6 oz (3)
Lecanium scale crawlers	As crawlers are detected.	Esteem 35WP, 5 oz (7)
1–2 WEEKS AFTER PETAL FALL		
Diseases		
Anthracnose	Early to mid-June, especially when weather is warm and rainy. Abound, Quash, and one of the active ingredients in Pristine are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in a different chemical class. Ziram has a 14-day PHI in NJ; however, applications should be avoided within 28 days prior to harvest due to the visibility of white residues. Captevate has a 48-hr REI.	Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Pristine, 18.5–23.0 oz (0), ***or*** Quash, 2.5 oz (7), ***or*** Captevate 68 WDG, 4.7 lb (0), ***or*** Omega 500F, 1.25 pt (30), ***or*** Ziram 76DF, 3 lb (—)—see special needs label (24C) allowing 4 lb/acre rate and 14-day PHI in NJ
Insects		
Sharpnosed leafhopper	Early to mid-June. As necessary. Sharpnosed leafhoppers transmit stunt, which is lethal to blueberries. Rogue out affected plants (refer to text discussion) and apply an insecticide when sharpnosed leafhoppers appear on yellow sticky traps.	Lannate SP, 0.5 lb or LV, 1.5 pt (3), ***or*** Asana XL, 4.8–9.6 oz (14), ***or*** Provado 1.6F, 3.0-4.0 fl oz (3), ***or*** Malathion 57EC, 2 pt or 8F, 1.25 pt (1), ***or*** Actara, 3.0–4.0 oz (3), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz, or 30SG 2.5–5.3 oz (1)
Blueberry aphids	Early to mid-June.	Lannate SP, 0.5 lb or LV, 1.5 pt (3), ***or*** Diazinon 50W, 1 lb or AG500, 1 pt (7), ***or*** Provado 1.6F, 3.0–4.0 fl oz (3), ***or*** Malathion 8F, 1.25 pt (1), ***or*** M-Pede, 1–2% v/v (0), ***or*** Actara, 3.0–4.0 oz (3), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz , or 30SG 2.5–5.3 oz (1), ***or*** ***NJ only***[d]: Asana XL, 4.8–9.6 oz (14)
Scale crawlers	As crawlers are detected.	Esteem 35WP, 5 oz (7)
LATER POSTPOLLINATION SPRAYS		
Diseases		
Anthracnose	Quash and Abound are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides per crop year. Captevate has a 48-hr REI. Watch days-to-harvest limitations for Omega.	Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Quash, 2.5 oz (7), ***or*** Omega 500F, 1.25 pt (30), ***or*** Switch 62.5 WDG, 11.0–14.0 oz (0), ***or*** Captevate 68WDG, 4.7 lb (0)
Phytophthora root rot	Several phosphorous acid products can be used. Product names include Aliette, Phostrol, Prophyte, and Rampart.	Phosphorous acid, see individual product labels

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
Insects		
Cranberry and/or cherry fruitworms	Confirm. Esteem, Spintor, Altacor, and Rimon are most effective against early Instars of larvae. Do not use an adjuvant with Avaunt. Growers using Guthion should be aware of restrictions on use and long reentry intervals for the general public. Guthion use on blueberries is prohibited after Sept. 30, 2012. A yearly maximum amount of 0.75 lb ai/a applies for 2012.	Diazinon 50W, 1 lb or AG500, 1 pt (7), ***or*** Malathion 57EC, 1.6 pt or 8F, 1.25 pt (1), ***or*** Sevin 80S, 1.87–2.5 lb or 4F, 1.5–2.0 qt (7), ***or*** Imidan 70W, 1.33 lb (3), ***or*** Asana XL, 4.8–9.6 oz (14), ***or*** Lannate SP, 0.5–1.0 lb or LV, 1.5–3.0 pt (3), ***or*** Assail 70WP, 1.9–2.3 oz, or 30SG, 4.5–5.3 oz (1), ***or*** Avaunt, 3.5–6.0 oz (7), ***or*** Danitol, 10.67–16 fl oz (3), ***or*** Confirm 2F, 16 oz (14), ***or*** Esteem 35WP, 5 oz (7), ***or*** Spintor 2SC, 4–6 fl oz (3), ***or*** Altacor, 3.0–4.5 (1), ***or*** Rimon, 20–30 fl oz (8), ***or*** Brigade WSB, 5.3–16.0 oz (1)
Leafrollers	When populations are high. Danitol is labeled for obliquebanded leafroller only. Confirm, Dipel, Spintor, Altacor, and Delegate are most effective against early instars of larvae. In NJ, leafroller resistance to malathion has been noted.	Imidan 70W, 1.33 lb (3), ***or*** Lannate SP, 1 lb or LV, 3 pt (3), ***or*** Confirm 2F, 16 oz (14), ***or*** Dipel DF, 0.5–1.0 lb (0), ***or*** Malathion 8F, 1.25 pt (1), ***or*** Spintor 2SC, 4–6 fl oz (3), ***or*** Sevin 80S, 2.5 lb or 4F, 2.0 qt (7), ***or*** Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Mustang, 4.3 oz (1), ***or*** Mustang Max, 4.0 oz (1), ***or*** Altacor, 3.0–4.5 (1), ***or*** Delegate WG, 3–6 oz (3), ***or*** Brigade WSB, 5.3–16.0 oz (1)
Sharpnosed leafhopper	As necessary. Sharpnosed leafhoppers transmit stunt, which is lethal to blueberries. Rogue out affected plants (refer to text discussion) and apply an insecticide when sharpnosed leafhoppers appear on yellow sticky traps.	Lannate SP, 0.5 lb or LV, 1.5 pt (3), ***or*** Provado 1.6F, 3.0–4.0 fl oz (3), ***or*** Asana XL, 4.8–9.6 oz (14), ***or*** Actara, 3.0–4.0 oz (3), ***or*** Malathion 57EC, 2 pt or 8F, 1.25 pt (1), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz, or 30SG 2.5–5.3 oz (1)
Aphids		Lannate SP, 0.5 lb or LV, 1.5 pt (3), ***or*** Provado 1.6F, 3.0–4.0 fl oz (3), ***or*** Malathion 8F, 1.25 pt (1), ***or*** M-Pede, 1–2% v/v (0), ***or*** Actara, 3.0–4.0 oz (3), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz, or 30SG 2.5–5.3 oz (1)
Blueberry tip borers	Insecticides applied for fruitworms usually also control this pest.	Malathion 8F, 1.25 pt (1)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
FRUIT MATURATION		
Diseases		
Anthracnose	Quash and Abound are strobilurin (group 11) fungicides. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides per crop year. Captevate has a 48-hr REI. Aliette is not effective for the prevention of anthracnose fruit rot; however, it can be used to improve storage.	Abound F, 6.0–15.5 oz (0)—see note in Table 7.14 about severe toxicity of Abound to McIntosh, Gala, and related apple cultivars, ***or*** Quash, 2.5 oz (7), ***or*** Switch 62.5 WDG, 11.0–14.0 oz (0), ***or*** Captevate 68WDG, 4.7 lb (0), ***or*** Aliette WDG, 5.0 lb (0.5)
Insects		
Spotted wing drosophila	Monitor for presence of male adults with vinegar traps. Pyrethroids and spinosyns are effective in controlling spotted wing drosophila. Be sure to alternate materials from different pesticide classes for resistance management. 2(ee) labels have been issued for most of the products listed. Success and Entrust have the same active ingredient. Entrust can be used in organic production. Pyganic has a very short period of residual activity; populations with resistance to Pyganic have already been reported in California.	Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Delegate WG, 3–6 oz (3), ***or*** Success, 4–6 fl oz (3), ***or*** Entrust, 1.25–2.0 oz (3), ***or*** Pyganic EC 5.0, 4.5–18 oz (0), ***or*** Mustang Max, 4 fl oz (1), ***or*** Imidan 70WP, 1.33 lb (3)
Brown marmorated stink bug	Brown marmorated stink bug has not been especially problematic on blueberries as of this writing but bears watching. 2(ee) labels for Lannate and Danitol have been issued for use on brown marmorated stink bug on blueberries for all states in the Mid-Atlantic region. Target immatures.	Lannate SP, 0.67–1.0 lb or LV, 2–3 pt (3), ***or*** Danitol 2.4 EC, 10.67–16 fl oz (3)
Blueberry maggots	Begin treatments 10 days after the first maggot adult catch in monitoring traps. Repeat every 10 days through harvest. If traps are not used and maggots are a problem, begin sprays when berries first turn blue. Adding a bait to the spray mixture will enhance its activity. Watch days-to-harvest limitations. Surround is for suppression and is recommended for application only within the first three weeks after fruit set due to likelihood of visible residues.	Sevin 80S 1.87–2.5 lb or 4F, 1.5–2.0 qt (7), ***or*** Lannate SP, 0.25–0.5 lb or LV, 0.75–1.5 pt (3), ***or*** Imidan 70W, 1.3 lb (3), ***or*** Malathion 8F, 1.25 pt (1), ***or*** Diazinon 50W, 1 lb or AG500, 1 pt (7), ***or*** Asana XL, 9.6 oz (14), ***or*** Brigade, 5.3–16.0 oz (1), ***or*** Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Surround 95WP, 12.5–50 lb (0), ***or*** Provado 1.6F, 6.0–8.0 fl oz (3), ***or*** Assail 70WP, 1.9–2.3 oz, or 30SG, 4.5–5.3 oz (1), ***or*** Rimon, 20–30 fl oz (8)
Sharpnosed leafhopper	Early to mid-June as necessary. Sharpnosed leafhoppers transmit stunt, which is lethal to blueberries. Rogue out affected plants (refer to text discussion) and apply an insecticide when sharpnosed leafhoppers appear on yellow sticky traps.	Lannate SP, 0.5 lb or LV, 1.5 pt (3), ***or*** Asana XL, 4.8–9.6 oz (14), ***or*** Provado 1.6F, 3.0-4.0 fl oz (3), ***or*** Malathion 57EC, 2 pt or 8F, 1.25 pt (1), ***or*** Actara, 3.0–4.0 oz (3), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz, or 30SG, 2.5–5.3 oz (1)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
Leafrollers	When populations are high. Danitol is labeled for obliquebanded leafroller only. In NJ, leafroller resistance to malathion has been noted.	Imidan 70W, 1.33 lb (3), ***or*** Lannate SP, 1 lb or LV, 3 pt (3), ***or*** Malathion 8F, 1.25 pt (1), ***or*** Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Brigade, 5.3–16.0 oz (1), ***or*** Mustang, 4.3 oz (1), ***or*** Mustang Max, 4.0 oz (1)
Japanese beetle adults and other scarab beetles as listed on label	As necessary if adults are a pest. A 2(ee) label was issued for Japanese beetles and other pests not on the full Mustang Max label for berries in the mid-Atlantic states.	Sevin 80S, 1.25–2.5 lb or 4F, 1–2 qt (7), ***or*** Imidan 70W, 1.33 lb (3), ***or*** Provado 1.6F, 6.0–8.0 fl oz (3), ***or*** Actara, 4.0 oz (3), ***or*** Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Mustang Max, 4 fl oz (1)
Fall webworm	No pesticides are currently labeled for this pest. However, broad-spectrum pesticides applied for other pests will give control.	
Oriental beetle larvae and other white grubs	Admire works well on young larvae as they hatch from eggs but has little effect if applied later in the summer. Apply from June to mid-July at least 7 days before harvest begins for most varieties and right after harvest for the earliest varieties. Material should be applied to moist soil and watered in with 0.5 to 1 inch of water. The active ingredient is broken down by sunlight, so evening applications are best. Once in the soil, the insecticide will remain present for several months.	Admire Pro, 7–14 oz (7)
POSTHARVEST		
Diseases		
Anthracnose	As soon as possible after harvest. Make this application August 1 to 20 in NJ. See Special Local Needs label for NJ.	Ziram 76DF, 3 lb (—), ***or*** ***NJ only***: Ziram 76DF, 4 lb (14)
Phomopsis twig blight	Late fall through early winter. This spray will also help with controlling black shadow, a recently identified disease that causes a blackened appearance to twigs and a decline of affected plants.	Lime sulfur, 5–6 gal in 100–150 gal of diluted spray/A (—)
Powdery mildew	Not often a problem. Indar, Orbit, and Tilt are in the same fungicide group (group 3) and cannot be rotated with each other for resistance management.	Indar 75WSP, 2.0 oz or 2F, 6 fl oz (30), ***or*** Orbit, 6 fl oz (30), ***or*** Tilt, 6 fl oz (30), ***or*** Quash, 2.5 oz (7)
Insects		
Sharpnosed leafhopper	As necessary. Sharpnosed leafhoppers transmit stunt, which is lethal to blueberries. Rogue out affected plants (refer to text discussion) and apply an insecticide when sharpnosed leafhoppers appear on yellow sticky traps.Actara and Platinum contain the same active ingredient. Actara is for foliar applications, while Platinum is applied to the soil.	Malathion 57EC, 2 pt or 8F, 1.25 pt (1), ***or*** Asana XL, 4.8–9.6 oz (14), ***or*** Lannate LV, 1.5 pt or SP, 0.5 lb (3), ***or*** Provado 1.6F, 3.0–4.0 fl oz (3), ***or*** Brigade WSB, 5.3–16 oz (1), ***or*** Assail 70WP, 1.0–2.3 oz, or 30SG, 2.5–5.3 oz (1), ***or*** Actara, 3.0–4.0 oz (3)

CONTINUED

Table 7.13. Pesticides for blueberry disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product[a] Labeled Rate/A (Days to Harvest)
White grub complex	This includes larvae of Japanese beetle, Oriental beetle, and Asiatic garden beetle.	Admire Pro, 7–14 oz (7)
Blueberry bud mite	Immediately after harvest and 6–8 weeks later. Use oil when Putnam scale is also a problem. In NJ, make applications between September 15 and 30.	Thionex 3EC[e], 2 qt or 50WP, 3 lb (—), ***or*** Superior oil, 3 gal

a. Some pesticides may be phytotoxic to plants. If in doubt, test a small area of the field first. This is especially important when new formulations are being used or tank-mixed. Be sure sprayer is calibrated properly. Diazinon and captan should not be tank-mixed as the combination may be phytotoxic. Liquid formulations of captan have caused phytotoxicity to blueberries under conditions of high humidity and cloudiness, when the leaf cuticle may be thinner than usual.

b. Berkeley, Coville, Jersey, and Weymouth cultivars are particularly susceptible to phomopsis twig blight.

c. Guthion is labeled for blueberries in the states of AL, AR, FL, GA, IN, MI, NC, NJ, and NY only and can be used only through Sept. 30, 2012.

d. Asana is labeled for use against aphids only in NJ.

e. Do not apply after buds are well formed. Do not make more than two applications per year.

Table 7.14. Additional restrictions on blueberry pesticides.

The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may be labeled for the same uses. Always consult the label before making pesticide applications. Information was current as of July 1, 2012.

Abound	For resistance management, do not apply more than 2 sequential applications of Abound or any other strobilurin (group 11) fungicide before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 7.11 for chemical activity groups of fungicides labeled for use on blueberries. Do not allow to drift to McIntosh, Gala or related apple cultivars (Bancroft, Bromley, Cortland, Cox, Discover, Empire, Jonamac, Kent, Spartan, and Summared). Do not use the same spray equipment for other materials that will be applied to these cultivars, even if thoroughly cleaned.
Actara	Do not apply more than three consecutive applications of Actara or other Group 4A insecticides before rotating to products with a different mode of action. Foliar applications of Actara should not be used on crops previously treated with long-residual or soil applied Group 4A insecticides. Do not use more than 12 oz of Actara per acre per growing season. The minimum interval between applications of Actara is 7 days.
Admire Pro	Do not apply more than 14 fl oz (0.5 lb ai) of Admire Pro per acre per season. Do not apply more than a total of 0.5 lb active ingredient per acre of Admire or Provado, or a combination of Admire and Provade per season.
Aliette WDG	Do not exceed 20 lbs of product per acre per season. Do not exceed 4 applications per year. Do not apply in less than 10 gallons per acre.
Altacor	Do not make more than 3 applications per season or exceed more than 9 oz of Altacor or 0.2 lbs .a.i. of chlorantraniliprole-containing proudcers per acre per season. Do not apply more often than once every 7 days.
Asana	Do not apply more than 38.4 oz of product of Asana per acre per season.
Assail	Do not make more than 5 applications per season or apply more often than once every 7 days. Do not exceed 0.5 lbs of active ingredient per acre per growing season.
Avaunt	Make no more than 4 applications per season, or apply more than 24 oz per acre per crop. Minimum interval between treatments is 7 days.
Brigade	Do not make applications less than 7 days apart or apply more than 0.5 lbs of active ingredient per acre per season.
Captan	Do not apply more than 35 lb of 50W, or specified amount of a different formulation, per acre per season.
Captevate 68WDG	Do make more than two consecutive applications of Captevate or Elevate, or any product containing the active ingredient fenhexamid, before alternating with a fungicide with a different mode of action. Do not apply more than 21.0 lb per acre per season.
Confirm 2F	Do not apply more than 64 fl oz of product per acre per season.
Danitol 2.4EC	Do not exceed 2 pts total application of Danitol per acre per season.
Delegate WG	To reduce the potential for resistance development in target pest species, do not make more than 2 consecutive applications of group 5 insecticides (active ingredients of spinetoram or spinosad). If additional treatments are required, rotate to another class of effective insecticides for at least one application. Do not apply more than at total of 19.5 oz of Delegate WG per acre per crop. Do not make more than 6 applications per calendar year or applications less than 6 days apart.
Diazinon	Do not apply more than one in-season foliar application per year.
Elevate	Do not make more than two consecutive applications of Captevate or Elevate. Do not apply more than 6 lb/a/season of Elevate.
Esteem 35WP	Do not make more than 2 Esteem 35 WP applications per growing season. Do not exceed 10 oz per acre per season. Do not apply earlier than 14 days after last Esteem 35WP treatment.
Indar 75WSP or 2F	Do not make more than 4 applications or apply more than 8 oz of Indar 75WSP or 24 fl oz of Indar 2F per acre per year.
Guthion (NJ only)	Do not allow persons not covered by the Worker Protection Standard, such as members of the general public involved in pick-your-own operations, to enter a treated area for 30, 35, or 42 days after application depending on rate used. Guthion use on blueberries is prohibited after September 30, 2012. A yearly maximum amount of 0.75 lb ai/a applies for 2012.
Imidan 70W	Do not apply more than 7 1/6 lb of Imidan 70W per acre per year or make more than 5 applications per year.
Intrepid	Do not apply more than 64 fl oz of Intrepid 2F per acre per calendar year. Do not make more than 3 applications per year or apply more often than once every 7 days.
Lannate	Do not apply more than 3.6 lb ai per acre per crop. Do not make more than 4 applications per crop.
Lime sulfur	Do not use within 14 days of an oil spray or when temperatures are above 75°F.

CONTINUED

Table 7.14. Additional restrictions on blueberry pesticides., continued.

Mustang	Do not apply more than 0.3 lb of active ingredient (25.8 oz of product) per acre per season. Do not make applications less than 7 days apart.
Mustang Max	Do not apply more than 0.15 lb of active ingredient (24 oz of product) per acre per season. Do not make applications less than 7 days apart.
Omega 500F	Do not use more than 7.5 pints per acre per growing season.
Orbit, Tilt	Orbit and Tilt both contain the same active ingredient, propiconazole. Do not apply more than 30 fl oz (0.84 lb of propiconazole) in total of Orbit and Tilt per season. Apply these products in minimum spray volumes of 5 gal/A for ground application and 15 gal/A for aerial application.
Platinum	Only a single soil application of Platinum should be made per growing season. Foliar applications of other Group 4A insecticides should not be made following an application of Platinum.
Pristine	Do not apply more than two sequential applications before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 7.11 for chemical activity groups of fungicides labeled for use on blueberries. Pristine may cause injury to foliage of Concord or related grape varieties such as Worden and Fredonia. Do not use Pristine on these varieties and use special care when applying to prevent contact with these sensitive varieties. Thoroughly rinse spray equipment, including the inside of the tank, hoses, and nozzles after use and before using the same equipment on these sensitive grape varieties.
Provado	Do not apply more than 40 fluid ounces of Provado 1.6F per year. Do not apply more than 5 applications of Provado per crop season.
Quash	Do not make more than 3 applications per season, apply more than 7.5 oz per acre per season, or make more than 2 sequential applications.
Rimon	Do not apply more than 90 oz per acre per season.
Sevin 80S	Do not apply more than 5 times, or more often than once every 7 days.
Spintor, Success, Entrust	Do not apply more than a total of 0.45 lb ai of spinosad per acre per crop. Do not make more than 6 applications per year. Do not make applications less than 6 days apart. Do not apply more than 3 times per crop. When applied two times in succession, rotate to another insecticide class for at least one application.
Switch	Do not exceed 56 oz of Switch per acre per year. Do not make more than 2 applications before using a fungicide in another resistance management group.
Thionex	Do not make more than 2 applications per year. Do not exceed 1.5 lb ai per acre per year.
Ziram 76DF	Ziram applications should be avoided within 28 days prior to harvest due to the visibility of white residues.

VERTEBRATE PESTS

With blueberries, birds are frequent vertebrate pests, as are voles. However, deer can also cause damage to young plantings, and miscellaneous other rodents cause occasional damage. Chapter 5 contains a complete discussion of vertebrate pests, including information on identification of various species of pests, diagnosis of damage when the culprit is not seen, and management/control measures.

WEEDS

Blueberry root systems are shallow and lack root hairs, which put them at a disadvantage when competing with weeds for water and nutrients. Weeds also compete with blueberry plants for light and space. They acts as hosts for insects, diseases, and nematodes; provide cover for undesirable animals; reduce quality and yield; and impede harvest. Thus, good weed control is essential if optimum growth and yields are to be realized. Weeds may be controlled by a number of different methods or combinations of methods, but an integrated approach including the following methods is the most effective:

1. Avoid sites infested with persistent perennial weeds such as quackgrass, nutsedge, and wild brambles.
2. If such sites must be used, eradicate weeds in the years before planting. Cover crops such as sudangrass or rye are very effective in "outcompeting" noxious weeds; they also help build up soil organic matter if plowed under at the end of the season. For a more complete discussion of cover crops, see Chapter 2. Weeds can also be controlled the year before planting with glyphosate (Roundup), Touchdown, and selective broadleaf herbicides in grass crops. For a general discussion of weed control practices that will aid in minimizing weed pressure, see Chapter 4.
3. Control weeds in crops that precede blueberries on the site.
4. Control weeds in fencerows and adjacent fields.
5. Correctly identify the weeds that are in your planting so you can implement measures that will be effective for the weeds that you have.
6. Minimize weeds between the rows through the use of cultivation or establishment of a weed-free sod.
7. Use weed-free mulching materials within the row.
8. If cultivation is required, do so only shallowly since the blueberry root system is easily damaged.
9. In conventional systems, use recommended herbicides properly (see Table 7.18).

Practices 5, 6, 7, and 9 are discussed below.

In organic production, cultural practices that successfully manage weeds take on increased importance. Weed management strategies include planting permanent sod between rows of blueberries, mulching along the length of the row of blueberries, and using mechanical or hand cultivation. Placing a wide and deep mulch (6 inches deep and 4 feet wide) or fabric weed barrier around blueberry plants are also weed management strategies to consider.

WEED IDENTIFICATION

Knowing what the weed is and its life cycle (whether a summer annual, winter annual, biennial, or perennial) is a critical first step in implementing effective control measures. General information on the above terms is provided in Chapter 4 and in Table 4.1. Resources for weed identification are provided in Appendix E.

PRACTICES FOR MINIMIZING WEEDS BETWEEN THE ROWS

Between the rows, use cultivation and/or herbicides to control weeds, or establish a perennial grass sod such as tall or hard fescue to suppress weeds. It is essential to integrate the vegetation management program with insect and disease control programs.

Cultivation

When cultivation is used between the rows, it should be shallow and frequent during the growing season. Annual weeds are easily controlled by cultivation when they are less than one inch tall. Weeds that are more than two inches tall are more difficult to control and may have already competed with the blueberries.

Using Sod Row Middles

Sod between the rows prevents soil erosion, provides traction for equipment and people, increases soil organic matter, improves soil structure and water permeability, and furnishes shelter for beneficial insects. Sod also creates a more friendly environment for pick-your-own fields. The sod should not include plants that are an alternate host for insect pests, or diseases and nematodes that attack the crop. In addition, the sod should be easily maintained, tolerant to drought, low pH, require little or no fertilization, and compete very little with the blueberries.

Tall fescue or hard fescue perennial grass sods are recommended for *row middles*. Both types of fescue are tolerant to disease, drought, low pH, and low fertility. They compete effectively with weeds, do not spread or creep into the row by rhizome or stolon growth, and are semidormant during the hot, dry summer months. Tall fescue is more vigorous and is more easily established but requires more frequent mowing. Newly developed "turf type" tall fescue varieties are vigorous and have a lower mowing requirement than the traditional 'Kentucky 31' tall fescue, but they have not been evaluated in blueberries. Hard fescue grows more slowly and close to the ground and has a minimal mowing requirement, but it is moderately slow and difficult to establish. The addition of clover or other legumes is not recommended.

Prepare for sod establishment before the blueberries are planted. Control perennial weeds and nematodes and correct soil pH and nutrient deficiencies first. Complete primary tillage operations the summer before planting. If building gently sloping raised ridges for blueberry rows to improve drainage, do so *before* sowing grass or planting blueberries.

The success of a sod planting will depend on accurate seeding and timing. Sow tall or hard fescue in late summer into a well-prepared seedbed. Use 50 to 75 pounds of seed per broadcast acre to establish tall fescue, or 25 to 50 pounds of seed per broadcast acre to establish hard fescue. Blend up to 5 pounds of perennial ryegrass per 100 pounds of hard fescue seed to provide a fast, thin cover while the hard fescue gets established. The

perennial ryegrass will be eliminated from the stand by disease and drought in a few years. If perennial ryegrass is not used, a significantly greater amount of hard fescue seed should be used. See Tables 7.3 and 7.4 for additional information on cover crop characteristics and rates.

Use a seeder that will ensure good seed placement in a firm seedbed with good seed and soil contact. Failure to use adequate equipment for seeding frequently results in poor establishment. In an area like New Jersey, complete seeding by September 1 in the northern counties of New Jersey and by September 20 in the southern counties. Apply 50 pounds of nitrogen (N) per acre at seeding and repeat in late fall or early spring to encourage rapid establishment.

Establishment of a dense sod that is competitive with weeds will require 15 to 20 months. Some additional effort during this period will ensure success. Broadleaf weeds are undesirable in a sod growing between blueberry rows. Competition with the crop and mowing requirements may be increased. Many weeds may be alternate hosts for diseases, insects, or nematode pests. The flowers of dandelion, clover, mustard species, and other weeds may coincide with bloom and are preferred by pollinating insects. The same weeds—and others—may also bloom before or after the crop blooms and attract bees into the field when insecticides must be sprayed. The seedheads of dandelion clog tractor radiators and cause overheating, which can interfere with crop maintenance operations.

Apply Gallery 75DF to the sod early each spring after the sod is at least 6 months old and while the field is nonbearing to control large crabgrass and other summer annuals. Use 1.0 pound of Gallery (0.75 pounds of active ingredient) per acre. This is the same rate of Gallery recommended for use in the row on newly planted nonbearing blueberries.

Clover is difficult to control but can be suppressed or controlled in a sod with good management practices and herbicides. Manage fertilizer applications to favor grass rather than the clover. Nitrogen fertilizer stimulates grass growth, and phosphorus and potassium stimulate clover growth in a mixed grass and legume sod. Do not apply fertilizer containing phosphorus or potassium to sod if clover control is a problem. Apply fertilizer for blueberry growth in the vegetation free strip only. Mowing height also influences the composition of a mixed grass and clover sod. Close mowing favors the clover. Taller sod will favor the grass. Mow no closer than 4 inches if clover control is a problem in the sod.

PRACTICES FOR MINIMIZING WEEDS IN THE ROWS

In the row, a weed free zone should be maintained where weed competition with the crop is severe. Control in-row weeds with mulches and/or herbicides. The use of mechanical cultivation equipment in the row is seldom recommended due to risk of damaging the shallow roots of the blueberries.

The width of the weed-free zone should be about 36 to 48 inches wide, or about 18 to 24 inches on each side of the row. This weed free strip should be about 40 percent of the distance between the rows. The width may vary, however, depending on soil fertility, water-holding capacity and exposure to erosion. Do *not* reduce the width of the weed-free zone in young nonbearing fields. Maintain the full width of the vegetation-free zone in new plantings to achieve maximum growth of the blueberries.

In-Row Sod before Planting

Excellent results have been obtained by seeding perennial grass in the row as well as between the rows. Use perennial ryegrass rather than fescue. Rapid establishment and growth and susceptibility to herbicides make perennial ryegrass a better choice than fescue for seeding in the row. Kill the sod in the row before the blueberries are planted and no-till the plants into the dead sod. Use recommended herbicides to control weeds. The sod's roots increase soil organic matter and improve soil structure and water permeability, and the sod acts as a mulch to conserve water and prevent erosion during the establishment year. By fall, the dead sod deteriorates and is not attractive to rodents.

Mulching

Mulches control annual weeds and provide additional horticultural benefits in many fields. When using mulch for weed control, apply the mulch 3 to 4 inches thick when the rows are weed free. Thinner layers of mulch may not smother emerging weeds. Organic mulches may tie up important nutrients as they break down, so the use of mulch may require additional fertilizer. Reapply mulches annually or when needed to maintain weed suppression. Choose mulch products such as sawdust or wood chips, or a mixture of the two for improved infiltration of water over sawdust alone. Avoid mulches such as straw that provide a favorable environment for rodents such as field mice and voles that may damage blueberries, materials that are not already decomposed, or those that have a high pH such as mushroom compost.

HERBICIDES

Choose herbicides for use in the row that are labeled, have adequate crop safety (Table 7.15), and control the weeds in your field (see Table 4.1). The use of a single herbicide repeatedly will lead to an increase in resistant weeds. Use herbicide combinations, herbicide rotations, and sequential or spot treatments in a well-managed weed control program to eliminate or minimize problems. The recommended herbicides covered below have been evaluated for crop safety and effectiveness. Information on all varieties is incomplete. Use herbicides with care on new varieties.

Remember that weeds also compete with each other besides competing with your crop. Thus, controlling a particular weed or group of weeds may allow other weed species to take over. A combination of two preemergence herbicides gives better weed control than a single herbicide. Combining a "grass herbicide" with a "broadleaf herbicide" results in wider-spectrum control. Consult the label and Table 7.18 for compatible tank mixes.

Terminology

Herbicide terminology may not be everyone's cup of tea, but it is important to understand in order to effectively use herbicides and to avoid undesirable consequences from herbicide application.

Residual herbicides remain in the soil and kill weeds for up to several months. They are applied before weeds germinate. Weeds begin to compete with most crops within 2 to 4 weeks. Some products are effective only on germinating seeds. If weeds are present, a postemergence herbicide can be combined with a residual herbicide. Residual herbicides are applied incorporated or preemergence.

Incorporated herbicides are mechanically mixed with the soil. This application method is *not* well suited to blueberries. It is difficult or impossible to incorporate herbicides near the crown of the blueberry plant, and shallow roots may be pruned by the incorporation equipment.

Preemergence herbicides are applied to the soil surface and are used to prevent weeds from establishing before they emerge from the soil, not to prevent weeds from germinating. Labels often state that preemergence herbicides must be "activated by cultivation or irrigation." As mentioned above, cultivation is not a recommended practice for incorporating herbicides in blueberries. However, rainfall or overhead irrigation is needed to move the herbicide into the soil before the weeds emerge and, ideally, just into the zone of weed seed germination. Use a preemergence herbicide in combination with a postemergence herbicide if weeds have emerged, unless the preemergence herbicide also controls weeds postemergence. Of preemergence herbicides labeled for blueberries, Devrinol, Kerb, and Surflan work by inhibiting cell division. Solicam and Callisto inhibit pigment synthesis. Casoron inhibits cellulose biosynthesis and Chateau disrupts cell membranes. Princep and Sinbar work by inhibiting photosynthesis. Sinbar, besides having this effect on germinating weeds, kills small emerged annual weeds. Casoron, Kerb, Chateau, and Callisto also control emerged plants of certain weed species. Repeatedly using herbicides that act on weeds with the same mode of action may lead to weed populations that are resistant to those herbicide(s).

Postemergence herbicides are used after weeds have emerged from the soil and kill weeds through the leaves. They are used by carefully applying the herbicide to the weeds without allowing it to contact desirable plants that could be affected, such as blueberries or sod row middles. The best time to apply postemergence herbicides is when weeds are growing rapidly. Do not treat weeds that are dormant or under stress. Most herbicides that enter the plant through the leaves need a minimum rain-free period of at least 1 to 8 hours after application for maximum effectiveness. Postemergence herbicides may be selective or nonselective.

Selective postemergence herbicides kill only certain susceptible weeds. Poast, Select, and Fusilade DX are examples that kill only grasses and will not control broadleaf weeds or harm the blueberries.

Nonselective postemergence herbicides kill or injure any treated plant. They may be *contact* or *translocated*. *Contact* herbicides (Gramoxone Inteon, Scythe) affect only the plant tissue with which they come in contact. Thorough spray coverage is essential for good results. Roots of established annual weeds and perennial weeds often survive. *Translocated* herbicides (glyphosate, Fusilade, Poast, Select) move systemically in the weed (or crop plant if contacted) after treatment. Application at the proper growth stage will often result in good control of the roots as well as tops of established annuals and perennial weeds. Results of translocated herbicides may not be evident for several days or weeks.

Herbicides have no activity after application for one of two reasons. Some herbicides are too tightly bound to the soil to be available to plants after application. Care must be exercised in soilless growing environments, where surprising residual activity can be observed from these herbicides. Other herbicides are highly soluble in water and are not bound to soil particles. Residual activity from these herbicides can be observed in the soil, but it often lasts only a few days. They are rapidly leached out of the zone of weed seed germination and degraded

Table 7.15. Crop safety of blueberry herbicides.

	New (Nonbearing)	Established (Bearing)
Preemergence, Residual		
Callisto	G	G
Casoron/Norosac	?	G
Chateau	F	G
Devrinol	G	G
Gallery	G	—
Karmex (NJ and MD only)	—	F/G
Princep	—	F/G
Sandea	—	G
Sinbar	—	F
Snapshot	?	—
Solicam	F/G	G
Surflan	G	G
Velpar	P	P/F
Postemergence, Selective		
Fusilade DX	G	—
Kerb (also preemergence)	—	G
Poast	G	G
Sandea	—	G
Select/Select Max	G	—
Postemergence, Nonselective		
Paraquat products	G	G
Glyphosate products*	G	G

G = good; F = fair (use with care; recommended); P = poor (not recommended); ? = labeled but data insufficient; — = not labeled (do not use).

*Do not allow spray to contact young or green (living) bark or leaves.

Table 7.16. Herbicide water solubility and soil adsorption characteristics.

	Solubility	Soil Adsorption
Residual Herbicides		
Callisto (mesotrione)	Moderate	Moderate/strong
Casoron/Norosac (dichlobenil)	Low	Moderate
Chateau (flumioxazin)	Very low	Not available
Devrinol (napropamide)	Moderate	Strong
Gallery (isoxaben)	Very low	Strong
Karmex (diuron)	Low	Strong
Kerb (pronamide)	Low to moderate	Strong
Princep (simazine)	Very low	Moderate
Sandea (halosulfuron-methyl)	Low to moderate	Moderate
Sinbar (terbacil)	Moderate	Weak
Solicam (norflurazon)	Low to moderate	Strong
Surflan (oryzalin)	Very low	Strong
Velpar (hexazinone)	High	Weak
Nonresidual Herbicides		
Fusilade DX (fluazifop-P-butyl)	Very low	Very strong
glyphosate products	Very high	Very strong
paraquat products	Very high	Very strong
Poast (sethoxydim)	Moderate to very high[a]	Moderate
Select products (clethodim)	Not available	Weak

Source: Weed Science Society of America (2002), *Herbicide Handbook*, 8th ed. *Controlling Weeds in Nursery and Landscape Plantings.* 2007. Penn State College of Agricultural Sciences.

a. pH dependent.

by soil microorganisms. Table 7.16 lists the solubility and soil adsorption characteristics of herbicides labeled for use on blueberries. A complete discussion of the effects that trickle irrigation can have on increasing weed growth under the trickle line is included in Chapter 4: Weed Management.

Glyphosate products—including Roundup products, Touchdown products, Glyphomax Plus and others—and paraquat products, including Gramoxone Inteon, Firestorm, and others are too tightly bound to the soil to have residual activity. These herbicides are completely unavailable to plants after application. They remain tightly bound to the soil until broken down. Glyphosate can be degraded or digested by soil microorganisms. Residual activity from glyphosate has been observed when used in greenhouses, on plastic mulch, and near hydroponic growing systems. Paraquat is degraded by sunlight and is less likely to cause problems when used on plastic mulch, in greenhouses, or near soilless growing systems.

On coarse-textured sandy soils low in organic matter, Surflan (oryzalin) and Princep (simazine), respectively, are the best choices for annual grass and annual broadleaf weed management based on very low water solubility of both herbicides. On fine-textured soils and soils higher in organic matter, Surflan (oryzalin) and Karmex (diuron; New Jersey and Maryland only), respectively, are the best choices for annual grass and annual broadleaf weed control based on their low and very low water solubility and strong adsorption to the soil. Unfortunately, certain weeds, including yellow nutsedge, escape this herbicide combination.

Rate Control

Strict rate control is necessary. Improperly applied herbicides or herbicides applied above recommended rates may cause damage to blueberries. Using rates that are too low will result in a lack of efficacy or short duration of control. Residual herbicide rates must be matched with soil type and percentage of organic matter to obtain good weed control and crop safety. Determine type and percentage of organic matter for each soil on the farm with a separate soil test.

Be aware that most herbicide labels are written for "typical agricultural soils" and that many common blueberry fields are not "typical." Most coarse-textured soils, such as loamy sands and sandy loams, are low in organic matter, often less than 2 percent. Medium-textured soils, such as loams, may have 2 to 4 percent organic matter. Many traditional "black" blueberry soils may be classified as loamy sands but may have organic matter contents over 8 percent. Have your soil analyzed for percent organic matter. This is a separate test that must be requested from most soils laboratories. If your soil has an organic matter content higher than the choices listed on the herbicide label for your soil texture, choosing the correct rate may be difficult. See Table 7.17 for recommended rates of specific herbicides for various soil types and organic matter levels. Consult your Cooperative Extension service for assistance in determining the correct herbicide rate to use on your soil if needed. Adjust by changing tractor speed and maintaining pressure when spraying a field with soil that requires different herbicide rates. Herbicide application and equipment are discussed in Chapter 4.

Herbicide Use in New (Nonbearing) Plantings

Weed control in a newly planted field should be planned to provide a maximum margin of crop safety. Tillage and/or herbicides prior to planting should control established biennial and perennial weeds. Apply a combination of herbicides to control annual grasses and broadleaf weeds. Surflan plus Gallery 75DF has been a safe and effective residual herbicide combination for newly planted blueberries. Apply in early spring after 1 to 2 inches of rainfall or irrigation has settled the soil around the roots of the new plants but before weeds emerge or the blueberry buds break. Waxed paper "milk cartons" are effective and recommended shields. The use of shields adds an additional margin of safety when installed prior to herbicide application.

An alternative to shields is the use of granular formulations when available. Granular formulations fall through the blueberry canopy to the soil surface, provided applications are made when the foliage and shoots are dry. The use of nonselective postemergence herbi-

Table 7.17. Per-acre rates per application for preemergence (residual) herbicides for common soil types for blueberries.

Rates for each active ingredient are followed by the corresponding rates of a commonly available product containing the active ingredient listed.

	Soil Type / % Organic Matter												
	Sand		*Loamy Sand*		*Sandy Loam*			*Loam*		*Silt Loam*		*Clay Loam*	
Herbicide	0–1	1–2	0–1	1–2	0–1	1–2	2–4	1–2	2–4	1–2	2–4	1–2	2–4
Napropamide (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Devrinol 50DF (lb)[a]	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8
Mesotrione (oz ai)[a]	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3	1.5–0.3
Callisto 4F (fl oz)[a]	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6
Flumioxazin (oz ai)[a]	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6	3–6
Chateau 51WDG (oz)[a]	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12	6–12
Isoxaben (lb ai)[b]	0.75	0.75	0.75	0.75	0.75	0.75	1	0.75	1	1	1	1	1
Gallery 75DF (lb)[b]	1.0	1.0	1.0	1.0	1.0	1.0	1.33	1.0	1.33	1.33	1.33	1.33	1.33
Pronamide (lb ai)[b]	2	2	2	2	2	2	2	2	2	2	2	2	2
Kerb 50WP (lb)[b]	4	4	4	4	4	4	4	4	4	4	4	4	4
Diclobenil (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Casoron CS (gal)[a]	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8
Simazine (lb ai)[b]	—	—	—	—	—	2	2	2	3	2	3	3	4
Princep 90DF (lb)[b]	—	—	—	—	—	2.2	2.2	2.2	3.3	2.2	3.3	3.3	4.4
Halosulfuron-methyl (oz ai)	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75	0.38–0.75
Sandea (oz)	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0
Terbacil (lb ai)[b]	—	—	—	—	—	1	1.6	1.6	1.6	1.6	1.6	2.4	2.4
Sinbar 80WP (lb)[b]	—	—	—	—	—	1.25	2	2	2	2	2	3	3
Norflurazon (lb ai)[b]	—	—	—	2	—	2	2.5	2.5	2.5	2.5	3	3	4
Solicam 80DF (lb)[b]	—	—	—	2.5	—	2.5	3.0	3.0	3.0	3.0	3.75	3.75	5
Oryzalin (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Surflan 4AS (qt)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Hexazinone (lb ai)[b]	—	—	—	—	—	—	—	—	0.5	0.5	0.75	0.75	1.0
Velpar L (pt)[b]	—	—	—	—	—	—	—	—	2.0	2.0	3.0	3.0	4.0
NJ and MD only:													
Diuron (lb ai)	—	—	—	1.0	—	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0
Karmex DF (lb)	—	—	—	1.25	—	1.9	1.9	1.9	2.5	2.5	2.5	2.5	2.5

a. Use the lower recommended rate when tank-mixing with another preemergence herbicide, unless annual grass pressure is severe.

b. Use one-half the recommended rate when tank-mixing with another preemergence herbicide.

— = not labeled or not recommended (do not use).

cides such as a paraquat or glyphosate product should be avoided during the year of planting unless shields are in place. Avoiding contact of these products with the plant is critical.

Herbicide Use in Established (Bearing) Plantings

Apply herbicides to the blueberry row in established fields in late fall and also in late spring. Herbicides are applied in late fall or when the soil temperature has dropped to between 40 and 50°F to control winter annuals, certain perennials, and early season summer annuals. The spring herbicide application extends summer annual weed control through harvest.

Late fall herbicide applications should all include a residual broadleaf herbicide. Use Princep in fields that are not irrigated or are watered with overhead irrigation. If trickle irrigation is used, apply Karmex (New Jersey and Maryland only) in the fall. Small seedling annual broadleaf weeds will be controlled by the residual herbicide, but if well established annuals are present, add a postemergence herbicide such as a paraquat product to the tank. In recent years, Princep and Karmex have not performed as reliably as in previous years at some sites. Reasons may include weed species shifts to annual broadleaf weeds, such as groundsel, that are less susceptible to these herbicides, the development of triazine-resistant biotypes, or the establishment of perennial broadleaf weeds. If this is the case on your farm, an alternative is to apply Casoron in the late fall at rates given in Table 7.18 to control these weeds. Casoron will control early season annual grasses, but a residual annual grass herbicide should be applied in the spring for full-season grass control.

The use of a grass herbicide in the fall depends on the product chosen. Kerb 50WP is the only grass herbicide that *must* be applied in the fall. Choose Kerb to control cool season perennial grasses such as quackgrass. An additional residual annual grass herbicide is needed in the spring to provide full season summer annual grass control following a fall application of Kerb 50WP. Solicam 90DF, Surflan 80WP, and Devrinol 50DF are annual grass herbicides that should be applied in late fall or as a split application, half in the fall and the second half in the spring. Use the split application when grass pressure is heavy for best results. The use of these herbicides in spring only has resulted in inconsistent weed control when dry weather followed the application. Sinbar 80WP applications should be applied only in the spring. The relatively high solubility of Sinbar 80WP results in leaching when applied in the fall. Increased risk of crop injury and poor weed control can result.

Consider spot treating with a labeled glyphosate product if perennial weeds are present; treatment is recommended in the fall. Application by use of a wick applicator is a safer option in order to avoid contact of the herbicide with the blueberry plants.

Follow-up late spring applications should include a different residual broadleaf weed herbicide and a residual grass herbicide. Add a postemergence herbicide only if needed. Use Karmex 80DF (New Jersey and Maryland only) for residual broadleaf weed control if Princep was used in the fall, or use Princep if Karmex was used in the fall. Apply Sinbar 80WP or the second half of a split herbicide treatment of Solicam 80DF, Surflan 80WP, or Devrinol 50DF for annual grass control. Include a paraquat product if seedling annual weeds are observed.

As mentioned above under "Late Fall Herbicide Applications," Princep and Karmex have recently not performed reliably at some sites. This has also been the case with the spring application of Princep and Karmex, as well as Sinbar. Reasons for failure at this time of the year may be the same as those listed above, plus the possibility that biotypes may exist that germinate later in the summer when these herbicides are less effective. In these cases, add Callisto or Chateau to your spring tank mixture to improve control of summer annual broadleaf weeds.

Spot treat with a labeled glyphosate product to control established perennial grasses and broadleaf weeds. Sinbar 80WP is also effective for seedling weed control postemergence. No other postemergence herbicide may be needed if no established weeds are present and seedling annual weeds are sprayed with Sinbar before they exceed 1 inch in height.

See Table 7.18 for recommended herbicides and timings at which they can be used.

PROBLEM PERENNIAL WEEDS

Especially in perennial crops such as blueberries, certain problem weeds can become well established since the field is not worked after crop establishment, and herbicides may have limited or no effectiveness at this point. Many of the weeds that are likely to become problematic are discussed below, along with their life cycle and cultural and chemical means for management.

Yellow Nutsedge

Yellow nutsedge, a perennial, may be the most serious weed in agriculture worldwide. Yellow nutsedge is sometimes referred to a "nutgrass," even though it is not a grass. Although yellow nutsedge can reproduce from seed, where it is established, annual reinfestation is primarily due to dormant nutlets in the soil. Nutlets are small, about the size of a pea, and are tan to reddish brown in color. They sprout in the spring and establish a plant about 8 to 12 inches tall with narrow leaves and parallel veins. At a glance the plant may appear to be a grass, but close inspection of the plant reveals that the leaves are not divided into two parts, a blade and a sheath. Further inspection reveals that just below the soil, the triangular stem could be detected by rolling the shoot between two fingers. Nutlets can resprout six to eight times if cultivation kills the shoot. After the plant becomes established, rhizomes, which are horizontal underground stems, begin to grow in late spring or early summer. By early to midsummer, the rhizomes curve upward and produce additional plants. The vegetative spread of the weed continues until late summer. By August in most locations, the weed can sense the approach of fall by the longer nights, and a burst of rhizome growth follows. These rhizomes do not curve up and produce more daughter plants. They grow out and down. By early fall, a pronounced swelling can be observed at the tip of each rhizome, which matures into a new dormant nutlet. Later in the fall, the still longer night signals that it is time

for the mother plant to enter dormancy, effectively separating the nutlets from the mother plant and each other.

Yellow nutsedge can be managed and eventually eliminated from a field by preventing new nutlet production. This can be done by persistent management of nutsedge from late summer through early fall (see below). The results of the effort will not be evident after one year. Too many "old" nutlets remain dormant in the soil for several years before they sprout, but after several years, success will be evident.

Cultural Management

Avoid spreading nutsdege into clean fields from infested soils with equipment or in mulches such as straw and manure. Nutsedge is intolerant of shade. Using close row spacing can result in shading and minimize yellow nutsedge growth. Mulches, including plastic, straw, and cover crop residues can also provide shade as well as provide a physical barrier that reduces plant emergence. Nutsedge is also a poor competitor with vigorous crops. Use management practices that promote crop health. Also, include vigorous cover crops in your rotation, and include corn and soybeans in the rotation to shade nutsedge and allow the use of herbicides that are effective against nutsedge. Repeated mowing prevents seed production and helps with depleting root reserves. While seeds are not the not the primary method for spreading yellow nutsedge, they are important for spreading the plant greater distances. Preventing seed production by mowing prior to flowering and seed set will prevent the formation of seeds. Mowing can exhaust the energy reserves of nutlets; however, it can take seven or more mowings until reserves are depleted. Tilling in fall can directly destroy small nutlets and expose larger nutlets to killing cold temperatures. In the fall, chisel plowing or using tillage tools that bring vegetative structures to the soil surface are better than tools that invert soil (moldboard plow) and bury the nutsedge. Tillage in the spring, however, can help spread yellow nutsedge. This is particularly a problem when using more shallow types of tillage. Yellow nutsedge tends to be a larger problem on low or wet areas in a field. Using raised beds in areas with poor drainage can help to manage yellow nutsedge.

Chemical Management

Sandea (halosulfuron, 0.375–0.75 oz ai/A). Use 0.5 to 1.0 dry ounce per acre of Sandea 75DF in mid- to late spring to control yellow nutsedge. Always add a non-ionic surfactant to be 0.25 percent of the spray solution. Direct the spray toward the base of the blueberry bush. Avoid contact with crop foliage or temporary chlorosis (yellowing) will occur. Use in combination or tank-mixed with other residual herbicides for annual grass control or to improve annual broadleaf weed control. When yellow nutsedge pressure is heavy, apply in the spring after the yellow nutsedge has emerged and developed several leaves, and repeat the application after harvest a minimum of 45 days later if additional yellow nutsedge emerges. Do not apply more than 2 dry ounces of Sandea per acre per year. Sandea will not injure established sod. Observe a minimum preharvest interval of 14 days.

Glyphosate products. Apply initial application at higher labeled rate when plants are more than 6 inches tall but before going to seed. Repeated subsequent applications at lower rates will be needed for control. Use lower gallonages of water to allow a greater amount of glyphosate to remain on the foliage, as nutsedge foliage will not retain much spray solution. *Broadcast:* 2.25 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet the weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for effectiveness. *Ropewick Applicator:* Wipe twice; travel in opposite directions for each wipe.

Bindweed Species (Hedge and Field)

These perennial weeds have deep vertical roots for food storage and horizontal roots that spread the weed vegetatively. Shoots emerge from this extensive root system in the spring. Flowers appear in late spring and throughout the summer. They are distinctively trumpet shaped, white, or lightly tinted with lavender. Hedge bindweed flowers are larger than field bindweed flowers. Bindweed species are often confused with annual morninglories, which have larger bright blue flowers, simple shallower roots, and are easier to manage. The leaves of bindweed species are triangular or arrow-head shaped. Hedge bindweed leaves are pointed, while field bindweed leaves have a blunt tip. The shoots grow as a vine across the ground or twining up the shoots of other plants for support. Management can be difficult due to the deep and extensive root system bindweed develops.

Cultural Management

Bindweed is sensitive to shading. However, because roots store significant reserves, shading is ineffective after bindweed is well established. Cultivation is effective only if repeated frequently. Regrown shoots begin to replenish root reserves in as little as 2 weeks after shoot emergence.

Chemical Management

Casoron/Norosac (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Casoron/Norosac 4G or 2.8 gallons of Casoron CS per acre. Apply between November 15 and March 15 to control labeled annual, biennial, and perennial weeds. Late-fall treatments, after November 15 but before the soil freezes, have had a more consistent effect on susceptible perennial weeds than late winter applications. Treat before weed growth begins and when daily high temperatures do not exceed 50°F. Casoron/Norosac is volatile in warm temperatures and must be irrigated or incorporated after application if applied in warm weather to prevent significant loss of the herbicide. This product is for established (bearing) fields.

Glyphosate products. Apply in fall when plants are translocating photosynthates to their roots. A follow-up application in spring may be needed. Applications made in late spring and early summer when bindweed is actively growing will have little effect. *Broadcast:* 2.25 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet the weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for effectiveness. *Ropewick*

Applicator: Wipe twice; travel in opposite directions for each wipe.

Canada Thistle

This perennial weed has deep vertical roots for food storage and horizontal roots that spread the weed vegetatively. Shoots emerge from this extensive root system in the spring. Flowers appear in late June, and seed is dispersed in July. The shoots die after the seed is dispersed. New shoots appear in late summer and grow vegetatively until frost. These fall shoots make food for the roots and do not flower.

Cultural Management

Mowing in spring at bud to bloom time will assist with depleting root reserves, as plant reserves are already at a low point, and mowing (either physically, or chemically with a burndown material) will force the plant to use additional root reserves for regrowth. Repeated frequent tillage will be effective prior to planting and between rows; however, if tillage is infrequent, this plant may become the dominant weeds as other more easily controlled weeds become less numerous. Only extremely shallow tillage can be used near blueberry plants in order to avoid damaging their root systems.

Chemical Management

Casoron/Norosac (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Casoron/Norosac 4G or 2.8 gallons of Casoron CS per acre. See paragraph on use of this product under "Bindweed Species."

Glyphosate products. Apply in late June when Canada thistle has flower buds or flowers, or in the fall after the shoots are 6 to 8 inches tall but before frost. Roundup translocates into the vertical roots of the plant well but in less quantity into the horizontal roots. Follow-up spot treatments may be needed to control regrowth from pieces of horizontal roots that were not killed by the initial application. *Broadcast:* 2.25 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet the weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for maximum effectiveness. *Ropewick Applicator:* Wipe twice; travel in opposite directions for each wipe.

Dandelion

This perennial plant grows actively during the spring and fall and forms a robust tap root that may resprout several new tops when the plant top is broken off.

Cultural Management

Hoeing or hand removal is typically ineffective since removing the entire tap root is difficult, and since cultivation in blueberry fields must be done shallowly, a significant portion of the root system is not likely to be destroyed. Mowing before flower heads bloom can aid in reducing the number of seeds produced.

Chemical Management

Norosac/Casoron (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Norosac/Casoron 4G or 2.8 gallons of Casoron CS per acre. Apply between November 15 and March 15 to control labeled annual, biennial, and perennial weeds. Late-fall treatments—after November 15 but before the soil freezes—have controlled susceptible perennial weeds more consistently than late-winter applications. Treat before weed growth begins and when daily high temperatures do not exceed 50°F. Norosac/Casoron is volatile in warm temperatures and must be irrigated or incorporated after application if applied in warm weather to prevent significant loss of the herbicide.

Glyphosate products. Apply when the weed is growing actively and has flower buds. Spring or fall applications are more effective than applications made in midsummer. (See warnings in Table 7.18.) *Broadcast:* 2.25 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for effective control. *Ropewick Applicator:* Wipe twice; travel in opposite directions for each wipe.

Goldenrod Species

These closely related weeds are perennials that begin growth in April from rosettes or rootstocks. Typically, yellow blooms appear in late summer and the stems die in the fall. Some regrowth, as short stems or rosettes, often occurs before winter. Strong root systems overwinter and resume growth in the spring. The weeds spread using underground horizontal roots. Once established, management of this weed is difficult since it is tolerant to most herbicides and the roots can be spread by cultivation or other tillage practices.

Cultural Management

Best options are shallow tillage or removal when first plants to invade field are small, and mowing of any nearby goldenrod infested areas to avoid spread of the weed into cultivated fields.

Chemical Management

Casoron/Norosac (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Casoron/Norosac 4G or 2.8 gallons of Casoron CS per acre. See paragraph on use of this product under "Bindweed species."

Glyphosate products. Apply in late spring after spring growth is 8 to 10 inches tall, but before the shoots become too tall for good coverage with the spray solution. Generally, banded or broadcast sprays must be applied earlier in the spring, while spot treatments and ropewick applications can be applied later in the spring. *Broadcast:* 1.5 to 3 pounds ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for maximum effectiveness. *Ropewick Applicator:* Wipe twice; travel in opposite direction for each wipe.

Horseweed

Horseweed is a biennial plant with seed that usually germinates in late summer or early fall. Though biennial, it usually behaves like a winter annual in that the seedling grows as a rosette during the fall and early spring. The plant bolts during the summer, flowers, sets seed, and dies during its second late summer and fall season. It may also behave like a typical spring-germinating biennial or summer annual as well. The weed produces a large number of wind-distributed seed in late summer

and early fall. Some people refer to horseweed as "marestail" which is a misnomer. Herbicide labels that state "marestail control" may be referring to another weed.

Note: *Glyphosate-resistant horseweed*, also called marestail or stickweed locally, has been identified in the Mid-Atlantic Region, including New Jersey. Due to the windborne distribution of the seed, it is likely that glyphosate-resistant biotypes will spread to your farm despite good integrated weed management by individual growers. Therefore, all horseweed populations should be considered potentially glyphosate resistant. Glyphosate, formulated as Roundup Ultra Max, Touchdown, Glyphomax Plus, and other generic formulations, were recommended for horseweed control prior to 2003 but have been removed from the recommendations for horseweed control due to the resistance development.

Cultural Management

Best options are shallow tillage or removal when first plants to invade field are small, and mowing of any nearby horseweed infested areas to avoid spread of the weed into cultivated fields.

Chemical Management

Casoron/Norosac (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Casoron/Norosac 4G or 2.8 gallons of Casoron CS per acre. See paragraph on use of this product under "Bindweed Species."

Karmex (diuron, 1.0–3.2 lb ai/A), New Jersey and Maryland only. Use 1.25 to 2.5 pounds/A Karmex 80DF, depending on soil texture and organic matter. Apply in late fall to weed-free soil, or tank-mix with a paraquat product to kill existing vegetation. This product is for established (bearing) fields.

Princep (simazine, 1–4 lb ai/A). Use 1.1 to 4.4 pounds/A Princep 90DF (or other labeled formulations), depending of soil texture and organic matter. Apply in late fall to weed-free soil, or add a paraquat product to kill existing vegetation. This product is for established (bearing) fields.

Paraquat (Gramoxone Inteon, Firestorm, or other labeled formulations, 0.6–1.0 lb ai/A). Use 2.4 to 4.0 pints/A Gramoxone Inteon or 1.7 to 2.7 pints/A Firestorm 3SC (or other labeled formulations). Contact killer only; has no translocation or residual activity. Best results occur when horseweed seedlings are treated in late fall or are less than 1 inch in diameter. Two applications two weeks apart are more effective than a single application. Regrowth may occur from the root systems of established weeds. Use a surfactant to be 0.25 percent of the spray solution (1 quart per 100 gallons of spray solution). Combine with recommended preemergence herbicide(s) for residual effectiveness. Do not allow spray or drift to contact green bark, leaves, or fruit. Crop damage may result. The use of shields, such as grow tubes or paper milk cartons, greatly reduces the risk of injury in young plantings. This product is for newly planted (nonbearing) fields and for established (bearing) fields. *DANGER: Do not breathe spray mist. Read safety precautions on the label.*

Poison Ivy

This woody perennial vine or shrub is capable of climbing a trellis. Contact with any part of the plant may result in an itching, blistering skin rash. Nonselective postemergence herbicides must be used to control this weed. Take measures to eradicate before the vine grows up into the plants or trellis.

Cultural Management

No cultural controls recommended.

Chemical Management

Glyphosate products. Apply in mid- to late summer after the weed flowers in late June or early July, or in early fall before fall colors appear. Results of the fall application may not become evident until the following spring. Best results have been obtained in late summer after the fruit has formed. *Broadcast:* 3 to 3.75 pounds ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for maximum effectiveness. *Ropewick Applicator*: Not recommended. *"Cut Stump" Treatment:* See your product's label for rate. Apply to the cambium (inner bark area) of the stump of woody plants *immediately* after cutting. Cut and treat stumps only when the target is actively growing and not under stress. Best results are often obtained in late summer and early fall before fall color is observed in the foliage. Warning: Injury due to root grafting may occur in adjacent plants. Do not treat cut stumps if there is a possibility of root grafting to desirable vegetation.

Quackgrass

This perennial plant grows actively in the late spring and early fall when daily high temperatures range between 65 and 80°F (18.3 and 26.7°C). High midsummer temperatures, above 85°F (29.4°C), and/or low soil moisture cause the weed to become dormant or semidormant until moisture and cooler weather return. The weed reproduces by seed and vegetatively by rhizomes, horizontal underground stems that eventually curve upward and make new shoots. The seedhead, which appears in June, resembles ryegrass, except each floret is rotated one quarter turn compared to ryegrass. The rhizomes are about 1/8 inch in diameter and may grow horizontally for up to several feet in length before curving upward and making a new shoot. Ryegrass does not have rhizomes.

Cultural Management

Prior to planting, plowing followed by disking or repeated disking chops rhizomes into small pieces that are more susceptible to herbicides and additional cultivation. Repeated cultivation forces plants to use rhizome reserves. Cultivation during hot dry spells causes rhizomes to dry out. Failure to follow initial cultivations with control measures will only result in propagation of rhizomes.

Chemical Management

Glyphosate products. Apply in late spring (May or June) or in the fall (October or November) when the weed has vigorous healthy foliage, a minimum of 4 to 6 leaves, and has begun to tiller. Do *not* till the field or otherwise disrupt the root and rhizome system of the weeds in the soil for a minimum of 8 months before treatment. *Broadcast:* 1.5 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as

possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet weed foliage as thoroughly as possible. *Ropewick Applicator:* Wipe in late May or June after the weed is at least one foot tall. Not recommended in the fall due to the more prostrate growth habit of the weed.

Kerb (pronamide), 1–2 lb ai/A. Use 2 to 4 pounds/A Kerb 50WP. Apply in November when soil temperatures are between 35 and 55°F (1.7 and 12.8°C). Primarily effective against perennial grasses, including quackgrass, bluegrass, ryegrass sp., and fescue sp., and also provides early management of annual grasses the following spring. Apply Surflan, Prowl (nonbearing only), Solicam, or Sinbar the following May or June for full season annual grass control. Tank-mix Kerb with Gramoxone Inteon or a glyphosate product and with Princep for postemergence and residual broadleaf weed control. This product is for established (bearing) fields.

Fusilade (nonbearing fields only), Poast, and Select. Provide partial control. Repeat applications needed for additional control.

Virginia Creeper

Virginia Creeper is a woody perennial vine capable of climbing a trellis and smothering a plant.

Cultural Management

No effective cultural controls have been identified.

Chemical Management

Nonselective postemergence herbicides must be used to suppress or control this weed. Remove the vine from the trellis during winter pruning and put it on the ground or plan a "cut stump" treatment during the growing season. Do *not* "prune out" the vine during the dormant season. Good growth and maximum leaf area are needed at the time of herbicide application during the summer.

Glyphosate products. Apply in mid- to late summer after the vine flowers in early July but before fall color appears in the foliage. Applications in spring or early summer, before flowering, have been less effective. Repeat applications may be needed. One application may merely suppress Virginia Creeper. *Broadcast:* 3 to 3.75 pounds ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for maximum effectiveness. *Ropewick Applicator:* Not recommended; the creeping nature of plant is difficult to wipe. *"Cut Stump" Treatment:* See your product's label for rate. Apply to the cambium (inner bark area) of the stump of woody plants *immediately* after cutting. Cut and treat stumps only when the target is actively growing and not under stress. Best results are often obtained in late summer and early fall before fall color is observed in the foliage. Warning: Injury due to root grafting may occur in adjacent plants. Do not treat cut stumps if there is a possibility of root grafting to desirable vegetation.

White Heath Aster and Other Aster Species

White heath aster is a perennial that begins growth in April from rosettes or rootstocks. (Other asters may be annuals or biennials.) Typically, blooms are about ½ inch in diameter. The flowers have white or slightly tinted purple petals with yellow centers. They appear in late summer, set seed, and the stems die in the fall. Some regrowth, as short stems or rosettes, often occurs before winter. The weed spreads using underground horizontal roots.

Cultural Management

Once established, management of this weed is difficult since it is tolerant to most herbicides and the roots can be spread by cultivation or other tillage practices.

Chemical Management

Casoron/Norosac (dichlobenil, 4–6 lb ai/A). Use 100 to 150 pounds of Casoron/Norosac 4G or 2.8 gallons of Casoron CS per acre. See paragraph on use of this product under "Bindweed Species."

Glyphosate products. Apply in May or June after spring growth is 8 to 10 inches tall, but before the shoots become too tall for good coverage with the spray solution. Generally, broadcast sprays must be applied in May, while spot treatments and ropewick applications can be delayed until June. *Broadcast:* 1.5–3 lb ae (acid equivalent)/A. *Spot Treatment:* See your product's label for rate. Wet weed foliage as thoroughly as possible. Use the highest labeled percent solution rate when only partial wetting of the weed foliage is possible. Wet a minimum of 50 percent of the weed foliage for maximum effectiveness. *Ropewick Applicator:* Wipe twice; travel in opposite direction for each wipe.

Table 7.18. Herbicides for blueberry weed control.

Note: See text discussion for additional discussion on timing and use of various herbicides in this chapter and Chapter 4. See Table 4.1 for efficacy ratings of herbicides on various weeds. See Table 3.2 for limits on states in which these cannot be used, use status (general vs. restricted), days-to-harvest limitations, and reentry intervals. The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist that may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Information was current as of July 1, 2012.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
NEW (NONBEARING) PLANTINGS			
Preemergence			
Primarily for annual broadleaf weeds	Add nonionic surfactant to be 0.25% of the spray volume, or 1 qt per acre crop oil concentrate. Apply in early spring before bud break as a spray directed toward the base of the bush. Broadleaf weeds controlled include horseweed and common lambsquarter. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improved annual grass control. Do not apply more than 6 fl oz of Callisto per acre within one year.	Mesotrione, 1.5–3.0 oz	Callisto 4F, 3–6 fl oz (prebloom)
Annual broadleaf weeds; also controls or suppresses annual grasses	Only if plants established less than 2 years are protected from spray contact by nonporous wrap, grow tubes, or waxed containers. Add crop oil concentrate to be 1% of spray volume. Apply in late fall after leaf drop or in early spring before bud break. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improve annual grass control. Do not allow spray to contact foliage or new green bark. Do not use more than 6 oz/a of product where the soil contains more than 80% sand until the plants have been in the field for more than 3 years. Follow instructions on label for tank clean-out if any part of the sprayer will be used to spray other crops; otherwise, crop injury may occur. See label for other cautions and restrictions, as even contact with treated residue can cause phytotoxicity.	Flumioxazin, 3.0–6.0 oz	With protection for first 2 years: Chateau 51WDG, 6–12 oz (7)
Primarily for annual grasses; suppresses or controls certain annual broadleaf weeds	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or reduced rates of Princep, Karmex (New Jersey and Maryland only), or Sinbar in the spring, if planting has been established for at least one year, to control annual broadleaf weeds. Activate with one-half-inch sprinkler irrigation within 24 hours after application. If left on the soil surface, napropamide (Devrinol) is broken down by sunlight. Irrigation moves the herbicide into the soil and prevents breakdown by the sun.	Napropamide, 2.0–4.0 lb	Devrinol 50DF, 4.0–8.0 lb (—)
Primarily for annual broadleaf weeds	Apply in late fall or early spring to weed-free soil to control many broadleaf weeds. If newly planted, allow the soil to settle and fill any depressions around the plant before application. Add a postemergence herbicide to improve the control of emerged weeds. Gallery primarily controls annual broadleaf weeds. Tank-mix with Surflan to control annual grasses. ***Note: Gallery is not labeled for bearing blueberries.***	Isoxaben, 0.75–1.0 lb	Gallery 75DF, 1.0–1.33 lb (365)

CONTINUED

Table 7.18. Herbicides for blueberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Primarily for annual broadleaf weeds	Add nonionic surfactant to be 0.25% of the spray volume, or 1 qt per acre crop oil concentrate. Apply in early spring before bud break as a spray directed toward the base of the bush. Broadleaf weeds controlled include horseweed and common lambsquarter. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improved annual grass control. Do not apply more than 6 fl oz of Callisto per acre within one year.	Mesotrione, 1.5–3.0 oz	Callisto 4F, 3–6 fl oz (prebloom)
Primarily for annual grass control; may provide partial control of many broadleaf weeds	Planting must have been in the ground for at least 6 months before application. Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix with Princep plus a postemergence herbicide in late fall, or with Karmex (New Jersey and Maryland only), or Sinbar in the spring if the planting has been established for at least one year, to improve the control of broadleaf weeds.	Norflurazon, 2.0–4.0 lb	Solicam 80DF, 2.5–5.0 lb (60)
Primarily for annual grasses	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or with Karmex (New Jersey and Maryland only), or Sinbar in the spring if the planting has been established for at least one year, to control annual broadleaf weeds.	Oryzalin, 2.0–4.0 lb	Surflan 4AS, 2.0–4.0 qt (—)
Postemergence—Selective			
Emerged annual grasses and perennial grasses, depending on rate (see information in column to right)	Add 2 pints crop oil concentrate or nonionic surfactant to be 0.25% of the spray solution (1 qt. per 100 gallons of spray solution). Use the lower rate on most annual grasses less than 6 inches tall and to control johnsongrass. Use the higher rate to control other perennial grasses, crabgrass, and annual grasses more than 6 inches tall. Do not tank-mix Fusilade DX 2EC with any other pesticide. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Fluazifop-P-butyl, 0.18–0.38 lb	Fusilade DX 2EC, 12.0–24.0 fl oz (365)
Emerged annual grasses	Use the lower rate to control annual grasses less than 6 inches tall. Use the higher rate to control annual grass 6 to 12 inches tall and to control perennial grasses. Do not tank-mix Poast with any other pesticide. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Sethoxydim, 0.2–0.5 lb	Poast 1.5EC, 1.0–2.5 pt, plus 2.0 pints crop oil concentrate per acre (30)
Most grass weed species, including certain hard-to-control grass weeds, such as small grain volunteers and cover crops, and perennials, such as hard fescue, tall fescue, Bermudagrass, orchardgrass, quackgrass, Johnsongrass, and wirestem muhly	Use the lower rate to control annual grasses and the higher rate to control perennial grasses. Repeat the application if regrowth occurs. Direct the spray toward the base of the crop plant and toward the weeds rather than as a broadcast spray over the planting. Add nonionic surfactant to be 0.25% of the spray solution to Select 2EC or Select Max. Do not tank-mix with any other pesticide unless labeled. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition. ***Select is currently labeled for nonbearing fields only. Do not apply within 12 months of harvest.***	Clethodim, 0.094–0.125 lb, or 0.068–0.121 lb	Select 2EC, 6.0–8.0 fl oz (365), ***or*** Select Max, 9.0–16.0 fl oz (14)

CONTINUED

Table 7.18. Herbicides for blueberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergence—Nonselective			
Annual weeds	Contact killer only; no translocation or residual activity. Best results occur when weeds are 2 inches tall or less. Regrowth may occur from the root systems of established weeds. Use a surfactant to be 0.25% of the spray solution (1 qt. per 100 gallons of spray solution). Combine with recommended preemergence herbicide(s) for residual weed control. Do not allow spray or drift to contact green bark, leaves, or fruit. Crop damage may result. The use of shields, such as grow tubes or paper milk cartons greatly reduces the risk of injury in young plantings. ***DANGER: Do not breathe spray mist. Read safety precautions on the label.***	Paraquat, 0.5–1.0 lb	Gramoxone Inteon, 2.0–4.0 pt (—), ***or*** Firestorm 3SC, 1.3–2.7 pt (—)
Annual and perennial weeds	Glyphosate is a translocated, slow-acting herbicide with no soil or residual activity. Results will become evident 1 to 3 weeks after application. Apply lower rates to control seedlings and annual weeds and to suppress established perennial weeds. Use shields and do not allow glyphosate to contact the foliage or green shoots. Optimum rate and time of application depend on weed species and growth stage. Weeds should be growing vigorously when treated. Do not treat weeds that are under stress from drought, extreme heat, cold, or other adverse growing conditions. When using a ropewick applicator, fill the pipe only half full to avoid excessive dripping. Repeated wiping may be needed to provide control equal to broadcast or spot applications. A ropewick applicator offers significant herbicide cost savings. Warnings: (1) ***Do not*** allow glyphosate to contact the leaves, young green bark, fresh trunk wounds, or root suckers, or severe crop injury may occur. (2) ***Do not*** allow glyphosate to contact any immature part of blueberry plants. (3) ***Do not*** use galvanized containers—glyphosate may react with the container to produce explosive hydrogen gas.	Glyphosate ***Broadcast:*** 0.56–3.0 lb ae (acid equivalent). ***Spot treatment:*** See label; wet foliage thoroughly. ***Ropewick applicator:*** See label for product/water ratio. One gallon of product will treat 10–100 acres depending on weed density.	Roundup, ***or*** Touchdown, ***or*** other labeled formulations (14)
BEARING FIELDS			
Preemergence			
Primarily for annual grasses; suppresses or controls certain annual broadleaf weeds	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or reduced rates of Princep, Karmex (New Jersey and Maryland only), or Sinbar in the spring, if planting has been established for at least one year, to control annual broadleaf weeds. Activate with one-half inch sprinkler irrigation within 24 hours after application. If left on the soil surface, napropamide (Devrinol) is broken down by sunlight. Irrigation moves the herbicide into the soil and prevents breakdown by the sun.	Napropamide, 2.0–4.0 lb	Devrinol 50DF, 4.0–8.0 lb (—)
Primarily controls perennial grasses, including quackgrass, bluegrass, ryegrass species, fescue species	Apply in late fall when soil temperatures are between 35 and 55°F. Spring transplants should be at least six months in the field, and fall transplants should be in the field for twelve months prior to treatment. When applied in the fall, also provides early control of annual grasses the following spring. Apply Surflan, Solicam, or Sinbar the following spring for full season annual grass control. Tank-mix Kerb with Princep for residual broadleaf weed control.	Pronamide, 1.0–2.0 lb	Kerb 50WP, 2.0–4.0 lb (—)

CONTINUED

Table 7.18. Herbicides for blueberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Primarily for annual broadleaf weeds	Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix with Surflan, Solicam, Devrinol, or a reduced rate of Sinbar. This rate is one-half the labeled Karmex rate for use alone for the soil type. Tank-mixing will improve crop safety and the range of weeds controlled. In recent years, Karmex has not perfomed as reliably as in the past in some locations. For fall applications, using Casoron in the fall plus a residual annual grass herbicide applied in the spring may be a suitable alternative. For spring applications, adding Callisto or Chateau to your spring tank-mix will improve control of summer annual broadleaf weeds.	***NJ and MD only:*** Diuron, 1.0–2.0 lb	***NJ and MD only:*** Karmex DF 1.25–2.5 lb (—)
Labeled perennial, biennial, and annual weeds	Apply in late fall/early winter to control labeled perennial, biennial, and annual weeds, or in late winter/early spring before weed growth begins and daily high temperatures exceed 50°F. Perennial weed control following late winter/early spring applications has been less consistent than late fall applications. Casoron/Norosac is volatile in warm temperatures and must be irrigated or mechanically incorporated after application. Significant herbicide loss may occur if applied in warm weather.	Diclobenil, 4.0–6.0 lb	Casoron/Norosac 4G, 100–150 lb (—), ***or*** Casoron CS, 2.8 gal (—)
Primarily for annual broadleaf weed control	Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix at 1.0–2.0 lb ai (1.1–2.2 lb of Princep 90DF), depending on soil texture and organic matter, with Surflan, Solicam, or Devrinol. This rate is one-half the labeled Princep rate for use alone for each soil type. Tank-mixing will improve crop safety and the range of weeds controlled. In recent years, Princep has not perfomed as reliably as in the past in some locations. For fall applications, using Casoron in the fall plus a residual annual grass herbicide applied in the spring may be a suitable alternative. For spring applications, adding Callisto or Chateau to your spring tank-mix will improve control of summer annual broadleaf weeds.	Simazine, 1.0–4.0 lb	Princep 90DF, 1.1–4.4 lb (—)
Primarily for annual broadleaf weeds; also controls or suppresses annual grasses	Add crop oil concentrate to be 1% of spray volume. Apply in late fall after leaf drop or in early spring before bud break. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improve annual grass control. Do not allow spray to contact foliage or new green bark. Do not use more than 6 oz/a of product where soil contains more than 80% sand until plants have been in the field for more than 3 years. Follow instructions on label for tank clean-out if any part of the sprayer will be used to spray other crops; otherwise, crop injury may occur. See label for other cautions and restrictions, as even contact with treated residue can cause phytotoxicity.	Flumioxazin, 3.0–6.0 oz	Chateau 51WDG, 6–12 oz (7)

CONTINUED

Table 7.18. Herbicides for blueberry weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Annual broadleaf weeds and yellow nutsedge	Apply in mid- to late spring. Always add a nonionic surfactant to be 0.25% of the spray solution. Direct spray toward the base of the blueberry bush. Avoid contact with crop foliage or temporary yellowing will occur. Use in combination or tank-mixed with other residual herbicides for annual grass control or to improve annual broadleaf weed control. When yellow nutsedge pressure is heavy, apply in the spring after the yellow nutsedge has emerged and grown several leaves, and reapply after harvest a minimum of 45 days later if additional yellow nutsedge emerges. Do not apply more than 2 oz of Sandea per acre per year. Sandea will not injure established sod.	Halosulfuron, 0.375–0.75 oz	Sandea, 0.5–1.0 oz (14)
Controls many annual broadleaf weed species but may be weak on pigweed species	Apply in the spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix using terbacil at 0.5 to 1 lb ai/A (Sinbar 80WDG at 0.63–1.5 lb/a), depending on soil texture and organic matter, with Surflan, Devrinol, or a reduced rate of Karmex (New Jersey and Maryland only). This rate is reduced from the labeled Sinbar rate for use alone for the soil type. Tank-mixing will improve crop safety and the range of weeds controlled. In recent years, Sinbar has not perfomed as reliably as in the past in some locations. Add Callisto or Chateau to your spring tank-mix to improve control of summer annual broadleaf weeds in these situations.	Terbacil, 1.0–2.4 lb	Sinbar 80WDG, 1.25–3.0 lb (—)
Primarily for annual grass control; may provide partial control of many broadleaf weeds	Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix with Princep plus a postemergence herbicide in late fall, or with Karmex (New Jersey and Maryland only), or Sinbar in the spring if the planting has been established for at least one year to improve the control of broadleaf weeds.	Norflurazon, 2.0–4.0 lb	Solicam 80DF, 2.5–5.0 lb (60)
Primarily for annual grasses	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or with Karmex (New Jersey and Maryland only), or Sinbar in the spring if the planting has been established for at least one year to control annual broadleaf weeds.	Oryzalin, 2.0–4.0 lb	Surflan 4AS, 2.0–4.0 qt (—)
For briars, wild cherry, goldenrod, aster species, meadowsweet, red (sheep) sorrel, sheep-laurel, and other perennial broadleaf weeds	Velpar is not recommended in New Jersey because of a narrow margin of safety when applied to soil with a sandy mineral component, and caution is recommended for all states. Blueberry plants must have been established for at least 3 years. Apply to pruned blueberries in the early spring before leaf emergence. Velpar is also labeled for use in renovating lowbush blueberry fields with a 450-day PHI. ***Warning:*** The effect of Velpar on blueberries varies with soils, plant vigor, uniformity of application, and rainfall. Most blueberries are resistant to Velpar, but some varieties are susceptible to injury. In some cases, productivity may be affected even when visible symptoms of phytotoxicity are not apparent. Use lower rates on poorly drained soils, but do not apply to standing water. Do not use on sands, loamy sand, or sandy loam soils. Do not apply to snow or frozen ground.	Hexazinone, 0.5–1.0 lb	Velpar L, 2.0–4.0 pt (90)

CONTINUED

Table 7.18. Herbicides for blueberry weed control.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergence—Selective			
Emerged annual grasses	Use the lower rate to control annual grasses less than 6 inches tall. Use the higher rate to control annual grass 6 to 12 inches tall and to control perennial grasses. ***Do not*** tank-mix Poast with any other pesticide. ***Do not*** apply within 1 hour of rainfall. ***Do not*** apply to grasses suffering from drought, heat, cold, or any other stress condition.	Sethoxydim, 0.2–0.5 lb	Poast 1.5EC, 1.0–2.5 pt, plus 2.0 pints crop oil concentrate per acre (30), ***or*** Select Max, 9–16 fl oz plus non-ionic surfactant to be 0.25% of the spray solution (14)
Postemergence—Nonselective			
Annual weeds	Contact killer only; with no translocation or residual activity. Best results occur when weeds are 2 inches tall or less. Regrowth may occur from the root systems of established weeds. Use a surfactant to be 0.25% of the spray solution (1 qt per 100 gallons of spray solution). Combine with recommended preemergence herbicide(s) for residual weed control. Do not allow spray or drift to contact green bark, leaves, or fruit. Crop damage may result. The use of shields, such as grow tubes or paper milk cartons greatly reduces the risk of injury in young plantings. ***DANGER: Do not breathe spray mist. Read safety precautions on the label.***	Paraquat, 0.5–1.0 lb	Gramoxone Inteon, 2.0–4.0 pt (—), ***or*** Firestorm 3SC, 1.3–2.7 pt (—)
Annual and perennial weeds	Glyphosate is a translocated, slow-acting herbicide with no soil or residual activity. Results will become evident 1 to 3 weeks after application. Apply lower rates to control seedlings and annual weeds and to suppress established perennial weeds. Use shields and do not allow glyphosate to contact the foliage or green shoots. Optimum rate and time of application depend on weed species and growth stage. Weeds should be growing vigorously when treated. Do not treat weeds that are under stress from drought, extreme heat, cold, or other adverse growing conditions. When using a ropewick applicator, fill the pipe only half full to avoid excessive dripping. Repeated wiping may be needed to provide control equal to broadcast or spot applications. A ropewick applicator offers significant herbicide cost savings. ***Warnings*:** (1) ***Do not*** allow glyphosate to contact the leaves, young green bark, fresh trunk wounds, or root suckers, or severe crop injury may occur. (2) ***Do not*** allow glyphosate to contact any immature part of blueberry plants. (3) ***Do not*** use galvanized containers—glyphosate may react with the container to produce explosive hydrogen gas.	Broadcast: 0.56–3.0 lb ae (acid equivalent). Spot treatment: See label; wet foliage thoroughly. Ropewick applicator: See label for product/ water ratio. One gallon of product will treat 10–100 acres depending on weed density.	Roundup, ***or*** Touchdown, ***or*** other labeled formulations (14)

a. Adding a surfactant to these herbicides may improve their effectiveness (see labels).

b. No days-to-harvest limitation is specified on the label if days-to-harvest is listed as (—).

ADDITIONAL NOTES

- All the rates in this table are given on a full-acre basis. If the material is to be banded along or over the row, use the following formula to calculate the banding rate: rate/A banded = rate/A broadcast x (band width in inches ÷ row spacing in inches).
- With all chemicals, follow label instructions and warnings carefully.
- Use pesticides safely. Consult label for restrictions.
- It is unlawful to use recommended chemicals for crops not covered on the label or to use chemicals not cleared for such use on blueberry plantings.
- Formulations other than those listed, with the same active ingredient, may be labeled for the same uses.

C H A P T E R 8

Brambles

CONTENTS

Introduction 171
The Bramble Plant 171
Types of Plants 171
Red Raspberries 171
Gold or Yellow Raspberries 171
Black Raspberries 171
Purple Raspberries 172
Blackberries 172
Other Types of Brambles 172
Cold-Hardiness 172
Pollination 172
Culture 173
General Considerations in Choosing a Site 173
Soil Fertility 173
Plant Sources and Care 173
Cultivar Selection 173
Planting and Establishment 177
Fertilization 178
Mulching 178
Irrigation 179
Row Middle Management 179
Pruning 180
Trellis Systems 182
Protected Culture 183
Harvest and Postharvest Handling 184
Economics 185
Pests 193
Fungal and Bacterial Diseases 193
Viruses 198
Nematodes 200
Insects and Mites 200
Weeds 215
Weed Control Between Rows 215
Mulching and Cultural Methods 215
Herbicides 215
Problem Weeds 218

INTRODUCTION

Brambles offer excellent potential for profit, having both a high value and an ample market, especially where metropolitan markets can be accessed. Many factors still may limit production, however, including a high initial investment, high labor requirements, winter weather, pest susceptibility, and a poor shelf life.

A bramble is defined as any plant belonging to the genus *Rubus,* of which there are many forms. However, raspberries and blackberries are the most commonly grown brambles. Cultivated raspberries and blackberries are related to the wild plants found in fencerows and bordering wooded areas. Wild red raspberries, *R. strigosus,* are found above 2,500 feet in the Appalachian Mountains and in northern and western Pennsylvania. Wild black raspberries, *R. occidentalis,* are found throughout the Mid-Atlantic region. The introduced wineberry, *R. phoenicolasius,* is also widespread. The common blackberries, *R. alleghaniensis* (having sticky glands on the stem) and *R. argutus* are also found growing throughout the region, with other species being common.

THE BRAMBLE PLANT

Brambles typically have perennial crowns and roots that produce biennial shoots. Specifically, the new shoots, called "primocanes," grow vegetatively the first growing season, go through a dormant winter season, and then are termed "floricanes" in their second year. Floricanes subsequently leaf out, flower, fruit, and die during the second growing season. The one exception to this growth habit is the primocane-fruiting bramble, which in the spring produces primocanes from the ground that grow, flower, and fruit in the same season. The base of these primocanes can survive and fruit the next year, while the top portion of the cane that produced fruit the previous fall dies.

TYPES OF PLANTS

The various types of brambles differ from each other not only in fruit color, but also in growth habit (and hence the cultural practices used for each type), pest problems, and other characteristics.

Red Raspberries

Red raspberries may be either of two types. Floricane-bearing red raspberries bear their fruit from late May in Virginia through July in Pennsylvania. They have the typical biennial life cycle of a bramble, so overwintered canes die after fruiting. Primocane-bearing types fruit in their first year from late July through October (or the first hard frost), depending on location and cultivar.

Because both of these red raspberries produce new canes (suckers) from the root system, they can be grown in a hedgerow or, less commonly, in individual "hills" or as single plants when restricted by mechanical removal of unwanted suckers or plastic mulches. Red raspberries are the most winter hardy of the raspberries (surviving to -30°F). Note that all winter-hardiness temperatures are estimates of the temperature some cultivars can tolerate without substantial injury when fully dormant. Once a plant begins to lose its dormancy after 1,200 hours of temperatures between 35 and 50°F (usually in January in Pennsylvania and February in Virginia), it can be injured at much higher temperatures.

Gold or Yellow Raspberries

Gold or yellow raspberries are usually types of red raspberries with a nonfunctioning pigment gene; therefore, they have the same basic management requirements as red raspberries. Although some yellow raspberries are highly flavored, in general, public acceptance is low, perhaps due to the ease of detecting botrytis or other fruit maladies on a light-colored background. All yellow raspberries that have acceptable quality at this time are primocane bearers. Yellow raspberries may have their highest value when mixed in a container of mainly red raspberries because the combination of colors is eye-catching.

Black Raspberries

Black raspberries initiate new canes solely from the crown of the plant. They are grown in a hill system—each plant is grown independently with pruning and maintenance done on a per-plant basis. They benefit from summer tipping, unlike red raspberries, because they branch readily. If tipping is not done,

individual canes grow to unmanageable lengths, they arch over, and their tips root where they touch the ground. To tip, cut 4 inches of growth off of the top of the cane, preferably during a 3- to 4-day period of dry weather. Black raspberries are also the most winter-tender raspberry (hardy only to -5°F).

Purple Raspberries

Purple raspberries (hybrids between blacks and reds) initiate new canes predominantly from the crown but may sucker between plants as well. They are grown essentially as black raspberries are grown and are intermediate in cold-hardiness (down to -10°F). Plants may be managed similarly to red raspberries or tipped, depending on the cultivar.

Blackberries

Eastern blackberries can be either thorny or thornless. Thorny plants tend to be very erect, whereas thornless plants range from semierect to trailing. Thornless types are generally more cold susceptible (damaged at about 0°F) than thorny types and cannot be grown consistently in the northern portions of Pennsylvania and New Jersey. Thornless types require trellising. However, with the release of additional new cultivars, these differences are somewhat blurred. Some low-sugar/high-acid exotic species have been used for breeding thornless blackberries, resulting in some varieties that have a tart fruit. However, breeders have concentrated on improving fruit quality in the last decade. Thorny types have excellent fruit quality but are not often grown commercially because the thorns are brutal and present an obstacle in harvesting. Generally, thorny types tolerate temperatures to about -10°F. Primocane-bearing blackberries have recently been introduced. They are similar to primocane-bearing red raspberries in habit. Trials are currently underway to determine their suitability within the region.

Other Types of Brambles

Several brambles originating from species not native to the eastern United States have also been developed. These include the western trailing blackberries from *Rubus ursinus*, of which Marion (a cultivar sometimes marketed as Marionberry) is the most well known. Similar forms of trailing, not very winter-hardy brambles include tayberry, tummelberry, loganberries, and boysenberries, all of which are hybrids between red raspberries and western blackberries. Tayberries are red, elongated bramble fruits that retain their receptacle when harvested. The fruit makes a beautiful ruby red jam but is extremely soft when fully ripe and only recommended for pick-your-own operations or for processing. Tayberries should be grown according to recommendations for trailing blackberries. Wyeberries are similar to tayberries but were developed from eastern U.S. blackberries and are thus more erect and slightly cold-hardier.

COLD-HARDINESS

Whenever temperatures warm after the cold temperature requirement has been met, the plant begins to lose its dormancy and, thus, its tolerance to cold temperatures. Winter injury is frequently the result of fluctuating winter temperatures rather than absolute low temperatures. This fluctuation occurs more toward the late winter to early spring when solar radiation on clear days can raise the internal temperatures of the canes several degrees higher than ambient air temperatures. After sunset when air temperatures drop, the overheated canes can be severely stressed by the rapid change in temperature as well as by a very low temperature. In locations where this type of injury is a problem, summer-fruiting cultivars should be planted on north-facing slopes, if possible, to minimize exposure to the heating effect of direct winter sunlight. South and southwest-facing slopes are less-optimal locations.

POLLINATION

Many species of cultivated and wild blackberries exist in North America alone. Most commercial varieties are self-pollinating. The blackberry flower has 5 to 8 petals and 50 to 100 stamens clustered around 50 to 100 pistils; it secretes nectar at the base of the flower. Each pistil, when pollinated and subsequently fertilized, develops into a succulent drupelet; thus, blackberry is an aggregate fruit.

Raspberries are also an aggregate fruit. Flowers have 50 to 100 stamens and up to 200 pistils, each of which has an ovary and a slender style. When the flower opens, stamens bend away from the styles and release pollen so only the innermost anthers have a chance to touch the outermost stigmas for self-pollination. Most varieties are self-fruitful, although cross-pollination with pollen from other varieties can improve development of maternal tissues with an accompanying increase in fruit weight and shape.

Nectar and pollen of blackberry and raspberry are attractive to a host of pollinators. In areas where wild plants are plentiful, honey bee colonies store surplus honey, which is harvested by beekeepers. Research has documented the importance of bee pollination to blackberry and raspberry crop yield and quality. Optimum pollination requires multiple bee visits over the first two-day period when individual flowers are viable. Incomplete pollination means poor distribution of pollen to receptive stigmas, resulting in small, crumbly, misshapen berries and reduced yield.

In the past, abundant, widespread, feral honey bee and native wild bee populations most likely provided adequate pollination of wild and domestic brambles, so pollination was not an issue of concern for bramble growers. However, due to the introduction of parasitic mites and increased diseases, feral honey bee populations have been decimated. In addition, while there is continuing debate among experts, pesticide use and destruction/fragmentation of nesting habitat have caused concern and are blamed for reduced native bee populations in some areas. Growers now need to carefully assess and make decisions concerning pollinators that could have significant economic impact on their operations. One to two colonies per acre of bearing plants is recommended to yield one bee per 100 flowers during favorable flight activity periods.

To date, nearly all of the research on insect pollination of blackberry and raspberries has been done with honey bees, and recommendations for ensuring adequate pollination have involved only this pollinator. The contribution of native

pollinators, especially bumble bees, is seldom considered. In cases where they are considered, recommendations are lacking on how growers might incorporate information about native bee populations into decisions made on assessing pollinators and/or providing adequate numbers or kinds of pollinators to maximize yield and quality.

CULTURE

GENERAL CONSIDERATIONS IN CHOOSING A SITE

Brambles require full sun and well-drained soil—they never tolerate wet soils. Brambles will use water at the rate of pan evaporation or higher during fruit production (see Appendix E for additional sources of information), especially in high temperatures or winds. Suitable soil can only hold 7 to 14 days of moisture before serious deficits occur, growth stops, and leaf desiccation or sunscalding occurs. Adding organic matter and using raised beds are especially helpful in assuring consistent growth, yield, and plant health. Before planting brambles, grow cover crops or green manure crops and incorporate them to increase the organic matter content, or add manure (10 tons per acre as a ballpark figure). For a complete discussion of soil management including use of cover crops and manure, see Chapter 2.

The planting site should be isolated from other brambles. Wild or neglected bramble plants are major reservoirs for wind-blown spores of the orange rust fungus and for viruses that are spread into the field by flying or windborne aphids, leafhoppers, white flies, and, very commonly, virus-infected pollen. They also harbor a number of specific bramble insect pests. Monitor a 500-foot border around your fields for any such "weed" brambles and, wherever possible, destroy them with an herbicide such as 2,4-D or glyphosate (Roundup). Fall applications are particularly effective; however, applications should be made when weather is still warm enough (highs in the 60s or 70s) for plants to translocate the herbicide. Also, be aware that cultivated brambles should not even be slightly exposed to glyphosate in the fall. Repeat this survey of border areas at least once each spring. Wild brambles are commonly found along the margins of wooded areas and fencerows.

Before planting brambles, control weeds, especially perennial bindweed, thistle, curly dock, johnsongrass, wiregrass, quackgrass, and nutsedge, by using a competitive preplant cover crop, by applying Banvel or Roundup herbicide to the site, or by fumigating with higher rates of approved fumigants. Treatments must be made by mid-fall at the latest to be effective. Raspberries frequently benefit from fumigation, which eliminates soilborne insects, nematodes (which transmit viruses), and most soilborne pathogens, but keep in mind that fumigation also eliminates beneficial organisms. For further information on fumigation, see Chapter 3.

SOIL FERTILITY

Test soil the year before planting. The soil pH should be between 6.0 and 6.5. Apply lime, phosphorus, and/or boron the fall before planting. Potassium may be applied in fall or spring, and nitrogen should be applied in the spring just before planting.

PLANT SOURCES AND CARE

Purchase brambles from a reputable nursery (see Appendix C). Tissue-cultured plants are preferred because they are certified to be virus free (make sure they are!) and should be free of verticillium, root rots, nematodes, and crown gall. When tissue-cultured plants leave the lab, they are very vigorous but are especially sensitive to herbicides the first year. Order tissue-cultured plants so they arrive close to the last frost date in your area.

A satisfactory alternative to tissue-cultured plants is nursery-matured plants. In the case of nursery-matured plants, stock is usually cold hardy and better established than tissue-cultured plants. They have been exposed to field conditions for several months, so there is some risk that they may have been exposed to sources of diseases, insects, and mites.

Dormant canes are not recommended since experience has shown that they are more often disease infected. Crown gall is a particular hazard because once it infects the soil it cannot be eradicated, even with fumigation. If dormant canes are purchased, they should be planted in March or April. If canes cannot be planted immediately, hold them at 32°F or "heel them in" in a sheltered area. Thoroughly soak dormant plant roots in water before planting.

When selecting planting stock for organic production, keep in mind that since brambles are perennial crops, planting stock does not need to be organically produced. However, the planting must be managed organically on a certified organic area for one year before harvested berries can be marketed as organic.

CULTIVAR SELECTION

Selecting appropriate cultivars may be the most important decision a grower makes and certainly a difficult one to change once the plants are established. Consider not only the degree to which a cultivar is biologically adapted to a particular site, but also available markets, postharvest facilities, and labor.

The listing below contains two letters, N and S, basically indicating the area in the Mid-Atlantic where the cultivars may be grown. Northerly areas (N) are roughly north and west of a line from New York City to Trenton, New Jersey, to Williamsport, Pennsylvania, to Cumberland, Maryland, to Bluefield, West Virginia. Southerly areas (S) extend from this line south and eastward if also below 2,500 feet in elevation. Descriptions of individual cultivars follow.

Summer-Bearing Red Raspberries

Early Season

BOYNE (N)

- Very winter hardy and productive.
- Berries are dark red and small to medium sized.
- Plants are short.

ESTA (S)

- Currently available through very few nurseries.
- Vigorous with high productivity. Trellising system that keeps primocanes and floricanes separate is recommended due to high vigor
- Canes and leaves resist diseases, including late leaf rust and botrytis.
- Moderately sized fruit with intense flavor.
- May winterkill but resists fluctuations in spring temperatures.
- Esta is resistant to raspberry bushy dwarf virus, the most common pollen

vectored virus in the Mid-Atlantic and one of the primary causes of crumbly berries.

LAUREN (N OR S)

- Has very large fruit with good flavor and firmness and a long fruiting season.
- Tends to winterkill, so avoid late summer fertilization to encourage hardening off. May be tried in areas with mild winters or where winter temperatures are moderated, such as along the shore of Lake Erie.
- Canes are very vigorous and somewhat brittle; therefore, they should be tied as soon as possible to a trellis.
- Susceptible to phytophthora root rot.

MOUTERE (N OR S)

- Productive and firm.
- Harvest season bridges early and midseason cultivars.
- Fruit is uniform in size and bright red, but flavor is lacking.
- Canes are uprights, semi-spineless, and vigorous.
- Resistant to raspberry bushy dwarf virus and raspberry aphids.

PRELUDE (N)

- Will fruit on primocanes, but produces the majority of its yield as a summer bearer. In warmer areas with a longer growing season, more fruit is produced on primocanes, limiting summer production.
- Fruit is mildly flavored, dark when fully ripe, and relatively small.
- Canes are dense and vigorous.
- Resistant to phytophthora root rot.
- Preferred by Japanese beetles.
- For trial.

REVEILLE (N OR S)

- A very early berry with good cold-hardiness and vigor.
- Fruit is too soft for shipping but is excellent for pick-your-own.
- Flavor is good, size is intermediate, and productivity is fair.
- Very cold-hardy.

Midseason

AMOS (N OR S)

- Currently available through very few nurseries.
- Flavorful, of moderate size and productivity.
- Fruit has round shape.
- Fairly hardy and resistant to fluctuating winter temperatures.

CANBY (N)

- Moderately winter-hardy and nearly thornless.
- Productive, with attractive, medium to large fruit.
- Susceptble to phytophthora root rot.

CLAUDIA (N)

- Currently available through very few nurseries.
- Very productive in part due to its good cold-hardiness.
- Canes start growing late in the spring and are stout, resulting in very well-presented fruit.
- Fruit is large, soft to moderately firm, and has good flavor.

KILLARNEY (N OR S)

- Old standard eastern cultivar that's still popular.
- Fruit is light colored and sweet
- Fruit size is small to medium.
- Winter-hardiness in cold locations may be its most important trait.
- Support is needed to keep fruit off of ground.

LATHAM (N OR S)

- Old standard eastern cultivar.
- Has excellent cold-hardiness and relative tolerance of wet soils.
- Fruit size is small to medium, flavor is acceptable, and firmness is good.
- Has a relatively long bearing season.
- While the plant is susceptible to powdery mildew, it tolerates mosaic viruses fairly well.

NEWBURGH (N)

- Another midseason berry of medium size, good flavor, and cold-hardiness.
- Fruit may be crumbly and may ripen unevenly.
- Particularly attractive to Japanese beetles and twospotted spider mites.

NOVA (N OR S)

- Fruit is bright red, firm with good flavor, and of moderate size.
- Fruit must be fully ripe in order to be released from the receptacle.
- Ripens fruit gradually over a long harvest season.
- Also produces a small fall crop on primocanes.
- Nearly thornless.
- Plants are vigorous, high-yielding, and winter-hardy.
- Resistant to cane diseases and late leaf rust.

TITAN (N)

- A productive cultivar with mildly flavored, very large, cone-shaped berries.
- Berries are soft, and some growers feel their appearance is too "rough."
- Plants have excellent vigor but poor to moderate winter-hardiness.
- Particularly susceptible to phytophthora root rot and crown gall but is resistant to raspberry aphid, a vector of certain viruses.

Late Season

ENCORE (N)

- Can be cold-damaged.
- Large berries with good flavor.
- Has average vigor and nearly spineless canes.
- Aphid-resistant.
- Susceptible to phytophthora root rot.

K-81-6 (N)

- Large, firm, with good flavor.
- Very vigorous.
- Winter-hardy but susceptible to high summer temperatures and fluctuating winter temperatures.
- Susceptible to fire blight.
- Very susceptible to phytophthora root rot.
- Will remain unnamed.

TAYLOR (N)

- Medium-sized fruit, excellent flavor, and moderate winter-hardiness.
- Very susceptible to raspberry mosaic complex, fungal diseases, and two-spotted spider mites.

Primocane-Bearing Red Raspberries

Primocane-bearing red raspberries bloom in early to midsummer and bear fruit from mid- to late summer until heavy frost or freeze.

Early Season

AUTUMN BLISS (N)

- Vigorous and extremely high yielding in cooler regions.
- Susceptible to some common viruses.
- Canes have a large diameter and are relatively short. Considerably earlier than Heritage (about 2 weeks).

- May be especially useful in cooler area like Pennsylvania's northern tier; however, fruit is too soft for areas with warm temperatures during ripening.

CAROLINE (N)

- Produces 1 to 2 weeks earlier than Heritage with fruiting continuing until first frost.
- Produces many suckers and is, therefore, very high yielding.
- Fruit is conical with very good flavor.
- Caroline fruit is 4 grams at 3,000 feet elevation in Maryland and 2 grams (relatively small) near sea level.
- Nitrogen applications may be lowered if fruit needs to be stored or shipped.
- Plants are somewhat susceptible to late leaf rust.
- Resistant to phytophthora root rot.

JACLYN (N OR S)

- Large, uniform, dark fruit that tends to be a little soft in higher temperatures.
- Fruit is long and conic, which makes removing it in cold weather somewhat difficult.
- The earliest primocane bearer in several trials in the United States and Europe. In unheated tunnels in Maryland, fruit ripens in early July on primocanes.
- Flavor is good to excellent, and production is high, with yields more than 9,000 pounds per acre.
- Susceptible to late leaf rust but is resistant to sunscald.
- Susceptible to damage by potato leafhopper.

JOAN J (N OR S)

- Fruit is of medium size, firm, glossy, and dark red.
- Flavor is good, but not exceptional.
- Canes are spineless and of medium height; foliage is dense.
- Limited grower trialing indicates good productivity with this cultivar.
- Disease susceptibilities in this region are undetermined.

POLANA (N)

- Early and high yielding; additional nitrogen is needed for high yields.
- Beautiful, glossy, clear-red, conical fruit.
- Fair flavor.
- In the southern part of the region, including DE, vigor and fruit size is lacking.
- In a Pennsylvania trial, it was fairly susceptible to anthracnose.
- Susceptible to phytophthora root rot and verticillium wilt.

POLKA (N OR S)

- Large, firm fruit with very good flavor.
- From the same breeding program in Poland that produced Polana.
- Shape and color is similar to that of Polana.
- Popularity is growing very quickly in Europe.
- Attractive to Japanese beetles and potato leafhoppers.

Midseason

AUTUMN BRITTEN (N OR S)

- Large, uniform fruit with excellent flavor.
- Cane density is lower than average, so plant at closer spacings than usual (18 to 20 inches).
- Fruit may be soft for southern growers, but the plant is vigorous.

DINKUM (N)

- Flavorful, rounded, fleshy fruit.
- Very good flavor.
- Shows more damage from leafhoppers than most other cultivars.
- For trial.

HIMBO TOP (N OR S)

- From Switzerland.
- Slightly later than Autumn Bliss.
- Large firm conic fruit has very good flavor and color.
- May need closer spacing (18 inches between plants) due to reduced suckering.
- Canes are tall and thin and need a trellis for support.

Late Season

CRIMSON NIGHT (S OR N IN TUNNELS ONLY)

- For trial.
- A specialty berry with very sweet distinctive flavor.
- Produces dark red conic fruit that is very large.
- Very late—only for tunnel production.

HERITAGE (N)

- Medium-sized, firm fruit of excellent quality but only fair flavor.
- Season begins in mid- to late August in Pennsylvania and continues through severe frost or freeze.
- Fruit tolerates light frosts well.
- Plants are vigorous and sucker well.
- A widely planted red raspberry cultivar, Heritage continues to be the standard among primocane-fruiting types.

JOSEPHINE (S)

- Very firm, round fruit that ships very well. Fruit is large even in warmer locations, but can average up to 5 grams at cooler locations in the southern Mid-Atlantic (at elevations higher than 2,500 feet).
- Too late for the north (zones 6a and cooler) but will grow well in the rest of the region.
- Where it can be grown, it has been productive; also produces a large crop on floricanes.
- Improved flavor over Heritage.
- Resistant to leafhoppers and late leaf rust.
- Susceptible to phytophthora root rot.

NANTAHALA (N OR S)

- Medium-sized, firm conic fruit of light color.
- Excellent intense flavor.
- Very late so best suited for tunnel production in the north.
- Yields are on the low side.

Primocane-Bearing Gold Raspberries

Primocane-bearing gold raspberries have the same traits as reds. All varieties recommended below produce in the late primocane-bearing season. *Note:* Golden Harvest has been trialed, but its fruit in this climate has been small and lacking in flavor and color.

ANNE (N)

- Large late fruit with excellent, unique flavor.
- Cane density tends to be sparse.
- Planting at closer spacing (16 to 18 inches) is recommended.
- Responds well to tipping canes at 3 to 3½ feet to encourage branching and fruitfulness.
- Can produce a large additional crop on floricanes the following spring/summer.
- For trial.

DOUBLE GOLD (N OR S)

- For trial.
- Fruit is peach colored and conic.
- Tends to be soft but has excellent flavor.
- Plants are vigorous.
- Yields can be increased by double-cropping for a summer and fall crop.

FALLGOLD (N)

- Fruit is soft, sometimes develops a reddish blush, and has excellent flavor.
- Ripens with Heritage in the fall and is moderately winter-hardy.

GOLDIE (N)

- Fruit color is gold to apricot.
- A sport of Heritage; therefore, bearing season and other plant characteristics are identical.
- Fair flavor.
- Very susceptible to sunscald.
- For trial.

KIWIGOLD (N)

- A sport of Heritage; therefore, bearing season and other plant characteristics are identical.
- For trial.

Black Raspberries

Black raspberries bloom in May and ripen in late June through early July. They generally fruit earlier than red raspberries, but very little difference exists among the ripening periods of black raspberry cultivars.

Many very old cultivars such as Cumberland and Munger still appear in nursery catalogs as they are still sold in large quantities. Munger, in fact, comprises the vast majority of processing black raspberry acreage in the Pacific Northwest and the world. Even though many older cultivars originated in this region—Cumberland is from Pennsylvania and Munger is from Ohio—they do not appear in this list as they generally have a smaller berry size than more recently released cultivars, and significant susceptibility to various diseases, making plantings fairly short lived. These characteristics are not as large of a drawback in regions where plantings are mechanically harvested or can be replaced economically every 3 to 4 years. Cultivars listed below have a relatively large size making them suitable for freshmarket sales.

BRISTOL

- High yielding and early with excellent flavor.
- Susceptible to anthracnose but tolerant of powdery mildew.

JEWEL

- The most widely grown black raspberry in the region.
- A particularly vigorous and productive plant with very good cold-hardiness.
- Fruit are larger than Bristol and more susceptible to botrytis development after harvest.

MAC BLACK

- Later than Jewel; extends season significantly.
- Vigorous stocky canes, large fruit.
- Fruit releases from receptacles easily.
- Reports indicate satisfaction with this cultivar in various locations across the region.
- Recommended for trial.

Purple Raspberries

Purple raspberries bloom in late May to June and are ready for harvest in late June to July.

ROYALTY

- Yields heavily, but flavor is not generally preferred.
- Has cone-shaped fruit that is sweeter than Brandywine.
- Fruit is too soft for shipping, although it can be picked slightly before ripe for this purpose.
- Suckers freely from roots, so it grows more like a red raspberry in hedgerows.
- Does not branch, so it should not be tipped.
- Especially susceptible to tomato ringspot virus and crown gall.

Thornless Semi-Upright Blackberries

Thornless blackberries can be grown in the southern area as designated for red raspberry cultivars. The following cultivars are recommended for culture in southern areas of the region. *Northern growers should try only a few blackberry plants on their site to determine likelihood of flower bud survival over the winter.*

APACHE

- Early.
- A favorite for flavor.
- Similar moderate yields to Navaho.
- Vigorous plants.
- Good fruit size.
- Prone to developing red drupelets.

ARAPAHO

- The earliest erect thornless blackberry.
- Fruit is medium sized, short, and conical with small seeds.
- May be cold-hardier than Navaho.

CHESTER

- Ripens late.
- Has smaller fruit than most.
- One of the most commonly grown thornless blackberries.

DOYLE'S THORNLESS

- Late.
- Productive in PA trial.
- Fruit on small side but firm.
- Flavor acceptable to good.
- Winter-hardiness similar to that of Triple Crown.
- Plants tend to be trailing, and produce few laterals even when tipped, so adjustments in pruning and trellising need to be made.
- Somewhat susceptible to Gnomonia stem canker, which may be an indication of winter injury.

HULL

- Flavor is sweeter (less tart) than that of other cultivars and may be preferred for pick-your-own.
- The berry does not lose color under high temperatures and is fairly cold-hardy.

NATCHEZ

- Untrialed in the Mid-Atlantic region.
- Sweet in cool regions.
- Very early, similar season to Arapaho.
- Large fruit.
- Needs to be trellised.

NAVAHO

- Fruits relatively late, and for a long time.
- Plant growth habit is fairly erect.
- Yields are moderate.
- Small to medium-sized fruit with good flavor.
- Fruit has attractive color and sheen but may be "rough."

- May be especially susceptible to orange rust.
- Somewhat susceptible to Gnomonia stem canker, which may be an indication of winter injury.
- Resistant to anthracnose, rosette, and root rot.

OUACHITA

- Fruited relatively early but only for a short time in PA trial, resulting in low yields.
- Good fruit size and flavor.
- Winter-hardiness similar to that of Triple Crown and Navaho.

TRIPLE CROWN

- Starts fruiting in midseason, with long gradual dropoff in yields.
- Large, flavorful fruit with good sweetness.
- Productive.
- Very stocky canes once established.
- Considerable susceptibility to Gnomonia stem canker, which may be an indication of winter injury.
- Susceptible to sunscald.

Thorny Upright Blackberries

Thorny blackberries are not widely grown, but they offer potential for small, diversified farms with niche markets. The thorns are a significant impediment in culture and harvest. Though it is often stated that thorny cultivars are more winter-hardy, many thorny cultivars are no more winter-hardy than thornless cultivars. See notes on winter-hardiness for individual cultivars below.

CHESAPEAKE

- Currently available through very few nurseries.
- Vigorous, productive cultivar with extremely large, sweet fruit.
- Has very large thorns.
- Probably too cold tender for northern New Jersey and most of Pennsylvania.

CHICKASAW

- Early in PA trial.
- Relatively brief harvest season.
- Improved winter-hardiness and yields compared to Shawnee.
- Bears very large fruit.
- Very good flavor.
- Good productivity in a moderate climate (southeast PA).
- Plants are very vigorous and quite thorny.
- Winter-hardiness questionable when temperatures are commonly less than 0°F.

CHOCTAW

- Very productive and early fruiting, producing large fruit with small seeds.
- Probably the least hardy of all cultivars in this group.
- For trial only.

DARROW

- An early, very erect plant that bears medium-sized, firm fruit with good flavor.
- Plants are vigorous and very winter-hardy.

ILLINI HARDY

- Early.
- Vigorous and very winter-hardy.
- Compensates for winter injury by producing fruit from secondary buds, resulting in consistent high yields.
- Thorns are nastier than with most.
- Smaller-sized berries with average flavor.
- Fruit size decreases through harvest season.
- Resistant to phytophthora root rot.
- The most cold-hardy cultivar but still will be injured in very cold locations.

KIOWA

- Highest yields in midseason, but produces for a long time.
- Large fruit and long harvest season are the characteristics of note.
- Winter-hardiness has been a problem even in southeastern PA, but it performed well in warmer areas such as DE.
- Variable yields depending on conditions in previous winter.
- Good flavor.
- For trial only.

SHAWNEE

- Early.
- Less productive than other thorny cultivars due to a short harvest season.
- Good fruit size.
- Questionable winter-hardiness.
- Resistant to orange rust.

Primocane-Bearing Thorny Blackberries

Prime-Jim and Prime-Jan were breakthrough cultivars, being the first released primocane-bearing blackberries. Growers experiencing problems with winter-hardiness may wish to try this crop on a small scale but should not expect high yields. Because the crop is produced very late in the season, protection may be needed to mature fruit on Prime-Jan and Prime-Jim. Even production in tunnels does not lengthen the season enough to mature the full crop of Prime-Ark 45 and Black Magic. Plants should not be relied on for a summer crop as the canes lack winter-hardiness. These berries probably have greater potential where very high prices could be obtained for a specialty item.

PRIME-JAN

- Flavor is acceptable.
- Somewhat less stocky than Prime-Jim.
- Larger fruit and more productive than Prime-Jim in PA trial but still not acceptable.

PRIME-JIM

- Stocky plants.
- Flavor somewhat poorer than that of Prime-Jan.
- Fruit on small side in PA trial.

PRIME-ARK 45

- Large fruit.
- Excellent flavor.
- Sweet when ripe.
- Production is very late, causing yields to be very low.

BLACK MAGIC

- Large fruit but too soft for commercial production.
- Excellent flavor.
- Sweetest of the primocane-fruiting blackberries.
- Very late, causing yields to be low.

PLANTING AND ESTABLISHMENT

Virus-tested, tissue-cultured raspberry plants should be planted in the spring. Tissue-cultured plants are tender and are damaged by frost, so they cannot be planted until the danger of frost has passed. Avoid planting in poorly drained soils or after any verticillium-susceptible crop (including tomatoes, potatoes, peppers, eggplant, or strawberries). This is particularly crucial for black rasp-

berries since there are no known sources for verticillium resistance. In-row spacings (distance between the plants within the row) are as follows:

- red and gold raspberries: 24 inches
- black raspberries: 30 inches
- purple raspberries: 36 inches
- thorny blackberries: 36 inches
- thornless blackberries: 4 to 6 feet

The number of plants required per acre for various plant spacings is shown in Table 8.1.

Between-row spacings in the region should be no less than 8 feet, although row spacing depends on the size of equipment that will be used to maintain the planting. Closely spaced rows reduce the wind movement and drying conditions necessary to minimize fungal spread. Allow at least 4 feet more between rows than the width of the widest implement to be used in the planting.

Fertilizer after planting should be applied as indicated in the fertilization section below, assuming that the soil was amended according to soil test results prior to planting.

FERTILIZATION

If proper preplant preparation is followed as outlined above (soil tested the year before planting; lime, phosphorus, and boron applied, if needed, the fall before planting; potassium applied in the fall or spring; and nitrogen incorporated just before planting), no additional fertilizer other than nitrogen should be needed the first year. Burning young roots and damaging the plants is extremely easy, especially if tissue-cultured plants are used. Therefore, a water-soluble starter fertilizer can be applied at planting according to package directions for transplants, but it should be applied after plants are in the ground and kept 6 inches away from the plants rather than being poured into the planting hole. On heavier soils, nitrogen incorporated prior to planting should be sufficient to supply the plant for the first growing season. Some additional nitrogen fertilization after planting may be needed on light soils, with a maximum of 10 pounds per acre of actual nitrogen applied at any one time. Granular fertilizers should not be applied until at least 8 weeks after planting and should be kept 4 to 6 inches away from the plants. Calcium nitrate is the preferred nitrogen source.

In established plantings, fertilizer should be applied at the full per-acre rate but concentrated in a 2- to 3-foot-wide band over the row, not adjusted downward as a proportion of the area covered (see Table 8.2 for recommendations). Nitrogen rates should be adjusted based on leaf analysis and plant vigor. In established bramble plants 3 years or older, the general rule of thumb for nitrogen is around 60 pounds of actual nitrogen per acre per year. This may be too much or not enough, depending on soil type, variety, and season. Actual nitrogen required may also vary, depending on management intensity (e.g., drip-irrigated intensive production and native fertility). During the first and second years, the nitrogen requirement may be one-half to two-thirds of the above rule of thumb. Tissue analysis can help you fine-tune your bramble fertility program, as can observations of plant vigor. Raspberry primocanes should grow 5 to 8 feet in a season, while thornless blackberries should fill their allotted space on the trellis. Weekly fertigation of a portion of the annual nitrogen is very efficient in well-managed plantings. Alternatively, apply half of the required amount of nitrogen at bud break and the second half in May to increase uptake efficiency and reduce the potential for fertilizer runoff. Avoid fall applications because they can reduce winter-hardiness.

Nutrients other than nitrogen should be applied according to tissue test recommendations. If corrective measures for low nutrient concentrations are not made until deficiencies are observed, yield reductions will have already taken place. For a more complete discussion, see NRAES-35, *Bramble Production Guide* (see Appendix E for information on obtaining this guide). Tissue analysis procedures and critical values are listed in Appendix B. Balance this information with your experiences, especially observations on vigor, yield, fruit flavor (K), and fruit firmness (N).

MULCHING

Good weed control during the first year is essential. However, tissue-cultured plants, and dormant plants to a lesser extent, are extremely sensitive to most herbicides until about 4 months after planting. Research from Cornell has shown that applying a clean straw mulch (4 inches deep) to newly planted, tissue-cultured raspberries provides good weed control. On heavy soils, mulch should be used only in the first year since straw mulch over a prolonged period can encourage the development of root rots. For further information, see "Weeds" at the end of this chapter.

A fast start is critical to successful establishment of bramble plantings in the Mid-Atlantic region. Vigorous bramble plantings outcompete weed seedlings by shading them, thus reducing the need for herbicides. If large patches of row exposed to sun still exist during the second year of the planting, weed pressure often necessitates greater use of residual herbicides. These residual herbicides can reduce bramble growth, particularly on red raspberries in warmer climates. This further necessitates greater weed control.

The use of plastic mulch may have merit in establishing a new planting. Landscape fabric, aluminized plastic, black plastic, or a black-on-white plastic (white side up) can be used. Advantages of plastic use are good weed and grass control the first season, along with moisture conservation. Growth and suckering should be increased; however, canes can become winter-tender if growth is pushed too far into the fall. The addition of trickle (drip) irrigation eliminates moisture stress and can be used for fertigation. When landscape fabric is used to completely cover the ground, the row spacing can be reduced to minimize costs.

Table 8.1. Number of bramble plants per acre at different spacings.

Inches between	Spacing between Rows		
Plants in Row	8 Feet	10 Feet	12 Feet
18	3,630	2,904	2,420
24	2,722	2,178	1,815
30	2,178	1,742	1,452
36	1,815	1,452	1,210
42	1,556	1,245	1,037
48	1,361	1,089	908
54	1,210	968	807
60	1,089	871	726
72	908	726	605

Table 8.2. Postplant nitrogen recommendations for brambles (lbs N/acre).

	Irrigated			Nonirrigated		
Year	Sand	Loam	Clay	Sand	Loam	Clay
FALL-BEARING RASPBERRIES (WITH NO SUMMER CROP)*						
0 (Year of planting) See text under the heading "Fertilization"						
1	40	30	25	35	30	25
2	70	60	50	70	65	50
3+	100	90	80	90	80	70
SUMMER-BEARING RED RASPBERRIES AND BLACKBERRIES						
0 (Year of planting) See text under the heading "Fertilization"						
1	35	30	25	30	25	25
2	50	45	40	45	40	35
3+	70	60	50	60	50	40
SUMMER-BEARING BLACK AND PURPLE RASPBERRIES						
0 (Year of planting) See text under the heading "Fertilization"						
1	30	25	20	25	20	20
2	45	40	35	35	30	25
3+	60	50	45	45	40	30

*Split the amount listed into two equal applications—one made in spring and the second made by early July.
Note: Rates should be adjusted according to leaf analysis.
Modified from information provided by Cornell University.

A propane torch with a self-igniter can be used to burn holes in the mulch. Burn a hole 3 inches in diameter for planting containerized plants and tissue-cultured plugs. If the mulch remains in place for the following years, enlarge the hole before April 1 since most suckers are formed in February and March, and heat damage can occur on these new canes, especially on the side facing south. For transplants with a larger root system, such as nursery-matured plants or vigorous cultivars that sucker heavily, lengthwise slits can be made.

If plastic mulch or landscape fabric is used with cultivars that produce a hedgerow of new canes (red raspberries, gold raspberries, and most thorny blackberries), any additional openings (a gap up to 8 to 12 inches wide) should be made near the center of the row. This will allow the new growth to emerge while encouraging the canes to remain contained in narrow hedgerows. Alternatively, the mulch can remain in strips between the hedgerows. If cultivars are being grown that produce new canes primarily from the crown area (black raspberries and thornless blackberries), the mulch may remain in place relatively intact. When using landscape fabric or plastic mulch for the long term, continuous cover has caused problems in enhancing winter injury, except in tunneled plantings. This effect may be due to the soil prematurely heating in winter, or to tender fall growth failing to harden off sufficiently. In any system, use of plastic mulch or landscape fabric can encourage a buildup of rodent populations.

Raised beds or hilled rows are recommended with or without plastic mulch because they minimize root rots and other root disease problems, especially phytophthora root rot. (See information on phytophthora root rot later in this chapter.) *Caution:* Before raising beds or hills in a field, the natural water drainage pattern must be taken into account. Failure to do so can create major drainage problems if raised beds become mini dams. Take care of your field water drainage first by installing a grass waterway, field tile, or drainage ditches.

In subsequent years, composted sawdust or woodchips or shredded hardwood bark can be used on light and medium soils. All are excellent mulch materials and help reduce weeds, heat stress, and water loss during the growing season, especially in warmer areas of the region. The depth should be 2 inches or less to minimize a buildup of vole populations. Noncomposted sawdust or woodchips should not be used since the biological breakdown of these products will use much of the available nitrogen needed for healthy plant growth. While labor and materials needed for mulching can be costly, mulched plantings generally require fewer herbicide treatments. Good mulches can and do lower the incidence of water and heat stress on the planting, reducing plant leaf drop and fruit sunscalding.

IRRIGATION

Brambles benefit from irrigation, especially during fruit swell, which occurs the week before fruit ripens. Trickle irrigation is preferred for brambles because wetting the fruit with overhead irrigation may encourage disease. Plants generally require 1 to 2 inches of water per week during the growing season and 2 to 3 inches per week during harvest. Correctly timed irrigation may help in reducing sunscald (see the later section on physiological disorders).

ROW MIDDLE MANAGEMENT

Establishing permanent sod middles is recommended between bramble rows. The goal is to prevent establishment of broadleaf weeds, which carry tomato ringspot virus and harbor insects. Therefore, the sod should be dense. Surveys of grower farms indicate that tomato ringspot virus is a major problem in our area. Other benefits of sod are decreased soil erosion, a hospitable environment for workers during operations such as harvest and pruning, and the elimination of the need for tillage or herbicides in row middles. Unfortunately, the drawback of sod is its preferred suitability for Japanese beetle larvae. The adult beetles that hatch from the sod will skeletonize bramble leaves and feed on fruit. Whether the benefits of the sod outweigh this drawback depends on the size of the planting and the amount of turf otherwise growing in the area. In most cases, the small size of the bramble plantings adds relatively few additional beetles to the ones that would be present anyway, so having the sod is preferable to having bare ground.

If clean cultivation is practiced in alleyways, another option is to plant

annual winter green manures. The green manure crop will improve soil health and eliminate the need for cultivation in the fall that can stimulate bramble growth, resulting in growth late in the season and possibly winter injury. See Chapter 2 for information on selecting a green manure crop.

Information on establishment and management of sod row middles is covered in greater detail in Chapter 7. Characteristics of various cover crops are listed in Table 7.3, and seeding rates and nutrient and pH requirements are listed in Table 7.4. Hard fescues such as Spartan, Aurora, SR3000, SR3100, and Reliant (the number of available cultivars is rapidly increasing) and sheep fescues are low growing and adapt readily to a wide range of soil pH. Once established, these plants are competitive enough to outgrow weeds. They do not propagate from rhizomes like many grasses but are a bunch grass, so no encroachment occurs on the crop plant. They form a dense sod with deep extensive roots that protect soil structure. Though the seed is relative expensive, fewer mowings are needed, which more than offsets the higher price of the seed.

While some growers have reported difficulty in establishing the hard fescues, this has not been our experience. Seeding rates can vary from 20 to 30 pounds per acre to 80 pounds per acre depending on how quickly dense cover is required. When seeded at the lower rate, plants take from 6 to 9 months to establish a good cover, while the higher seeding rate will result in a full cover much more rapidly. Plan on seeding the fall before or the fall after planting because this will improve establishment since grasses prefer cool seasons of the year for growth. This will also give the grass a chance to establish during a time of the year when dry spells are not likely and few operations using equipment are taking place in the field. For additional information on sod row middle management, see Chapter 7 and additional resources listed in Appendix E.

PRUNING

Red Floricane-Fruiting/Summer-Bearing Raspberries

Floricanes of all brambles die after fruiting is completed. Prior recommendations have stressed that spent fruiting canes should be removed immediately after fruiting to allow air circulation through the canopy and to remove possible sources of disease inocula from the canopy. Research has shown, however, that winter injury was more severe on the cold-tender cultivar Titan when spent fruiting canes were removed in the summer as opposed to during the subsequent fall or winter. For this reason, when floricanes retain their leaves (primarily in the north), we now recommend leaving the spent fruiting canes until dormant pruning if cane diseases are minimal. However, if cane diseases are present to any significant extent, or if excessive summer heat or previously unnoticed winter injury weakens canes and causes leaves to abscise, spent fruiting canes should be removed as soon as possible after harvest.

Floricane-bearing red raspberries grow naturally in a hedgerow system, as indicated in Figure 8.1a. The suckers, originating from the root system, fill in the entire length of the row, spreading to several feet wide. This would reduce drying conditions in the middle of the row. Thus, row widths should be reduced to no more than 1 foot wide in the spring and maintained at this width. Removing a portion of suckers if excessive in number further improves air movement. Removing excess canes in the spring will stimulate more cane growth to some extent, but removing canes outside the 1 foot width of the row encourages growth of taller, more easily trellised canes for next year's crop. The optimal number of canes per foot of row is site dependent. Growers should monitor yearly numbers of healthy canes produced to determine whether the planting's productivity is changing due to an excessive or insufficient number of canes being allowed to fruit. Brambles have an ability to adapt to excessive number of canes by reducing the productivity of each bud or cane. Raspberries can also adjust for excessive shortening of canes by winterkill or pruning.

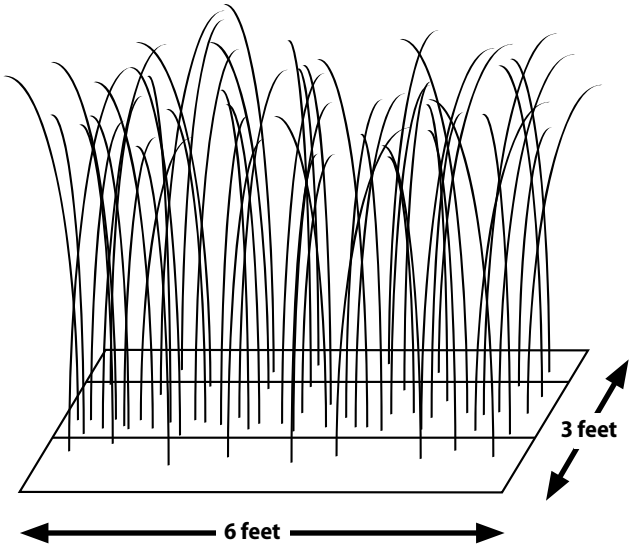
For final adjustment of cane numbers, early spring is the best time to prune because any cane dieback from cold will be apparent. However, raspberries can be pruned any time canes are fully dormant. In the dormant season, remove canes outside the 12-inch width of the row (Figure 8.1b), thin canes to 4 to 6 inches between canes, leaving about 4 to 6 canes per linear foot (Figure 8.1c), and top remaining canes to 48 to 72 inches in height, ideally removing about one-fourth of the cane (Figure 8.1d). Be sure to keep canes that have the largest diameters.

Black and Purple Raspberries

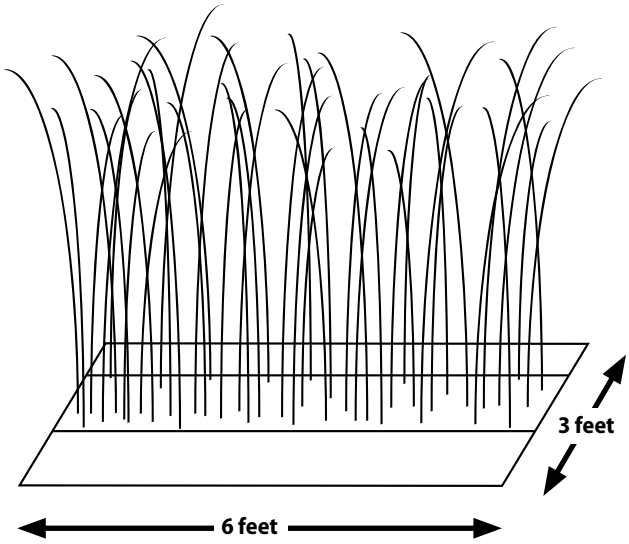
Black and purple raspberries require primocane topping throughout the summer in addition to floricane removal after harvest (Figure 8.2a). When possible, topping should be done 3 days before expected rain to reduce the chances for rain-splashed disease inocula to enter through the new wound. Black and purple raspberries should be topped at 36 to 48 inches during the season when only 3 to 4 inches of new growth need to be removed to reach the desired height when grown without a trellis system. Removing more than 3 to 4 inches can result in a greater incidence of cane blight since the wound that results from removing larger-diameter wood takes longer to heal. If this operation is missed at the optimal time, or a trellis system is in place, canes can be topped slightly higher, still removing only 3 to 4 inches of growth. Topping encourages lateral (fruiting) branches to develop and increases cane strength (Figure 8.2b). If the topping operation is missed, whether or not it is too late to top depends on stockiness of the cane growth and date—topping past midsummer may produce spindly laterals. *Note:* Black raspberries tend to have a very prostrate growth habit in the first year.

For dormant pruning, remove all dead, damaged, and weak canes. Thin remaining canes to 5 to 10 canes per plant. Head back lateral branches to 4 to 7 inches for black raspberries or 6 to 10 inches for purple raspberries (Figure 8.2c). More vigorous plants can support longer lateral branches. Canes should all be topped to 40 to 48 inches if they were not topped earlier if grown without a trellis sytem.

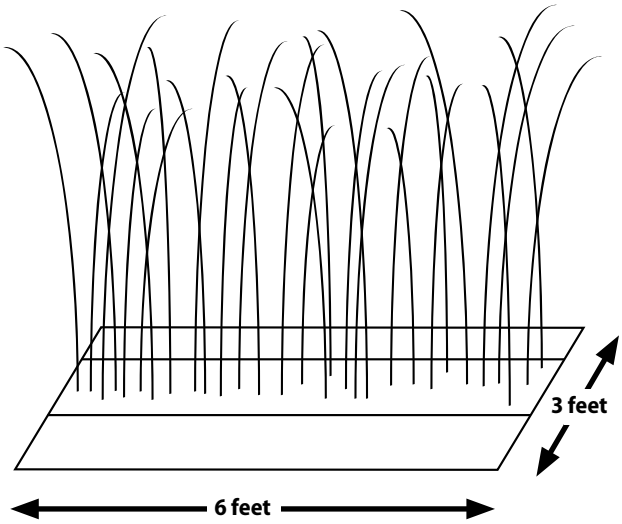
Figure 8.1. Pruning red raspberries.



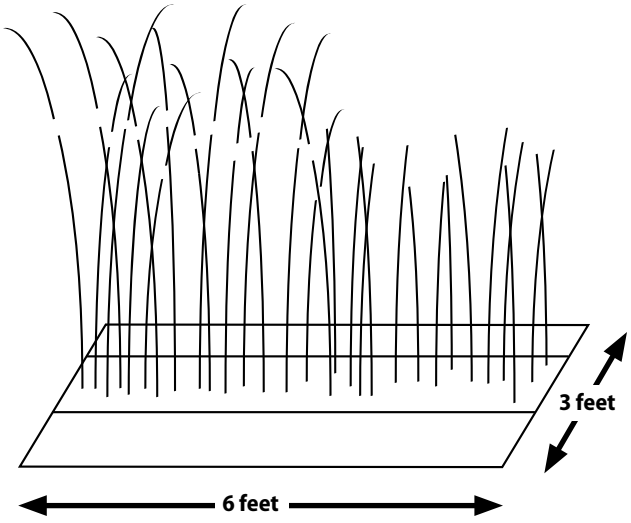
(a) Red raspberries before pruning.



(b) Pruning red raspberries—row narrowed to 1 foot wide.



(c) Pruning red raspberries—canes thinned to four to six per foot of row.



(d) Pruning red raspberries—canes winter-tipped.

If a trellis system is in use—even a nominal one such as the supported hedgerow trellis shown in Figure 8.3—canes can be topped higher (up to 60 inches) as long as they are supported by the trellis. Stockiness of the canes should be guide for the appropriate height to top canes at this time (i.e., when the topping operation was missed during the previous summer), with the goal being adequate cane strength to support the fruit load.

Primocane-Bearing/Everbearing Raspberries (Red or Gold) or Blackberrries

Everbearing red raspberries and blackberries should be mowed to a height of 1 to 2 inches. Mowing should be delayed until late winter—this allows some of the reserves in the cane to be mobilized to the roots. Fall removal of the canes from young plantings reduces their vigor.

Some growers may opt to fruit raspberry canes again in June and July. Fruit is borne on the overwintered canes at the leaf axils below where fruiting occurred the previous fall. Typically, only about 10 to 25 percent of the total Heritage yield is borne during June and July when fruited this way in field production. However, if canes are tall and less than one-quarter of the cane length produced flower buds in the fall, a substantial summer can be expected. Reasonable June and July yields have been obtained from floricanes for some of the late season, primocane-fruiting types; however, their cold-hardiness is largely untested. Thus, most commercial growers prefer to plant a summer-cropping cultivar for this purpose.

Retaining canes of primocane-bearing blackberries is not recommended as the floricanes of currently available cultivars are winter tender.

Summer-Bearing Blackberries

Erect blackberries (thorny or thornless) do not require trellising; but even they will benefit from having a trellis sytem in place. They have, as the name suggests, very strong upright canes. They can be pruned similarly to black and purple raspberries: specifically, head primocanes back to 36 to 48 inches in the summer. Spent floricanes should be removed immediately after harvest. Also, during dormant pruning, cut back laterals to 12 to 18 inches and thin canes to 10 inches apart in the hedgerow.

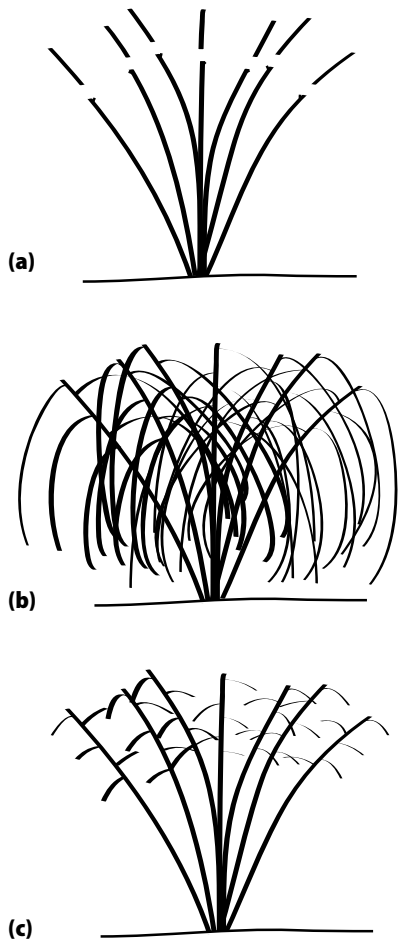


Figure 8.2. Pruning black raspberries.
(a) Primocanes tipped in midsummer.
(b) Lateral branches grow.
(c) Laterals are shortened during dormant pruning.

Semi-upright and erect blackberries can be grown with either a supported hedgerow or a V-trellis system as described under "Red Raspberries." They should be summer tipped at about 6 inches above the highest trellis wire and tied to it during the summer months. Spent floricanes should be removed immediately after harvest. For dormant pruning, select 5 to 8 of the strongest canes per plant, remove all laterals originating on the lower 2 to 3 feet of the canes, and tip back remaining laterals to 12 to 18 inches.

TRELLIS SYSTEMS

Trellis systems can increase yields per acre because they expand the bramble canopy surface area by supporting it. Several trellises have been developed and successfully used.

A simple supported hedgerow trellis (Figure 8.3) consists of a wire at 3 feet high, a second optional wire at 5 feet high, and posts every 30 to 50 feet of row. This trellis can be used with all overwintered brambles in all situations. Experiments in Pennsylvania using the "T" or Lincoln canopy trellis (Figure 8.4) resulted in black and red raspberry fruit that was borne on top of the canopy, allowing for excellent fruit exposure. This was particularly true for black raspberries. Better fruit exposure also allows harvesters to avoid the thorny canes. With the "V" trellis (Figure 8.5), the floricanes are tied to the wires during dormant pruning and the primocanes grow in the center of the row. Both "T" and "V" systems are fairly labor intensive during pruning, but fruit is more easily found during harvest.

Where vigorous growth and satisfactory winter-hardiness are commonly achieved, the Gjerde system has been found to be productive, easy on fruit, and labor saving. The Gjerde system uses wires that can be moved from the center of the row to the outside, forming a "V." Canes are held in the center before flowering to force flowers to grow toward the outside of the trellis. After flowering, the top wires (and the canes attached to them) are moved to the outside of the trellis so the crop is borne on the outside, leaving room in the middle for newly emerging primocanes.

The rotatable cross-arm trellis system is designed for use with blackberry production in areas where winter protection is needed. With this sytem, canes can be rotated to ground level so they can protected with row covers or snow in areas that receive reliable snowfall. In the spring and early summer, three or four new primocanes are tied horizontally to a low trellis wire and pinched after reaching canes from a neighboring plant. Because they are tied horizontally, once tipped, many laterals break along the full length of the canes. These laterals grow upwards and are tied to several trellis wires that are run horizontally above the wire that supports the main canes. For winter, this tellis is pivoted to ground level, remaining in this position until fruiting

laterals break in the spring. At that point, fruiting laterals are all growing upward, and the system is then pivoted back past the original position so that the fruiting laterals are on one side facing slightly downward, allowing ease of harvest. One main drawback to this system has been its cost; however, commercialization of production using fiberglass components rather than metal, and some adoption by the industry is reducing the cost considerably. Additional information on this sytem is listed in Appendix E.

The Stiles shift trellis was developed at Virginia Tech. Canes are attached to a movable side arm containing several wires. The arm is held at the nine-o'clock position during flowering. This sets the fruiting trusses upright since they grow toward the sun. At 2 weeks post flowering, the arm is swung around to the one-o'clock position. Immature fruit now hangs down to reduce sunscald and ease picking. Shift trellises are particularly useful for maximizing yield and providing exposure for thornless blackberry fruit.

Additional Trellising Considerations for Organic Production

Trellising facilitates harvest and improves air circulation within the canopy, which can decrease the incidence of certain diseases and presence of certain insect pests. According to the National Organic Standards, the producer must not use lumber treated with arsenate or other prohibited materials for new installations or replacement purposes in contact with soil or livestock. This means that chromated copper arsenate (CCA) or other types of pressure-treated lumber are not allowable materials for trellising. Other options include nontreated lumber, metal, plastic, or composite materials or lumber that has been treated with allowable products.

PROTECTED CULTURE

Brambles may be grown in protected culture to increase the length of the harvest season or to produce berries during the off-season when production otherwise might not be possible. Both high tunnel and greenhouse production involve higher costs. Production difficulties can be considerably different in

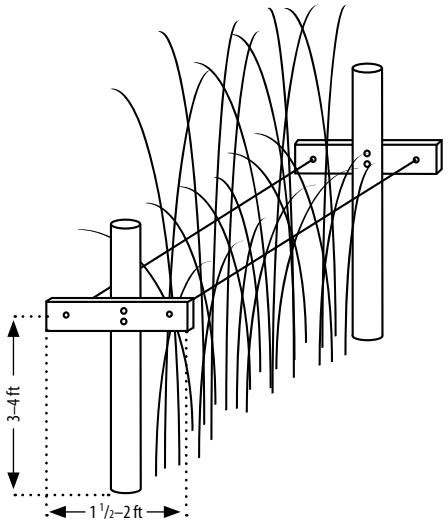


Figure 8.3. Supported hedgerow trellis.

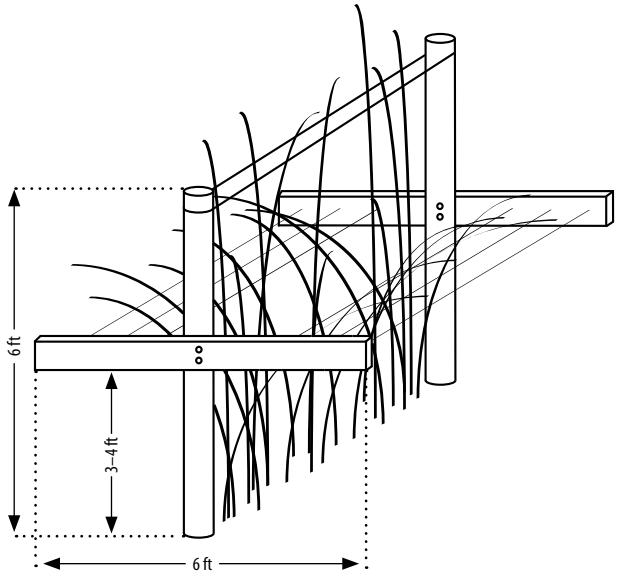


Figure 8.4. T or Lincoln trellis.

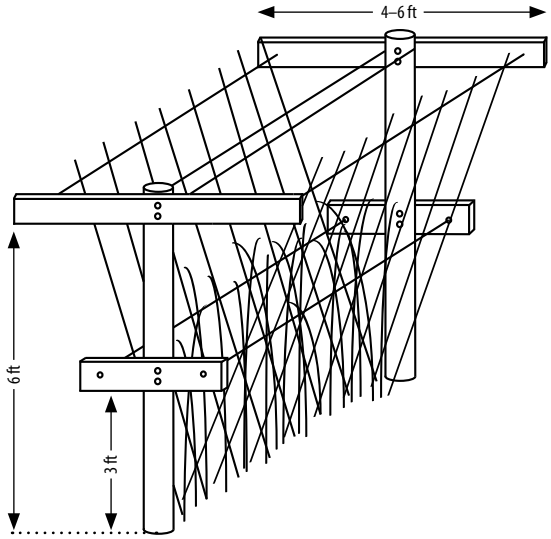


Figure 8.5. V trellis.

type or magnitude from those encountered in field production. For these reasons, growers are advised to proceed with caution when embarking on a new enterprise in these areas. It is expected, however, that interest in these systems will grow and that the amount of production under protected cultivation will rise as time goes on, as has been the case in Europe.

High Tunnel Production

Work done by university personnel and various growers in the Mid-Atlantic region has shown that in areas where fall frost can prematurely end primocane-bearing raspberry production, high tunnels can easily add an additional 3 to 4 weeks or longer to the harvest season. In addition, high tunnels allow plants to begin growing 3 to 4 weeks earlier in the spring. Besides the advantage of the longer harvest season, fruit quality has been exceptional and pesticide usage can be markedly decreased or eliminated.

Plants can be grown in the ground, as in field production. Trickle irrigation is obviously a must in this case. Rows can be slightly closer than in field production—6 to 8 feet between rows has worked well. Using landscape fabric as a ground cover works well in this situation. Plants must be planted as early in the spring as possible, at least 1 month and preferably 6 weeks prior to the last expected frost date to allow time to harvest a reasonable fall crop the first year. High tunnels can also be used to mitigate low winter temperatures, making thornless blackberry production possible in locations where it otherwise might not be, such as central and northern Pennsylvania. Be prepared for massive amounts of cane growth, however, and a continual need for tipping. The only significant pest problem to date in high tunnel bramble production has been twospotted spider mites. Predatory mites have given good control when released while spider mite populations are still low (i.e., fewer than 20 mites on a few of the most heavily infested leaves).

Alternatively, plants can be grown in containers and moved into the tunnel after a different spring crop has been grown in the tunnel. However, this management scheme is entirely different from field production and is more expensive and requires close attention to details. See Appendix E for additional sources of information.

Greenhouse Production

A greenhouse raspberry production system to produce berries during the winter and early spring was developed at Cornell University and is adapted only in the northern part of the Mid-Atlantic. Raspberries grow best in cool temperatures, so less supplemental heat is needed than for most other crops. In this system, summer-bearing raspberries (usually Tulameen) are grown. Tissue-cultured plants are planted into pots in the spring, grown outdoors until December, and then brought into the greenhouse.

Here, supplemental lighting may speed up fruit development but is not mandatory for production. Plants are moved outdoors again after fruiting and the cycle is repeated. As is true of high tunnels, spider mites are the primary pest. We recommend that growers who wish to try greenhouse raspberry production become familiar with details of the required management practices first since these are very different from the practices of field production. See Appendix E for Web sites with additional information. A similar tunnel system in Spain utilizes dormant, bare-root, chilled long-cane plants grown in northern nurseries.

HARVEST AND POSTHARVEST HANDLING

Raspberries are notorious for their poor shelf life, due in part to the fruit's form and structure—the berry is composed of many individual drupelets held together by hair and wax. Poor shelf life is also a result of the fruit's very high postharvest respiration rate (the highest of any temperate zone fruit) as well as its susceptibility to the botrytis fungus. The following are steps for achieving maximum shelf life from the very short-lived bramble fruit.

1. Maintain fungicide schedules in the field, especially during flowering. This step is particularly important for brambles since a primary cause of postharvest deterioration is infection with gray mold. Gray mold spores germinate and enter the fruit through the stigma and style during pollination.
2. Harvest as early in the morning as possible, after the dew has dried. Try to harvest all berries before noon, and keep harvested fruit out of direct sunlight. For long-distance shipping, fruit must be harvested when pink to slightly unripe. Never ship ripe fruit long distances.
3. Always handle berries gently. Roll, don't pull, berries off the plant. Be sure to instruct harvesters and drivers to pick and transport the fruit gently.
4. Harvest into appropriate containers. For raspberries and blackberries, use either half-pints or low pints (pints with the footprint of a quart). This ensures that fruit is never stacked more than two or three berries high. Research has shown that having more than three layers crushes the bottom layers.
5. Remove field heat from berries as soon as possible. The best approach is to use convective cooling before placing fruit in a cold room. A fan inside a cooler, with tarps placed to direct airflow through the fruit, forces air through the berries and works quite well for smaller operations.
6. Cover fruit after cooling to minimize moisture loss. You may also loosely cover berries before cooling, being sure to remove the covering (and the water from condensation) after cooling has occurred.
7. Keep fruit cool during transport and make sure berries are not treated roughly. Ensuring your customers know the limitations of small fruits is essential for your continued existence as a wholesaler. If you are retailing, also provide information for consumers to help them extend the shelf life of their purchases.
8. The optimal storage temperature is 31 to 32°F, and the optimal relative humidity is 90 to 95 percent. Fruit will freeze at lower temperatures. Maintaining relative humidities this high at such low temperatures is often difficult, but the highest possible relative humidity should be maintained. By adhering to the above

precautions, field-grown raspberries can be kept for 3 to 5 days, and high-tunnel-grown raspberries for 5 to 7 days. Controlled-atmosphere storage (15 to 20 percent carbon dioxide and 2 to 5 percent oxygen) extends shelf life even more, although it cannot be used as a substitute for refrigeration.

Blackberries should be handled similarly, although their shelf life is several days longer than that of raspberries. For more information on bramble production, consult NRAES-35: *Bramble Production Guide* (see Appendix E for ordering information).

ECONOMICS

The summer-bearing red raspberry and thornless blackberry budgets given here were prepared to provide general information and do not apply to any specific operation. Use them, with appropriate modifications, as guides for preparing budgets for individual situations. Budgets can be used:

- for general farm business planning purposes
- as a basis for obtaining credit
- to project cash flows
- to assess profitability

Using these sample budgets as guides should help ensure that all costs and receipts are included in budgets you prepare for your farm. Costs are often difficult to estimate in budget preparation because they are numerous and variable. Therefore, you should think of these budgets as a first approximation and then make appropriate adjustments using the "Your Farm" column to add, delete, and adjust items to reflect your specific growing conditions and resource situation.

The sample cost-of-production budgets were developed using a computerized budget generator. Input data reflect recommended production practices and current input costs. Major subheadings in the budgets are variable costs, fixed costs, and total specified costs. They are defined as follows:

Variable costs are costs that vary depending on the level of production. These include such inputs as fertilizer, herbicides, insecticides, fungicides, and labor.

Fixed costs are costs that do not vary by level of production and are incurred by virtue of owning assets such as machinery and land. Depreciation and taxes are examples.

Total specified costs are the sum of variable and fixed costs. Most land-preparation activities are assumed to be custom hired in these budgets because the small acreages for many berry farms do not justify the ownership of these implements. If you use your own tillage equipment, the variable costs for custom hire should be subtracted from the budgets and your labor variable costs and machinery fixed costs should be substituted.

For red raspberry and thornless blackberry production, one budget is presented for the years of land preparation (Table 8.3) since costs for either crop at this time would be the same. For red raspberries, additional cost-of-production budgets are presented for the planting year (Table 8.4), the year after planting (Table 8.5), and mature production (Table 8.6). For thornless blackberry production, similar cost-of-production budgets are presented for the planting year (Table 8.7), the year after planting (Table 8.8), and for a mature planting (Table 8.9).

Returns to risk and management is the estimated profit attributable to the acceptance of risk and the contribution of management expertise by the grower (Tables 8.10 and 8.11). The tables estimate the return to the grower for a range of prices and yields. Because yields, grades, and prices are so variable, growers should use representative values for their operation. It is important to account for cash flows over the life of the investment when assessing the overall profitability of the enterprise, so prorated land preparation and planting costs are subtracted in the estimates. Breakeven prices and yields are shown in the tables. Breakeven price is an estimate of the unit price required to cover all costs at a given yield; it is also the average cost per unit of production. Breakeven yield is an estimate of the yield required to cover all costs at a given price.

Berry production involves large initial investments and can be very risky; weather and animal related crop losses are common and crop prices can be highly variable. Use of whole-farm risk management tools such as AGR-Lite crop insurance can help you reduce these risks.

A land charge of $200/acre has been included in the budgets, but this charge can vary greatly from location to location. If you own the land, you could include your principal, interest payments, and property taxes as a fixed cost. If you lease the land, then the annual rental cost could be included as a variable cost.

Production assumptions used in generating the budgets include the following:

- Fumigation is not used. Under certain conditions, fumigation may be warranted.
- Irrigation system costs are calculated assuming that they apply water to 5 acres.
- Fungicides are rotated to reduce the likelihood of disease resistance.
- The numbers of pesticide and irrigation applications are average. In any given year or location, growers will need to adjust these for their particular set of circumstances.
- Hard fescue is planted in the aisles to reduce the need for mowing.
- A supported hedgerow trellis is used to support the canes.
- A trickle irrigation system is used in calculating water application.
- Berries are harvested as ready-picked in ½ pint plastic clamshells for red raspberries and pint plastic clamshells for blackberries.
- For raspberry budgets, the plant spacing assumed is 2 feet within the row and 10 feet between rows (approximately 2,200 plants per acre).
- For thornless blackberry budgets, the plant spacing assumed is 5 feet within the row and 12 feet between rows (726 plants per acre).

Table 8.3. Summary of estimated costs per acre, 2011: year of land preparation for summer-bearing red raspberries or thornless blackberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Soil test	acre	10.00	1.00	10.00	
Spread lime	acre	12.20	1.00	12.20	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	1.00	17.90	
Grass seeding	acre	11.20	1.00	11.20	
Herbicides					
Glyphosate 4	gal	12.78	0.50	6.39	
Seed					
Annual ryegrass seed	lb	0.35	25.00	8.75	
Labor					
Seasonal	hour	12.00	0.50	6.00	
Operator	hour	15.00	0.46	6.84	
Diesel Fuel	gal	3.50	1.12	3.92	
Repairs and Maintenance					
Tractors	acre	1.40	1.00	1.40	
Implements	acre	1.16	1.00	1.16	
Interest on Operating Capital				3.05	
Total Variable Cost				139.81	
FIXED COST					
Tractors	acre	2.68	1.00	2.68	
Implements	acre	2.39	1.00	2.39	
Total fixed cost				5.07	
Land Charge	acre	150.00	1.00	200.00	
TOTAL SPECIFIED COSTS				344.88	

* Estimated fixed costs in this budget assume that all field operations for land preparation are done by custom operators. Ownership of tillage equipment, grain drills, and grass seeders is not economically justified for growers engaged solely in small fruit production. Fixed costs in this budget reflect the ownership of a sprayer and mower.

Table 8.4. Summary of estimated costs per acre, 2011: planting year for summer-bearing red raspberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	1.00	17.90	
Post driving	acre	100.00	1.00	100.00	
Grass seeding	acre	11.20	0.70	7.84	
Fertilizer					
10-10-10	lb	0.21	300.00	63.00	
Urea	lb	0.25	100.00	25.00	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Other					
Drip tape	ft	0.03	4,350.00	130.50	
Raspberry plants	each	0.81	2,200.00	1,782.00	
Wheat straw	ton	160.00	0.60	96.00	
Hard fescue seed	lb	4.30	21.00	90.30	
Trellis posts	each	6.00	200.00	1,200.00	
Trellis wire	ft	24.00	8.70	208.80	
Trellis anchors/tensioners	each	20.00	34.00	680.00	
Labor					
Seasonal	hour	12.00	49.38	592.50	
Operator	hour	15.00	0.62	9.24	
Diesel Fuel	gal	3.50	34.00	119.00	
Repairs and Maintenance					
Tractors	acre	23.24	1.00	23.24	
Implements and irrigation	acre	77.78	1.00	77.78	
Interest on Operating Capital				90.47	
Total Variable Cost				5,375.95	
FIXED COST					
Tractors	acre	48.86	1.00	48.86	
Implements & irrigation	acre	204.31	1.00	204.31	
Total Fixed Cost				253.17	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS			5,829.12		

Table 8.5. Summary of estimated costs per acre, 2011: year after planting for summer-bearing red raspberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Urea	lb	0.25	60.00	15.00	
Fungicides					
Captan 80W	lb	6.99	8.00	55.92	
Elevate 50WDG	lb	45.55	3.00	136.65	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Princep 90DF	lb	5.70	2.20	12.54	
Surflan AS	gal	48.10	0.50	24.05	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Plant analysis kit	acre	25.00	1.00	25.00	
Clamshell, ½ pint	each	0.11	1,000.00	110.00	
Flats, ½ pint	each	0.85	84.00	71.40	
Labor					
Seasonal	hour	12.00	20.88	250.50	
Operator	hour	15.00	2.83	42.45	
Raspberry harvest	½ pt	0.70	1,000.00	700.00	
Diesel Fuel	gal	3.50	40.18	140.60	
Repairs and Maintenance					
Tractors	acre	29.45	1.00	29.45	
Implements and irrigation	acre	82.33	1.00	82.33	
Interest on Operating Capital				46.62	
Total Variable Cost				1,924.12	
FIXED COST					
Tractors	acre	61.68	1.00	61.68	
Implements	acre	215.39	1.00	215.39	
Total Fixed Cost				277.07	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				2,401.19	

Table 8.6. Summary of estimated costs per acre, 2011: mature planting of summer-bearing red raspberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Urea	lb	0.25	140.00	35.00	
Fungicides					
Captan 80W	lb	6.99	8.00	55.92	
Elevate 50WDG	lb	45.55	3.00	136.65	
Lime sulfur	gal	17.86	12.00	214.32	
Pristine 38WG	oz	3.11	20.00	62.20	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Princep 90DF	lb	5.70	4.40	25.08	
Surflan AS	gal	48.10	0.50	24.05	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Plant analysis kit	acre	25.00	1.00	25.00	
Clamshell, ½ pint	each	0.11	10,000.00	1,100.00	
Flats, ½ pint	each	0.85	834.00	708.30	
Labor					
Seasonal	hour	12.00	54.88	658.50	
Operator	hour	15.00	4.47	67.06	
Raspberry harvest	½ pt	0.70	10,000.00	7,000.00	
Diesel Fuel	gal	3.50	45.59	159.55	
Repairs and Maintenance					
Tractors	acre	34.71	1.00	34.71	
Implements and irrigation	acre	87.80	1.00	87.80	
Interest on Operating Capital				264.59	
Total Variable Cost				10,840.94	
FIXED COST					
Tractors	acre	72.52	1.00	72.52	
Implements and irrigation	acre	224.89	1.00	224.89	
Total Fixed Cost				297.41	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				11,338.35	

*Calculations assume that a ½-pt clamshell of red raspberries weighs 5 oz.

Table 8.7. Summary of estimated costs per acre, 2011: year of planting for thornless blackberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Moldboard plowing	acre	22.00	1.00	22.00	
Disking	acre	17.90	1.00	17.90	
Post driver	acre	100.00	1.00	100.00	
Grass seeding	acre	11.20	0.70	7.84	
Fertilizer					
10-10-10	lb	0.21	300.00	63.00	
Urea	lb	0.25	100.00	25.00	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Other					
Blackberry plants	each	2.18	2,200.00	4,796.00	
Drip tape	ft	0.03	4,350.00	130.50	
Trellis posts	each	6.00	200.00	1,200.00	
Trellis wire	mft	24.00	8.70	208.80	
Trellis anchors/tensioners	each	20.00	34.00	680.00	
Hard fescue seed	lb	4.30	21.00	90.30	
Wheat straw	ton	160.00	0.60	96.00	
Labor					
Seasonal	hour	12.00	49.38	592.50	
Operator	hour	15.00	0.62	9.24	
Diesel Fuel	gal	3.50	34.00	119.00	
Repairs and Maintenance					
Tractors	acre	23.24	1.00	23.24	
Implements and irrigation	acre	77.78	1.00	77.78	
Interest on Operating Capital				161.41	
Total Variable Cost				8,495.89	
FIXED COST					
Tractors	acre	48.86	1.00	48.86	
Implements and irrigation	acre	204.31	1.00	204.31	
Total Fixed Cost				253.17	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				8,949.06	

Table 8.8. Summary of estimated costs per acre, 2011: year after planting for thornless blackberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Urea	lb	0.25	60.00	15.00	
Fungicides					
Captan 80W	lb	6.99	8.00	55.92	
Elevate 50WDG	lb	45.55	3.00	136.65	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Princep 90DF	lb	5.70	2.20	12.54	
Surflan AS	gal	48.10	0.50	24.05	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Plant analysis kit	acre	25.00	1.00	25.00	
Clamshell, 1 pt	each	0.14	2,500.00	350.00	
Flats, 1 pt	each	0.85	209.00	177.65	
Labor					
Seasonal	hour	12.00	20.88	250.50	
Operator	hour	15.00	4.17	62.50	
Berry harvest	pt	0.85	2,500.00	1,875.00	
Diesel Fuel	gal	3.50	44.59	156.04	
Repairs and Maintenance					
Tractors	acre	33.73	1.00	33.73	
Implements & irrigation	acre	87.57	1.00	87.57	
Interest on Operating Capital				83.64	
Total Variable Cost				3,527.40	
FIXED COST					
Tractors	acre	70.51	1.00	70.51	
Implements and Irrigation	acre	223.26	1.00	223.26	
Total Fixed Cost				293.77	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				4,021.17	

Table 8.9. Summary of estimated costs per acre, 2011: mature planting of thornless blackberries.

Item	Unit	Price ($)	Quantity	Amount ($)	Your Farm ($)
VARIABLE COST					
Custom					
Spread dry fertilizer	acre	9.85	1.00	9.85	
Pest scouting	acre	35.00	1.00	35.00	
Fertilizer					
Urea	lb	0.25	120.00	30.00	
Fungicides					
Captan 80W	lb	6.99	8.00	55.92	
Elevate 50WDG	lb	45.55	3.00	136.65	
Lime sulfur	gal	17.86	12.00	214.32	
Pristine 38WDG	oz	3.11	20.00	62.20	
Herbicides					
Devrinol W	lb	12.35	8.00	98.80	
Princep 90DF	lb	5.70	4.40	25.08	
Surflan AS	gal	48.10	0.50	24.05	
Insecticides					
Assail 30SG	oz	5.76	5.30	30.53	
Provado 1.6F	oz	0.93	8.00	7.44	
Other					
Plant analysis kit	acre	25.00	1.00	25.00	
Clamshell, 1 pint	each	0.14	8,000.00	6,000.00	
Flats, 1 pint	each	0.85	667.00	566.95	
Labor					
Seasonal	hour	12.00	60.88	730.50	
Operator	hour	15.00	4.84	72.58	
Berry harvest	pt	0.75	7,000.00	5,250.00	
Diesel Fuel	gal	3.50	46.80	163.80	
Repairs and Maintenance					
Tractors	acre	35.89	1.00	35.89	
Implements and irrigation	acre	89.25	1.00	89.25	
Interest on Operating Capital				198.88	
Total Variable Cost				9,732.68	
FIXED COST					
Tractors	acre	74.95	1.00	74.95	
Implements and Irrigation	acre	227.06	1.00	227.06	
Total fixed cost				302.01	
Land Charge	acre	200.00	1.00	200.00	
TOTAL SPECIFIED COSTS				10,234.69	

Table 8.10. Returns to risk and management for red raspberries, 2011.

	Yield (half pt/A)					
Price ($/half pint)	6,000	8,000	10,000	12,000	14,000	Breakeven yield
$2.00	$3,304	$5,542	$7,780	$10,019	$12,257	3,048
$2.50	$6,304	$9,542	$12,780	$16,019	$19,257	2,107
$3.00	$9,304	$13,542	$17,780	$22,019	$26,257	1,610
$3.50	$12,304	$17,542	$22,780	$28,019	$33,257	1,302
Breakeven price	$1.45	$1.31	$1.22	$1.17	$1.12	

Prorated land preparation and planting costs included based on a productive life of 7 years.
A half-pint clamshell of red raspberries weighs 5 ounces.

Table 8.11. Returns to risk and management for thornless blackberries, 2011.

	Yield (pt/A)					
Price ($/pint)	6,000	7,000	8,000	9,000	10,000	Breakeven yield
$1.50	-$474	$65	$604	$1,143	$1,682	6,880
$2.00	$2,526	$3,565	$4,604	$5,643	$6,682	3,570
$2.50	$5,526	$7,065	$8,604	$10,143	$11,682	2,410
$3.00	$8,526	$10,565	$12,604	$14,643	$16,682	1,819
Breakeven price	$1.58	$1.49	$1.42	$1.37	$1.33	

Prorated land preparation and planting costs included based on a productive life of 8 years.
A one-pint clamshell of blackberries weighs 14 ounces.

PESTS

Pest control involves many aspects of production—pesticide application is only one. All available practices to reduce the potential for disease and insect problems should be used. Consider site selection, crop rotation, variety selection, the use of tunnels, soil treatment, and planting stock in relation to disease and insect control before you plant.

Information on individual diseases and insects is presented below, with cultural controls discussed. Disease control strategies are given in Table 8.12. Pesticide information, including activity groups, efficacy, labeled uses, and restrictions, are presented in tables that follow. Because avoiding buildup of resistant strains of fungi and insects is important, activity groups (for rotational use to avoid buildup of resistant strains) of fungicides and their efficacy on common diseases are presented in Table 8.13, and activity groups and efficacy of insecticides are listed in Table 8.14. Fungicides, insecticides, and miticides that can be used to assist in management are given in Table 8.15, arranged by various growth stages during the year for the crop. Pests are listed at the stages where they are most likely to be problematic or when treatment is most effective. Information in Table 8.15 should be supplemented with the reading below. Table 8.16 presents additional restrictions beyond preharvest intervals and reentry intervals that appear on the label. For information on bird and deer control, see the section on vertebrate pests in the blueberry chapter.

FUNGAL AND BACTERIAL DISEASES

Diseases are grouped according to the plant part on which they are most commonly noted or on which damage is most important. However, most of the following diseases can affect plant parts in addition to those under which they are listed. This information is included within the text for each disease.

Fruit Diseases

Gray Mold *(Botrytis Fruit Rot)*

Symptoms: In the field, ripe berries or receptacles remaining on the plant after harvest are covered with a dusty gray mold. This disease is equally important as a postharvest rot, where, due to high humidity, mycelial growth is less dense and appears as a light-gray growth. If extended wet weather occurs during bloom, blossoms may be blighted and the infection invades their supporting stems. If the weather becomes dry after such infections, blossoms and stems will blacken and appear like fire blight disease on apples and pears. Botrytis can also cause a cane blight and leaf spotting.

Causal Agent: The fungus *Botrytis cinerea.*

Epidemiology: The fungus has a wide host range and can survive on either living or dead tissue. It overwinters in dead leaves and plant debris and on stems. Inoculum is produced from fruiting structures on canes, from dead leaves, and from mummified berries in the spring. Flowers are infected soon after they open as the inoculum lands on the stigma, germinates, and grows into floral tissues that will develop into the fruit. The fungus then lies dormant in the developing fruit until the fruit is nearly ripe or harvested, at which time gray mold symptoms develop. Some direct fruit infection can also take place at harvest when moldy berries infect nearby fruit.

Controls: To help control the disease, choose a planting site with good air movement and prune out weak canes to speed the drying of plants. Also eliminate weeds (again, to aid in quicker drying of foliage and fruit) and harvest fruit before it is overripe. Under protected culture, tunnels should be opened early in the morning to reduce humidity or left open. If using a type of tunnel where covering is temporary, plants should be covered by bloom and remain covered until after fruiting. Fungicides should be applied during bloom, with additional applications made during harvest if necessary. Refer to Table 8.15 for fungicide recommendations.

Late Leaf Rust

Symptoms: Yellow masses of spores are noticed primarily on fall fruit of primocane-bearing cultivars, making the fruit unmarketable. Because symptoms on the fruit do not usually develop until late in the season, infections in plantings of summer-bearing cultivars may go unnoticed. Powdery, yellow spores also form on the undersides of leaves, causing badly infected leaves to drop prematurely.

Causal Agent: Several species of late leaf rust fungi are present worldwide. In

our region, *Pucciniastrum americanum* is believed to be the causal agent.

Epidemiology: Late leaf rust infects red and purple raspberries but not black raspberries or blackberries. Late leaf rust, unlike orange rust, is not systemic. White spruce and Engelmann spruce serve as alternate hosts, and their closeness to a planting may increase the likelihood of occurrence. Spores are produced on infected spruce needles in early summer and can infect raspberries. High humidity is necessary for infection to take place. If the infection spreads, the raspberries will show symptoms shortly afterward. However, spruce are not thought to be necessary for the rust to survive in a planting once infected since this disease has occurred in successive years in plantings with no spruce in the vicinity. Spores are disseminated by wind but may also be physically moved from infected to uninfected plantings by people or machinery.

Controls: Clean nursery stock is important since planting stock can be the initial source of inoculum. Control is aided by cultural practices that increase air circulation within the planting, such as thinning canes, keeping rows narrow, and practicing good weed control. Removing floricanes and infected primocanes in winter will reduce the amount of inoculum. This disease has been especially problematic on summer-bearing Festival and fall-bearing Heritage and Jaclyn. Josephine fall-bearing and Nova and Esta June-to-July-bearing red raspberries tend to be resistant. Plants grown yearlong in a tunnel have a very low amount of rust occurrence compared to outdoor grown plants. Because this fungus is not systemic, eliminating the disease from plants is possible. See Table 8.15 for recommended fungicides.

Downy Mildew

Symptoms: Blackberries and red raspberries may be affected. Berries dry up and split. Fruit infected while green may redden prematurely before drying up. On most cultivars, leaves develop a yellow angular lesion on the upper surface that then turns to a dark red or purple color. The margin of the lesion may remain bright yellow. A corresponding light tan or pink area appears on the leaf undersides from which white or gray sporulation takes place. Symptoms may also appear as purple blotches near the midvein or a mosaic pattern of red and yellow lesions. Suckers may be stunted, and canes may have irregular reddish blotches.

Causal Agent: The fungus *Peronospora sparsa*, which may be synonymous with *Peronospora rubi* Rabenh.

Epidemiology: This disease is most prevalent under humid conditions, moderate temperatures, and when rainy. The fungus may be found in any plant part that overwinters. Sporulation takes place from leaves of new primocanes at first, especially where foliage is dense. Spores are windborne and may infect leaves or berries.

Controls: Wild roses and blackberries can serve as inoculum sources and should be removed from the vicinity. Keeping rows narrow and controlling weeds will minimize sporulation by decreasing humidity levels in the rows. Old canes should be removed after harvest if this disease is present. Strobilurin fungicides and products containing potassium phosphite (Phostrol) have been effective and should be alternated to delay resistance development.

Postharvest Minor Fruit Rots

An assortment of fungi cause fruit rots that appear during postharvest storage, usually affecting a low percentage of fruit. These include *Alternaria* spp., which forms a dark gray mold on the fruit surface; *Cladosporium* spp., which produce an olive-green, velvety mold; *Penicillium* spp., which cause a blue-green mold and fruit leak; and a *Colletotrichum* sp., which is primarily problematic when rainstorms have occurred during harvest, causing a sunken, water-soaked area that can have a slimy center.

Cane and Leaf Diseases

Orange Rust

Symptoms: Diagnostic symptoms occur early in spring when new shoots begin growth. New leaves are stunted, deformed, and pale green or yellowish, and shoots are numerous and spindly. Waxy blisters cover the undersides of leaves, which generally aren't noticed until they turn bright orange and powdery, hence the disease name "orange rust." Canes produced by diseased plants in June and later may appear relatively healthy, but they are infected nonetheless and will produce the diagnostic orange pustules the following spring. Infected plants generally take on a bushy appearance because many short upright shoots arise from one bud.

Causal Agent: The fungi *Arthuriomyces peckianus* and *Gymnoconia nitens.*

Epidemiology: Orange rust is a fungal disease that occurs only on black raspberries, blackberries, dewberries, and possibly purple raspberries. The two fungi that cause the disease are very similar. The disease is not known to affect red raspberries. The fungus is systemic and overwinters in diseased roots and canes. When the orange spore pustules mature and break open in late spring and early summer, spores spread to other plants by wind and possibly rain. Leaves that produce the pustules dry up and die. The fungus enters plants through the leaves and remains localized for a few weeks. Then a second type of spore forms on these newly infected leaves that infects buds and growth at the base of new shoots in August and September and travels into the roots. The fruiting bodies for these spores are not visible. Newly infected plants don't show symptoms until the following spring when the shoots arising from these newly infected roots show characteristic symptoms. Orange rust is favored by cool, wet conditions. Disease development is greatly reduced when the temperature is above 80°F.

Controls: Start with disease-free nursery stock. Inspect all plants in the spring for symptoms of infection. As soon as symptoms are visible, remove the entire plant. Ideally, plants should be removed at the time when spindly growth is seen, rather than waiting until orange pustules are seen, because infection of nearby plants has already begun to take place by the time the pustules are noticeable. If orange pustules are noted, infected plants should be removed and the planting should be monitored for areas with spindly, light-green growth the following spring with additional plants removed at that point. Any practice that speeds

the drying of foliage, such as keeping plantings weeded and rows narrowed back, will assist in control since spores need a relatively long period of leaf wetness in order to be able to germinate and penetrate the leaves in the spring. Avoid tipping canes in the fall since transporting inoculum on hands is easy during this operation. Remove and destroy all wild blackberries and raspberries in the area that may serve as a source of disease. Some blackberries, but not ones currently grown in the Mid-Atlantic region, are reported to exhibit resistance. Recommended fungicides should be applied from the time that orange pustules are first seen until the leaves on which they were produced die and dry up, and then again during late summer or fall when temperatures cool. See Table 8.15 for fungicides. All effective fungicides are at risk for resistance development, so unnecessary use should be avoided and fungicides of different classes should be rotated.

Anthracnose

Symptoms: The symptoms of infection can be found on all plant parts, including canes, leaves, petioles, flowers, and fruit. In late spring the primocanes will have small, purplish, slightly raised spots. As the disease progresses, the spots enlarge. The center of the lesion (referred to as a "pit lesion") becomes sunken and cracked. Infections that occur later in the season cause "gray bark" lesions, which are grayish white and more superficial. Gray bark is apparent on the current season's shoots by fall or winter. On red raspberry canes, pit lesions tend to be less numerous and smaller than on black raspberries. With many individual lesions, the disease can be severe enough to girdle and kill canes. Lesions like those formed on the canes may also form on petioles. Leaf lesions start out as small, purple spots, which may turn white in the center, and eventually become "shot holed." Flower parts can be infected, but the lesions are not easily seen. Fruit infection is not common, except with high levels of inoculum (spores). Infected fruits wither while still green, or individual drupelets shrink and turn brown. In severe infections, fruit is typically dry and seedy. Most economic loss results from defoliation, reduction in fruit size and quality, and death of canes, either directly from the disease or from winter injury.

Causal Agent: The fungus *Elsinoe veneta.*

Epidemiology: Black and purple raspberries are more susceptible than red raspberries. The fungus overwinters on canes infected the previous season. Inoculum is produced in the spring from fungal hyphae in both gray bark lesions and pit lesions and is washed by rain to the plant's crown. Here, new shoots are infected as they emerge among old, diseased canes. Infection of new canes and leaves can continue through the summer. During rainy periods in late spring, spores are also produced that are shot from the fruiting bodies into the air and carried by wind to other bramble plants where new infections become established. Fruiting bodies develop on the new lesions as the season progresses, but spores do not mature until the following spring. Young and succulent growth is most subject to infection.

Controls: Infections that take place early in the growing season cause the most damage, so controls should be instituted early in the season. Anthracnose can be managed by sanitation and spraying. A dormant to delayed-dormant application of lime sulfur is the most effective method of reducing the incidence of this disease. Sanitation is a labor-intensive but effective tactic for a long-term management strategy. Planting clean, disease-free nursery stock is also important. Cut off cane handles and any infections observed on new plants after planting. Since the spores that infect new shoots come from lesions on the previous year's canes, diseased canes must be cut out as close to the ground as possible immediately after harvest when anthracnose is present. Weeds and weak spindly canes should be eliminated to improve air movement since moisture provides favorable conditions for spore germination and infection. All noncultivated brambles in the vicinity should be removed to eliminate outside sources of infection. Refer to Table 8.15 for fungicide recommendations. Fungicides used for anthracnose control should be concentrated on protecting new, emerging canes.

Gnomonia Stem Canker

Symptoms: Lesions start out a chocolate brown color on the stem of blackberry cultivars, often surrounded by a scarlet red area. Lesions do not appear until the spring, at first near a bud, and they then rapidly enlarge, commonly reaching 6 to 8 inches long by full bloom, sometimes larger. The lesions may girdle and kill the entire cane, killing it and causing a light gray surface to develop on the oldest portions of the lesion.

Causal Agent: The fungus *Gnomonia rubi.*

Epidemiology: Very little is known about the epidemiology of this disease, but there seems to be a strong relationship between winter injury and disease development. In roses, which are affected by the same species of fungus, canes weakened by severe winters are also more susceptible.

Controls: Because little is known about the life cycle of this fungus, it is difficult to pinpoint an optimum time when various practices should be employed. However, any practices that maximize airflow should help. Floricanes should be removed soon after harvest. There appear to be variations in cultivar susceptibility, but whether this is due to disease susceptibility or winter injury susceptibility is unknown. Operations that employ a regular fungicide schedule seem to have a lower incidence of problems than low-spray or no-spray operations.

Cane and Leaf Rust

Symptoms: Blackberries are primarily affected. Yellow bark-splitting pustules form on floricanes in the spring. During the summer, small, circular, yellow pustules appear on the undersides of leaves. Buff-colored telia can be found along with yellow pustules in the fall. In severe cases, defoliation may occur. Fruit is unaffected, though spores may land on fruit and thus be present. This rust should not be confused with orange rust, which is bright orange and found only on leaves in late spring and early summer, or late leaf rust, which affects only red raspberries.

Causal Agent: The fungus *Kuehneola uredinis.*

Epidemiology: This disease is not systemic. Though this disease is primarily problematic on blackberries, red and black raspberries can be infected as well. Spores produced from lesions on floricanes infect leaves during the summer, and spores produced from these infected leaves then infect primocanes in the fall. The disease is worst in years with warm, wet springs.

Controls: Any practices that maximize airflow should help. There are variations in cultivar susceptibility; most grown in the east are not especially susceptible. Floricanes should be removed soon after harvest. Lime sulfur sprays in late winter will minimize inoculum. Applications of fungicides in activity groups 3 (triazoles) and 11 (strobilurins) should be applied when pustules are first seen on the canes then and on a 10- to 14-day schedule until symptoms disappear. Be sure to rotate chemistries.

Cane Blight

Symptoms: Failure of buds to beak in the spring, wilting of lateral shoots, or death of fruiting canes, usually when fruit begins to ripen. Canes are usually brittle at the point of infection and may break if bent. On raspberry primocanes, a brown stripe can be found under the epidermis near a wound, but the epidermis needs to be scraped off for this to be visible. On blackberry primocanes, lesions are dark-red to purple areas around wounds, with the lesion center becoming grayish. Symptoms also appear late in the season on new shoots where plants are tipped. Infected areas are at first brownish purple and develop from the cut ends. Laterals originating in the infected areas wilt and die. Weakened canes are more susceptible to winter injury. By spring, the epidermis develops a silver color.

Causal Agent: The fungus *Leptosphaeria coniothyrium.*

Epidemiology: Black raspberries are more susceptible to cane blight than other brambles. The fungus overwinters on dead canes, and it is here that inoculum is produced in the spring. Old stubs can continue to produce inoculum for several years. Infection continues to occur in late spring or summer through wounds made by pruning or insects or through sites of injury from cane abrasion or spines. Spores are spread by splashing rain, wind, and insects.

Controls: Any practice that improves foliage drying, such as keeping rows narrow and weeded. Prune out and dispose of old canes promptly after harvest (see the section on pruning). Time pruning and tipping so that cuts have 3 days to dry before a rain. Fungicide coverage should be thorough, especially toward the base of canes. Dormant and delayed- dormant lime sulfur sprays are important. Refer to Table 8.15 for fungicide recommendations.

Spur Blight

Symptoms: In late spring or early summer, chocolate-brown, dark-blue, or purplish spots or bands appear on new canes and petioles, usually on the lower half of the plant. These lesions enlarge until the cane is girdled. By late summer, canes may crack and split lengthwise, revealing reproductive, pimplelike, black fruiting structures of the fungus. Cane symptoms become less obvious in the fall. Symptoms on leaves occur as chocolate-brown, V-shaped areas with yellow margins with the wide area at the leaf edge. Damage from winter injury may be increased. Yield may be reduced as a result of the withering and eventual death of infected laterals.

Causal Agent: The fungus *Didymella applanata.*

Epidemiology: Red and purple raspberries are more severely affected than other brambles. Blackberries appear to be immune. The fungus overwinters in infected canes. The following spring, spores are discharged into the air or may ooze to the surface of the stem during wet periods from May to August. Infection can continue to take place through the growing season.

Controls: Suggested controls are the same as for cane blight, botrytis blight, and anthracnose. Thorough pruning that includes the removal of pruned canes from the planting is helpful. Lime sulfur and sanitation are useful, and keeping row width narrow to increase air movement is particularly effective. Studies in areas outside of the Mid-Atlantic suggest that a moderate amount of spur blight is tolerable without reduction in yield. Producing only the fall crop on primocane bearers has greatly reduced the incidence of the disease. Several fungicides can be used during the season.

Raspberry Leaf Spot and Septoria Leaf Spot of Blackberry

Symptoms: Circular to angular spots on leaves. The center will usually develop a whitish center and may drop out, creating a shot-hole effect.

Causal Agent: The fungi *Sphaerulini rubi* (raspberry leaf spot) and *Septoria rubi* (septoria leaf spot).

Epidemiology: These two fungi, though specific to raspberries and blackberries respectively, behave similarly. Both overwinter in dead leaves and infect new growth primarily in the spring, though infection can continue to take place during rainy spells when susceptible tissue is present.

Controls: Any management practices that improve canopy drying are beneficial. Few fungicides are labeled for either disease. However, fungicides specifically applied for leaf spots are not normally necessary since most materials applied for other diseases, especially botrytis, usually give sufficient control.

Powdery Mildew

Symptoms: The characteristic sign of this disease is a white, powdery growth, primarily on the undersides of leaves. Infected leaves are dwarfed and twisted and appear yellow on their upper surfaces.

Causal Agent: The fungus *Sphaerotheca macularis.*

Epidemiology: The fungus overwinters in infected cane tips and dormant buds. When temperatures reach 50 to 60°F, spores are discharged and spread by wind. Powdery mildew is favored by warm weather without rainfall, so tunnel culture is conducive to powdery mildew. It is most serious in years and in plantings where there is poor air circulation. Blackberries are seldom severely infected by powdery mildew. However, powdery mildew is occasionally a serious problem for red and black raspberries, especially in tunnel culture.

Controls: Unlike with most fungi, free water will reduce the incidence of this disease. Whether this effect, higher humidity, or an effect of tunnels on reducing cuticle thickness (by reducing water stress) contributes to additional mildew incidence in tunnels is not known. Apply fungicide sprays (see Table 8.15) when symptoms first appear, usually from midsummer through fall. In black raspberries, if powdery mildew was severe last season, begin fungicide sprays in mid-June and continue applications at 14-day intervals. Three to four applications may be required.

Botryosphaeria Cane Canker

Symptoms: Reddish or reddish-brown cankers develop near and below buds and then extend above them, eventually encircling and killing the cane. Leaves on affected canes wilt and die, and fruit may dry up. Cankers often have light and dark concentric rings as they develop. Old cankers lighten and have a silver color, and large ones may split open. Thornless blackberries, especially cultivars that retain leaf petioles for much of the winter, are more frequently affected than other types of brambles. Other pathogens can cause similar symptoms. Damage is sporadic but can be devastating when it occurs.

Causal Agent: The fungus *Botryosphaeria dothidea.*

Epidemiology: This fungus can also infect other woody plants, including apples and blueberries, which may be a source of inoculum in addition to the blackberry planting and wild blackberry plants. The fungus overwinters in and on leaf buds, petiole scars, retained petioles, dead canes, and in cankers on current canes. Invasion takes place through leaf buds, wounds, or tissue that was injured by freezing.

Controls: Start with clean plants and utilize any practices that decrease foliage wetness and improve sanitation. Locating plantings away from apple and blueberry plantings may help. Chester, Arapaho, and Triple Crown appear to be resistant. Chickasaw is susceptible. No information is currently available on effectiveness of fungicides.

Crown and Root Diseases

Phytophthora Root Rot

Symptoms: Symptoms show up primarily in wet sections of the field. Death may be sudden or gradual, with cane stunting, weak lateral shoot growth, and leaf yellowing or scorching along the margins and between the veins. Severely infected fruiting canes wilt and die as the weather grows warmer before harvest. Few canes are produced, in contrast to when the cause originates above ground (winter injury, cankers, cane borers), where normal numbers of primocanes are produced. To tentatively diagnose phytophthora root rot, dig up plants that are wilting but have not yet died and scrape away the outer surface (epidermis) of the main roots and crown. Tissue just beneath the epidermis of healthy plants should be white, while that of infected plants will be a characteristic red brown. A distinct line can often be seen where infected and healthy tissues meet, especially on the crown.

Causal Agent: Several related species of soilborne fungi belonging to the genus *Phytophthora*.

Epidemiology: Depending on the species of *Phytophthora* causing the infection, inoculum may already have existed in the planting site, or may have been brought in on infected plants. Once present, this pathogen will persist in the soil for many years. Saturated soil is necessary for spread of the disease, as *Phytophthora* zoospores move by swimming through free water, or are carried by flowing or splashing water to other plants. A certain period of flooding may be necessary in order for infection to take place. Multiple sporulation events may occur throughout the growing season under favorable conditions, resulting in rapid spread of disease throughout the planting.

Controls: An integrated approach involving avoidance, cultivar resistance, and chemical control is necessary. Only clean planting stock originating from certified nursery stock should be used. Other keys to controlling phytophthora root rot are good soil drainage, the use of raised beds, and proper cultivar selection. All brambles should be planted in well-drained soil—at no time should water be standing in the field or in a tunnel. If well-drained soil is not available, planting on raised beds will minimize exposure to saturated soil conditions. Highly susceptible cultivars include Ruby and Titan. Canby, Cumberland, Festival, K81-6, Munger, Reveille, and Taylor also appear to be very susceptible and should be avoided when planting on ground known to contain this pathogen. Tolerant/resistant red or gold raspberry cultivars such as Anne, Boyne, Caroline, Killarney, Latham, Newburgh, and Prelude and are the least susceptible and the safest choices if berries are to be planted on marginal sites. Black raspberries Bristol and Jewel are relatively resistant, but not completely. The purple raspberry cultivars Brandywine and Royalty are susceptible under greenhouse testing but display some degree of field tolerance. Ridomil fungicide can be used as a soil drench for raspberries (see Table 8.15) in fall and/or early spring, although Ridomil use cannot make up for poor site selection. Repeated use is also likely to result in the development of resistant strains of the fungus. Aliette is absorbed through the leaves and is labeled for phytophthora control as are Phostrol and similar materials. Phostrol is a salt of phosphorous acid, may stimulate the plant's defense system, and has a zero-day preharvest interval.

Crown Gall and Cane Gall

Symptoms: Spongy, rough, tumorlike swellings that resemble callus growth at first, but then become brown and woody with age. The growths range in size from that of a pinhead to that of a golf ball. Crown galls develop in the spring on the underground plant parts, the roots, and the crown. Cane galls develop as whitish eruptions on the fruiting canes in mid-June. More intense gall formation seems to occur in years with higher incidence of winter injury. These eruptions later turn brown and then black and begin to disintegrate. The diseases cause dry, seedy berries to be produced and can stunt or prevent cane formation. Weakened canes are easily broken by wind and become more susceptible to winter injury. The plants may show water stress and nutrient deficiency symptoms as the movement of water and nutrients throughout

the plant is disrupted. With cane gall, black and purple raspberries are more often infected than red raspberries and blackberries.

Causal Agent: Soilborne bacteria *Agrobacterium tumifaciens* (crown gall) and *Agrobacterium rubi* (cane gall).

Epidemiology: Plants are infected only through wounds. The bacteria overwinter in the soil and galls and are spread by splashing rain, running water, cultivation, and pruning. The bacteria can survive in galls for years, so soil containing galls can remain infested for many years.

Controls: The best control measure is prevention. Plant only certified, disease-free nursery stock and take care not to wound plants, especially the root system, at planting. Titan seems to be especially susceptible, as do some of its relatives. Plant only in sites with no history of the diseases, or wait at least 3 to 5 years before replanting in the site. If a diseased plant is detected, remove and burn the roots and tops of the plant and dispose of the soil surrounding the roots. No chemical control is known. Fumigation is not effective.

Verticillium Wilt

Symptoms: Symptoms become obvious by June or early July. Shoots are stunted and leaves, starting at the base of the infected plant, turn yellow, wilt, and drop. Soon the entire shoot withers and dies. Black raspberry canes may show a blue or purple streak from the soil line extending upward. This purple streak is not detectable on red raspberry canes. Fruiting canes infected the previous year either die in the spring or the new leaves at the base of the cane may be yellow and stunted. If canes die before reaching maturity, fruit becomes mummified. Verticillium is favored by cool weather and is most severe in poorly drained soils following a cool, wet spring. Most blackberry plants and red raspberry plants are less severely affected than black raspberries.

Causal Agent: Two species of fungi are implicated: *Verticillium albo-atrum* and *Verticillium dahliae*.

Epidemiology: Black raspberries and susceptible cultivars of blackberries are most severely affected, though red raspberries also can be affected. This common soilborne fungus has a wide host range and attacks more than 300 woody and herbaceous plants. It can exist in the soil prior to planting, may be brought in on planting stock, or may move in on windblown soil. The fungus survives either in plant debris or free in the soil. The fungus enters the roots and moves into the vascular system, causing a systemic infection. After the plant or plant portions die, the fungus continues to survive in the soil.

Controls: Chloropicrin-based fumigants can be used prior to planting (refer to Chapter 3); however, no effective fungicides exist for management once the plants are in the ground. The use of competitive fungi as a plant dip or soil drench is being investigated, but no conclusive results are yet available. Choose a planting site with no known history of this problem. Avoid land recently planted with tomatoes, potatoes, eggplant, peppers, strawberries, raspberries, or stone fruits and land infested with horsenettle, ground cherry, red-root pigweed, nightshade, and lambsquarters. The number of years required to eliminate verticillium from the soil is unknown. In spite of this, planting with verticillium-free black raspberry stock on uninfested soil usually ensures many years of avoidance of this disease.

VIRUSES

Virus infections lower productivity and fruit quality and reduce the productive life of a raspberry planting. Virus diseases are widespread in our plantings and are easily spread. No cure for viruses exists—once a plant is infected, the entire plant is diseased for the remainder of its life. Therefore, it is important to start a raspberry planting with healthy plant stock from a reputable nursery and take steps to reduce the spread of any viruses in the field.

If virus-indexed negative, i.e., clean, plants are established in a field, viruses can move to raspberry bushes only by means of a vector. The vectors responsible for spreading viruses are pollen, aphids, nematodes, and possibly leafhoppers and whitefly. Thus, the control of virus diseases is based on preventing the infection of clean stock by removing virus reservoirs such as wild brambles and broadleaf weeds, and by controlling the vectors. If a planting shows virus symptoms during the same season it was planted, the planting stock was probably infected at the time of planting. After its first winter or after its first flowering, however, entire plantings can be infected by infected pollen from wild plants or from neighboring infected cultivars.

Only ELISA testing, PCR-based testing, or mechanical or graft inoculation of indicator plants can indicate whether a virus is present in a plant. Even with testing, obtaining false negatives (i.e., test results indicating no virus is present when plants are in fact infected) is possible since viral content is not evenly distributed within the plant and is much lower in hotter weather. Consequently, sampling the correct plant part (usually shoot tips or young leaves) in the spring or fall may increase the chances of detecting the virus. Symptoms are not proof of virus content nor are they reliable for identification of a virus. Herbicides, winter injury, zinc or boron deficiencies, genetic maladies, fungi (mildew), and poor care or management can mimic viral symptoms.

Raspberry Bushy Dwarf Virus ("Crumbly Berry")

Symptoms: Raspberry plants affected by raspberry bushy dwarf virus can appear normal, yet they produce small fruits that fall apart when picked. This results from the failure of some of the drupelets to develop because this virus primarily acts on the vitality of pollen (and perhaps eggs). Poor pollen performance results in unfertilized seed and undeveloped seed, which result in undeveloped drupelets. This is seen easily in picked fruit, where unset drupelets are present as whitish, 1- to 4-millimeter-long sections of tissue inside the fruit cavity. Healthy fruit should have only an occasional unset drupelet. This virus can reduce plant vigor, particularly on some varieties.

Epidemiology: Plants are infected when pollen is transferred by pollinators or wind from infected plants, such as those found in the wild, to flowering plantings. New plantings located near infected plants frequently become infected within two or three flowering seasons.

Controls: Because this virus is pollen vectored, management is especially difficult. Wild brambles in the vicinity should be eliminated, but because pollinators can travel long distances, eliminating enough plants to eliminate the virus may not always be possible. Esta and Heritage seem to be resistant to this virus.

Tobacco Streak Virus (Raspberry Streak, Black Raspberry Latent Virus)

Symptoms: Characteristics diagnostic of the virus include uneven ripening of drupelets and small, blotchy, seedy fruit that lacks the glossy appearance. Plants infected with tobacco streak virus can form inconspicuous purple streaks less than 1 inch long on the lower part of their canes during warm periods. Infected plants are usually vigorous, sometimes showing no symptoms of virus infection.

Epidemiology: Though pollen and seed transmitted, it is not certain that this is the primary means of transmission since some studies show that thrips may be involved as a possible vector of this virus with other plant species. This virus is very unevenly distributed in plants, which makes detection difficult.

Controls: Use planting stock from virus-free indexed mother plants and isolate new plantings from potential sources of this virus.

Tomato Ringspot Virus

Symptoms: Symptoms of the disease vary with raspberry variety. They include yellow ringspots, especially in Royalty, which often cease appearing in midsummer on the expanding leaves of new shoots. Other symptoms on spring foliage may be streaks or chlorosis. Some cultivars produce crumbly fruit, whereas others may eventually die out. Canes are more commonly stunted, and this virus will eventually render a planting unproductive. Fruit is commonly crumbly and small, as with other viruses that affect pollen viability.

Epidemiology: Tomato ringspot virus is very common in the Mid-Atlantic region. It is vectored by dagger nematodes (*Xiphinema* spp.) and possibly pollen. This virus has a wide host range, including many weeds such as dandelion and chickweed and other fruit crops including strawberries, blueberries, apples, and peaches. Seeds of chickweed and dandelion can be infected, and plants developing from these seeds can serve as sources of infection if spread throughout or into the field.

Controls: Prior to planting, fields should be tested for the presence of dagger nematodes. If test results indicate that a high enough population to warrant management exists, the field should be fumigated, the protocol for management of dagger nematodes with green manure crops should be followed (see Chapter 2 and Appendix A), or the field should be kept free of possible hosts plants for a period of 18 months. Planting stock that is free of tomato ringspot virus should be used, along with roguing of infected plants and their neighbors, which may be symptomless. Weeds should be controlled. Yield and fruit quality in the cultivar Canby appear to be relatively unaffected even when the plants are infected.

Raspberry Mosaic Complex

Symptoms: Symptoms of raspberry mosaic vary with variety, type of virus infection, and time of year. In general, symptoms may include delayed leafing out, dieback of shoot tips, and stunted canes or clusters of shoots from the same node. Plants usually die in a few years. A mottling or yellowish spotting and cupping or blistering of the leaves is common. These symptoms are most easily seen in early spring when the new leaves are expanding. Leaf symptoms often disappear during hot weather later in the season. Red raspberries are not as severely affected as black or purple raspberries, but they still suffer reduced plant vigor and yield. Blackberries may also be infected, but they are tolerant of the virus and show no symptoms. Several viruses that affect only *Rubus* are involved and, when present in combination, result in more severe symptoms.

Epidemiology: The mosaic virus complex overwinters in infected plants and is spread by aphids. Feeding time needed to transmit viruses in the complex is only a few minutes.

Controls: The standard practices of establishing plants as far as possible from wild or older populations of brambles and using planting stock propagated from virus-free plants are useful. Controlling aphids may assist in slowing the spread of viruses within the planting; however, because the viruses are transmitted very quickly, it is unlikely that transmission can be thwarted. Of purple and black raspberries Bristol is tolerant; Cumberland is very susceptible. Canby, Reveille, and Titan red raspberries are reportedly resistant because aphid vectors avoid them; most other red raspberry varieties are susceptible. Aphid vectors also avoid Royalty.

Leaf Curl Virus

Symptoms: Symptoms of infection by the leaf curl virus gave rise to the disease's name. The leaves of infected canes are stiffly arched or curled downward. Leaves of red raspberries become yellow, while those of black raspberries take on a dark-green, greasy cast. Clusters of stunted lateral fruiting shoots arise from single nodes on the canes. The canes are stiff and brittle and the fruit is small and crumbly. Symptoms on red raspberries are very mild or may not appear until the season after infection.

Epidemiology: Two different strains of this virus exist, with one strain infecting red raspberries and the other infecting black raspberries. Both infect blackberries, although most cultivars are symptomless. This virus is spread by at least one species of aphid. Spread of the virus is slow.

Controls: Besides the standard practices of starting with clean stock and keeping plantings away from wild raspberries or infected plants, roguing of plants showing symptoms has been effective. Using insecticides to control aphids also slows the spread of this virus.

Managing Viral Diseases

Control measures aim mainly at removing sources of the virus that are within and around the raspberry planting. Destroy wild and neglected brambles within 600 to 1,000 feet of the planting.

Follow a good weed control program to eliminate host plants for the viruses. Establishing a thick sod as row middles,

using plastic mulch, or using landscape fabric are effective cultural methods to eliminate broadleaf weed carriers of tomato ringspot virus. Test the soil for dagger nematodes, which vector viruses. Fumigate, if indicated by the dagger nematode count, before starting a new planting. Alternatively, plant the soil to Dwarf Essex rapeseed (see Chapter 2), solarize the field (in warmer areas), or leave the field fallow to starve nematodes in the summer. Tomato ringspot virus will last in the gullet of dagger nematodes until their next molt. The period before the last adult molt in dagger nematodes is 18 months.

Examine plants throughout the season for virus infection symptoms. Those plants showing symptoms should be tested for viruses, preferably before mid-May (see Appendix B for laboratory information). If any viruses are detected, remove the plant or, if viral symptoms are extensive, remove the entire planting.

Strict aphid, whitefly, and leafhopper control should be maintained to prevent infection; plant aphid-resistant cultivars if possible. The migration and dispersal of aphid populations—occurring from June through mid-August—must be understood to appreciate aphids' potential for transmitting diseases. The local dispersal of aphids within rows is accomplished mainly by wingless females early in the season. Winged females are responsible for long-distance dispersal. The maximum distance that aphids travel is unknown, but if an aphid flies into a stiff breeze, it can be carried for miles. Of course, the probability of aphids establishing new colonies declines rapidly with distance. Aphids can also be carried to new plants by animals, equipment, and even people.

Aphid control is important in reducing the secondary spread of the virus. To reduce the virus problem:

1. Eliminate virus-infected wild and cultivated raspberries. One aspect to remember is that not all viruses show symptoms, and healthy-looking plants may still harbor viruses—a reason to remove wild brambles.
2. Plant raspberries certified to be virus free and use proper fertilization, pruning, and irrigation practices. Certified virus-free stock remains infection free for at least 2 years after planting, if well isolated and well managed, and produces larger crops on healthy, vigorous plants. However, the local spread of viruses after planting must be maintained at low levels. This means roguing infected plants and controlling aphid vectors.
3. Control aphids with insecticides and by conserving natural enemies.
4. Use aphid-resistant varieties. For instance, the varieties Canby, Royalty, and Titan are immune or resistant to two aphid species.
5. Check virus susceptibility information of raspberry types and cultivars in the above virus descriptions. Use varieties that are virus resistant.
6. Maintain 500 to 1,000 feet between new plantings and potentially virus-infected wild and cultivated raspberries.

NEMATODES

Two types of nematodes cause concern in Mid-Atlantic region bramble plantings: dagger nematodes (*Xiphinema* spp.) and root-lesion nematodes (*Pratylenchus penetrans*).

Dagger nematodes are efficient vectors of tomato ringspot virus (see above). Because they are virus vectors, a low tolerance exists for this type of nematode.

Root-lesion nematodes cause symptoms that contribute to a lack of winter-hardiness. The symptoms of their damage can be confused with those of root rots. In early stages, small, elongate lesions appear on new roots. Eventually, fine feeder roots are killed, leaving only large-diameter roots. Above ground, the number of canes is reduced, vigor is lessened, and winter injury appears to increase. Symptoms may occur in patches.

Sampling should be done from both poor and good areas to determine if nematodes are at high enough levels to cause a problem, as nematodes are likely to exist in many fields (see Chapter 1 for more information). Nematode populations may take a number of years to increase to the point where symptoms are apparent and another 2 to 3 years before canes begin to die out. Root–lesion nematodes have a very wide host range, so rotations are of limited use in controlling them.

Preplant fumigation is the chemical option for controlling either type of nematode. See Chapter 3 for more information on fumigation.

INSECTS AND MITES

Raspberries and blackberries are susceptible to a variety of insect and mite pests. Bramble plantings are typically small, so a high proportion of plants are exposed to the edge of the planting. Many insects that affect raspberries are generalist feeders and often enter the field from the outside. In addition, raspberries are rarely the only crop grown on a particular farm and many of the insect pests found in bramble plantings originate in other nearby crops.

The key to any successful pest management program is regular, careful monitoring of the crop. Monitoring information coupled with the knowledge of a pest's appearance, life cycle, and habits will allow the bramble grower to manage pest problems in the most efficient manner. Raspberries should be monitored weekly from the time leaf buds break until the fall. The planting should also be inspected at least once during the winter when the leaves are off. Evidence of cane and crown damage may be more easily seen at this time.

Many insects will be seen in the plantings, but not all are pests. Instead, many insects, such as bees, some wasps, beetles, and flies, may be beneficial. Another aspect of field monitoring is recognizing plant damage. More often than not, a damaging insect itself is not seen but rather only evidence of its presence, such as holes in leaves, wilted cane tips, weakened canes, and deformed fruit. Any insect or plant damage that is unrecognizable and significant in numbers or extent should be collected and brought to the county extension office for identification.

Fruit Feeders

Spotted Wing Drosophila, Drosophila suzukii Matsumura *(Diptera: Drosophilidae)*

Symptoms of Damage: Tiny white larvae are found in otherwise marketable fruit. Tiny holes surrounded by sunken

tissue may be found where oviposition wounds were made. Flies are capable of laying eggs in fruit as soon as it begins to ripen. Primocane-fruiting raspberries and late season blackberries are most likely to be infested as populations of this pest are highest in the fall.

Identification: This pest is similar in appearance to other vinegar flies or fruit flies. Most adult males have one large black spot on each wing, forward of the tip. Other species of vinegar flies have a spot on their wings, but the spot is smaller and either at the tip or farther forward. The definitive feature that differentiates this vinegar fly from other species is two black bands (sex combs) on each front leg on the males. Adult females lack wing spots and black bands on the legs but have a large sawlike ovipositor. Larvae are 2–3 millimeters long, white, and have no obvious head.

Life Cycle: Due to this pest's recent arrival, its local life cycle is still uncharacterized. It is likely that a small number of adults will survive the winter. The pest can also be transported into the region in fruit at any time. Each female can lay between 200 and 600 eggs. Eggs hatch in 1 to 3 days depending on temperature, after which larvae feed in the fruit for 5 to 11 days. Pupation lasts 4 to 15 days. Eight to nine generations per growing season are likely.

Monitoring and Controls: Vinegar traps can be bought or made and are used to monitor for pest presence, but they are not a method of control. Traps containing vinegar should be hung in the crop as the fruit begins to color. Pyrethroids and spinosads are efficacious on the adults; neonicotinoids and some other broad-spectrum materials are less so. See Tables 8.14 and 8.15 for more information on specific materials. Natural enemies are being found in the region, but little is yet known about them.

Brown Marmorated Stink Bug, Halyomorpha halys (Stal) *(Hemiptera: Pentatomidae)*

Symptoms of Damage: Direct feeding on fruit by adults and all stages of nymphs. Blackberries are the preferred bramble crop, though this pest has a very wide host range and may feed on any bramble crop.

Identification: Adults are mottled brown, about ¾ inch long, and nearly as wide. They are similar in shape to other stink bugs exhibiting a shield shape. Adults can be differentiated from common brown stink bugs by alternating brown and white bands on their antennae and along the edges of their abdomens. Nymphs are smaller and, like adults, exhibit white bands on brown antennae. Their coloration varies with instar, but each has some yellow or red coloration, and their eyes are red. Eggs are yellowish green, oval, and laid in clusters that are attached side to side on leaf undersides.

Life Cycle: One generation per year is expected in this region, but at least two can occur with warmer temperatures. Adults overwinter in protected locations and emerge in spring. They lay eggs from May through August. Nymphs progress through five instars.

Monitoring and Controls: Direct observation; other monitoring techniques are in development. Pyrethroids are the most effective chemical class. Nymphs should be targeted during pesticide applications as they cannot fly away; a direct hit of nymphs or adults is necessary for efficacy. Natural enemies are present but have a wide host range and thus currently provide insufficient control.

Tarnished Plant Bugs, Lygus lineolaris *(Heteroptera: Miridae)*

Symptoms of Damage: Feeding on buds and immature berries causes deformed berries.

Identification: Adult tarnished plant bugs are about ¼ inch long and coppery brown with a yellow-tipped, triangular area on the back (see Figure 6.4). The nymphs are smaller and bright green. Several generations of this insect develop each year using various host plants.

Life Cycle: Plant bugs, especially tarnished plant bugs but also including stink bugs and others, are generalist plant pests, feeding on a variety of crop and noncrop species. Tarnished plant bugs appear when fruit buds form and plants begin to bloom. Plant bugs are more serious in small fields bordered by woods and fencerows, where weeds are plentiful.

Monitoring and Controls: Deformed berries can have a variety of causes, and being able to diagnose the causes of the various deformities is important. Raspberry fruits are clusters of drupelets attached to a central receptacle. Each drupelet is made up of a hard seed and a sugary, soft, fleshy portion. If the fruit appears abnormally small, then problems of fertility, plant vigor, or soil moisture should be suspected. If the fruit is of normal size but has abnormally few drupelets with no deformed drupelets, then poor pollination should be suspected, which can have several causes. However, if abnormally few fully developed drupelets are present and the remaining drupelets are shriveled and seedlike, then plant bug feeding should be suspected. Mowing nearby forage crops or alfalfa during the bramble flowering and fruit-setting stages encourages the movement of tarnished plant bugs into blackberry and raspberry plantings. Weeds, especially red sorrel, also harbor plant bugs. If an insecticide treatment is necessary, apply when more than 20 to 25 plant bug nymphs per 50 flower clusters are found. Pay particular attention to field borders.

Picnic Beetles, Glischrochilus *spp. (Coleoptera: Nitidulidae)*

Symptoms of Damage: Holes bored into fruit, from which adults beetles frequently emerge. The beetles are also implicated in transmitting rot organisms. Damage to raspberry fruit by larvae usually is inconsequential because it does not take place until the fruit begins decomposing and is unmarketable.

Identification: The picnic beetle, a member of the sap beetle family, is the most frequent sap beetle pest of raspberries, though other species of sap beetles are also occasionally found in raspberries. The adult is about ¼ inch long, black, and has four orange spots on its back (see Figure 6.6). Larvae are small, white, and maggotlike in appearance, and can be found in decomposing fruit that has fallen to the ground.

Life Cycle: Ripening fruit attracts adult beetles. They are especially drawn to overripe or decaying fruit. Moreover, anything that damages fruit during harvest can stimulate picnic and other sap beetle attacks. The adult beetles bore

into the fruit, devour a portion, and lay eggs. If disturbed, the adults fall to the ground and seek cover.

Monitoring and Controls: Adults are easily found if present, though often not until after the fruit has been picked into a container. Field control is best accomplished by prevention. Remove damaged, overripe, or diseased fruit from plantings at regular intervals. Other decomposing fruit should also be removed from the area.

Thrips, Various Species (Thysanoptera: Thripidae)

Symptoms of Damage: Thrips have been noted among ripe drupelets of berries during harvest. Their actual presence, when noticed by consumers, is usually of more consequence than their feeding damage to the fruit. When thrips feed on flowers, they may cause a brownish discoloration on the calyx, flower stems, and bases of petals, pistils, and anther filaments.

Identification: Thrips are tiny insect pests of various horticultural and ornamental crops. Adult thrips are very small—less than 2 millimeters in length—and usually yellow tan to dark brown with four featherlike wings. Young thrips are smaller, wingless, yellowish, and active.

Life Cycle: Thrips breed on grasses, weeds, and various flowering species and then move to brambles at blooming time. They insert their eggs in plant tissue at the base of flowers and in tender, new foliage.

Monitoring and Controls: Under normal conditions, thrips predators such as lady beetles, mites, and spiders should provide adequate control. Under very heavy pressure, an insecticide application may be necessary, but sprays must be timed to avoid injury to pollinators.

Raspberry Fruitworms, Byturus unicolor *(Coleoptera: Byturidae)*

Symptoms of Damage: Adults feed on the buds, which they may kill; on the leaves, which they skeletonize; and on the blossoms, feeding mainly on the pistil and stamens. When adults feed on developing leaves, symmetrical, lengthwise holes may be seen as the leaves unfold. Injury from larvae may cause the berries to dry up or decay and fall off, or worms may be present in the berries at picking time, reducing the value of the crop.

Identification: Raspberry fruitworm adults are small (⅛ inch), hairy, light-brown beetles. Larvae are light brown, wormlike, and ¼ inch long when fully grown. Larvae are usually found inside the berry cup during harvest.

Life Cycle: Overwintering adult beetles emerge from the soil during mid-spring. The female deposits eggs on or near blossom clusters or on the green berries. Eggs hatch in a few days, and the larvae feed inside the flower bud at first, working their way into the center of the developing receptacle and eventually out toward the drupelets onto the receptacle surface. After feeding is completed, the larvae fall from the plant and enter the soil to pupate.

Monitoring and Controls: The adult beetles are active mainly during early evening hours. They are more of a problem on early red raspberry varieties, but they may also attack other bramble types. This pest is reportedly more of a problem in weedy fields. Cultivating plant rows during the late season will reduce larval and pupal population in the soil. If long holes on leaves are visible, giving them a tattered appearance, fruit should be checked for larvae. If this pest is a significant problem, insecticides should be applied before eggs are deposited—when blossom buds separate and again just before blossoms open.

Green June Beetles, Cotinus nitida *(Coleoptera: Scarabaeidae)*

Symptoms of Damage: Adult beetles feed on fruit resulting in its destruction. Larvae cause damage to turf by burrowing through the sod feeding on dead organic matter, and roots to a lesser extent. The larva's large size and physical damage to the turf from burrowing is of more consequence than larval feeding damage.

Identification: Unlike other June beetles, adult green June beetles are active during the day. They are a metallic medium shade of green and are very large, ¾ to 1 inch long by ½ inch wide. The larvae appear similar to other white grubs, and they can reach ¼, ¾, or 2 inches long as they progress through 3 instars. Grubs come up to the ground surface at night and have a unique manner of locomotion in that they wriggle along upside-down by flexing their backs.

Life Cycle: Green June beetles have one generation per year. Adults are present from June through September. Shortly after emerging, June beetles mate and the females burrow into the soil and lay eggs. The eggs hatch in June and August. Third instar larvae burrow deep into the soil for the winter, then resume feeding once soil temperatures warm. They pupate in late May and early June, and adults emerge 3 weeks later.

Monitoring and Controls: Presence of the beetles will be quite obvious. Only one pesticide is labeled specifically for green June beetles, but materials that work on Japanese beetle appear to be fairly effective for green June beetles. These beetles appear to be more problematic than in the past.

Crown and Cane Feeders

Raspberry Crown Borer, Pennisetia marginata *(Lepidoptera: Sesiidae)*

Symptoms of Damage: Infested canes become spindly, lack vigor, and often break off at ground level. If damaged canes are tugged on, the cane often breaks and damage (holes in canes and/or galleries in the crown) is found. Because the larvae are rather large, they consume a substantial portion of the crown. Raspberries are most commonly affected, though other brambles can be hosts. This is the only crown and root feeder in the Northeast to cause significant damage. In other parts of the country, root weevils and other insects are also significant.

Identification: The day-flying, wasplike, adult moths are black with yellow bands on the body, resembling those of a yellow jacket wasp (Figure 8.6). Larvae are whitish with a light-brown head. They are ½ to ¾ inch long by the end of their first full summer and about 1¼ inches long when mature. They have three pairs of true legs and four pairs of hooked prolegs. Pupae are about ¾ inch long and reddish brown.

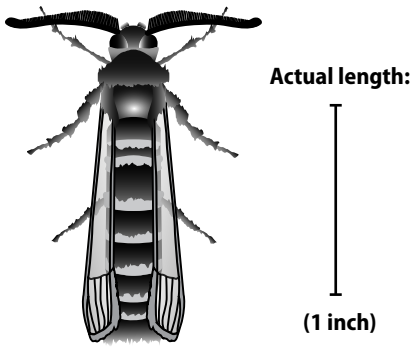


Figure 8.6. Raspberry crown borer adult.

Life Cycle: Raspberry crown borers have a two-year life cycle. The adult moths emerge in late summer and live for about 10 days. During August each female lays about 100 reddish-brown eggs singly on the undersides of leaf edges. When the eggs hatch (September to November) the young borers crawl down the canes and enter the soil near the crown to overwinter. In late April of the following spring, the larvae enter the canes near the base and remain in the crown area, feeding until midsummer of their second year. They then pupate and emerge as adults in late summer.

Monitoring and Controls: Plantings near wild bramble populations have been extensively damaged since crown borer populations frequently build in wild raspberry and blackberry patches. Therefore, the first step in management is removing nearby wild sources of this pest, as well as removing infested plants within the planting. An insecticidal soil drench may be used if necessary. Controlling this pest may take more than 2 years because of its long life cycle.

Rednecked Cane Borer, Agrilus ruficollis *(Coleoptera: Buprestidae)*

Symptoms of Damage: Characteristic injury caused by these borers is a swelling of the cane, which may be from ¼ inch to 3 inches long and may occur anywhere on the cane. The cane is weakened and may break off at the swelling or die.

Identification: The adult rednecked cane borer is black and ¼ inch long with a reddish section (prothorax) behind the head (Figure 8.7). Mature larvae are ½ to ¾ inch long and creamy white with a flattened head and have a pair of dark-colored, forcepslike prongs on the abdomen. They decrease in size during the pupal stage. On sunny days, adults can be seen feeding on the new canes and leaves.

Life Cycle: Adult beetles are present from late May until early August. Eggs are deposited on the bark of new growth, usually within 10 inches of the base of the cane. The young larvae bore into the sapwood of the current year's growth (primocane), make winding tunnels around the stem that splits the bark and causes the gall, and finally work into the pith. They may tunnel either downward as much as 5 inches from the point of the gall, but more commonly tunnel upward, as far as 30 inches from the point of entry. In midspring, the larvae pupate inside the cane and then emerge from the cane as adults in late spring and early summer by chewing a D-shaped hole through the cane.

Monitoring and Controls: This insect is usually controlled by cutting out and removing infested canes with swellings from late fall to early spring. A prebloom spray and/or postharvest sprays may be considered when populations are heavy.

Raspberry Cane Borer, Oberea bimaculata *(Coleoptera: Cerambycidae)*

Symptoms of Damage: Wilted tips of canes, with two rows of punctures ¾ to 1 inch apart found within 6 to 8 inches of the tip. Infested canes usually die before the fruit matures.

Identification: Adults are ½-inch-long beetles with long antennae (Figure 8.8). The beetles are black except for a section behind the head that is bright orange with two or three black spots.

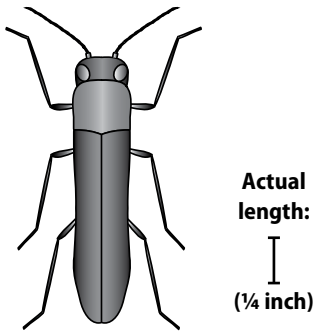


Figure 8.7. Rednecked cane borer adult.

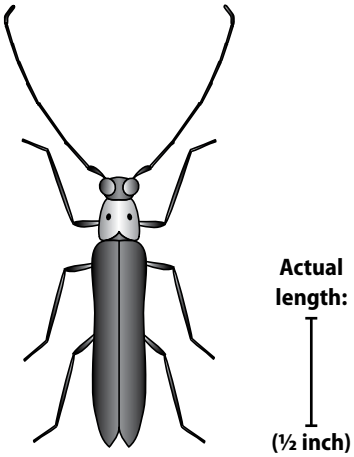


Figure 8.8. Raspberry cane borer adult.

Life Cycle: Adult beetles appear in raspberry plantings in June, and females singly deposit their eggs about 6 inches below the cane tip in the pith of tender new growth. The beetle makes two characteristic rows of punctures that encircle the cane about ¾ to 1 inch apart; an egg is inserted between these, nearer the lower row. The girdling of the cane causes the tip to wilt. After hatching, the larvae tunnel toward the base of the cane. By one account (MacNab and Tetrault), the larvae reach the base of the cane by fall. By another account (Mills and Dewey), the larvae spend the first winter within an inch or two of the lower row of punctures, then complete their journey to the base of the cane the next growing season and spend their second winter in the crown near or below ground level. The following spring, they pupate and then emerge as adults.

Monitoring and Controls: Remove wilted tips several inches below punctures by midsummer. Check for hollowed-out centers and make cuts farther down the cane, if needed. Remove and destroy older canes whenever observed. Destroy any wild brambles nearby. Insecticide applications made just before blossoms begin to open will have some efficacy against raspberry cane borers.

Tree Crickets, Oecanthus species *(Orthoptera: Gryllidae)*

Symptoms of Damage: Tree crickets deposit eggs in punctures in long rows in the canes of raspberries. Each puncture is distinct and more or less circular in outline so that the row of eggs appears as a series of dots, from a few to

more than 50. The eggs are laid through the outer layer of wood and placed diagonally across the pith. Occasionally, egg−laying injuries may girdle and kill the cane above the injury.

Identification: Nymphs and adults look like field crickets but are a pale whitish-green to green color. Their size ranges from ¼ inch long when nymphs to 1 inch long when adults.

Life Cycle: Eggs hatch into tiny nymphs in the early spring toward the end of May and undergo five molts, reaching adulthood in late summer. Eggs, which are laid in August, are the overwintering stage. The nymphs and adults feed on a variety of plants.

Monitoring and Controls: If egg-laying damage is visible, clip the canes off below the egg-laying scars and destroy them. Under heavy pressure, an insecticide may be applied before adults lay eggs.

Foliage Feeders

Most leaf-feeding insects of raspberries can be tolerated to some degree. Monitoring for these insects is straightforward and, if done diligently, problems can be treated well before they become serious. Many years, one or more leaf-feeding insects may occur in low numbers or not appear at all. In these years insecticide costs can be trimmed.

Aphids, Various Genera and Species (Homoptera: Aphididae)

Symptoms of Damage: Aphids cause two types of damage to raspberries. First, they are piercing-sucking insects that remove nutrients from phloem tissue. Second, their feeding can spread disease, notably viruses. Viruses can in turn stunt plant growth, distort and discolor leaves, and reduce flower and fruit production.

Identification: Aphids are pear-shaped, tiny (1⁄16 to 3⁄8 inch), soft-bodied, sucking insects with small heads and a pair of cornicles. Their color ranges from yellowish green to bluish green depending on the species, often matching well with the plant growth on which they are found. At least three genera and eight species of aphids occur on raspberries in North America. Four species are found in the Northeast.

Life Cycle: Aphids have a complex life cycle. Overwintering eggs hatch in spring into wingless females (though a few winged females may be produced at this time), which give birth parthenogenetically (i.e., without mating) to young that mature as wingless females. Populations increase quickly during times of rapid plant growth. Later in the summer, winged females are produced and may fly to other plants (many times other plant species). The last winged female generation of the season flies back to the primary host species. In the fall, wingless males and egg-laying females are produced and mated; eggs are laid on the primary host. All stages except the egg in the aphid life cycle can transmit virus. The minimum feeding time necessary for aphids to pick up a virus from infected plants is about 15 to 30 minutes. Aphids can retain the virus for several hours and are very efficient in transmitting it from plant to plant—a single feeding probe by a single aphid lasting a few minutes is enough to transmit a virus.

Monitoring and Controls: Monitor plantings starting when aphid eggs hatch (approximately May), and begin a spray program when aphids are spotted. Look for aphids on new growth and on the undersides of leaves. To reduce within-field spread of viruses, apply an insecticide if more than two aphids per cane tip are detected. Other insects such as ladybird beetles can devour great numbers of aphids. These beneficial insects should be conserved by using insecticides only when necessary and by using recommended rates. See additional information on aphids in the discussion of virus transmittal.

Blackberry Psyllid, Trioza tripunctata *(Homoptera: Psyllidae)*

Symptoms of Damage: Feeding causes tightly curled leaf clusters, twisted canes, and shortened internodes, which are sometimes mistaken as a viral disease or herbicide damage. Blackberry psylla are mainly blackberry pests and have been particularly troublesome on thornless blackberries.

Identification: Adults resemble a very small fly, about 1⁄5 inch long, with clear wings with stripes. Nymphs are often mistaken for aphids but have no cornicles on the abdomen.

Life Cycle: Females move from conifer trees, the overwintering host, into the field slightly before, during, or after bloom. Females lay up to 100 eggs on petioles or undersides of new leaves over a period of a month. Eggs hatch in 10 days, and nymphs feed throughout the summer and fall on the underside of curled leaves. Adults emerge in October, and migrate to conifers to overwinter shortly thereafter.

Monitoring and Controls: Monitor plants at the field edge weekly, especially edges near woods and fence rows. Insecticides should be applied when adults first appear. Inspect curled leaf clusters for nymphs. If nymphs are not found, inspect additional leaf clusters since symptoms remain even when the nymph has moved to a new location. Curled leaf clusters should be removed and destroyed immediately. Avoid planting within 250 yards of conifers.

Japanese Beetles, Popillia japonica *(Coleoptera: Scarabaeidae)*

Symptoms of Damage: Leaves are skeletonized, with those on the upper parts of the canes more severely affected. Raspberry varieties differ in their susceptibility to beetle attack. Red raspberries are generally more favored by the beetles than black varieties.

Identification: Adult Japanese beetles have copper wing covers and metallic-green heads and are ½ inch long. The larva is a C-shaped white grub about ¾ to 1 inch long when fully grown. The grub of Japanese beetles can be distinguished from other white grubs by checking for two rows of six or seven spines in the shape of a V on the ventral side (underside) of its posterior.

Life Cycle: One generation occurs per year. Grubs overwinter in the soil and pupate in late May. Adults appear in large numbers starting in late June during harvest of summer-bearers and feed on the leaves. Adults will live for 30 to 45 days. Infestations peak in July but may continue through September. Females lay approximately 50 eggs in the soil, which hatch after 2 weeks. Larvae feed primarily on grass roots until the

soil temperatures cool in the fall and then remain dormant until spring.

Monitoring and Controls: Beetle feeding can be controlled with insecticide applications, if necessary. Watch days-to-harvest limitations, and take precautions to protect pollinators if open blossoms are present. Beetles can fly substantial distances from untreated overwintering sites like pastures and reinfest plantings. Therefore, inspecting plantings weekly is recommended from harvest onward. Japanese beetle larvae feed on sod planted in row middles. This should be considered in developing a soil and weed management plan. However, this source of adults is minor compared with neighboring fields if pasture is adjacent to the planting. Entomopathogenic nematodes are effective for larvae but have a limited shelf life and must be applied strictly according to directions.

Twospotted Spider Mites, Tetranychus urticae *(Acari: Tetranychidae)*

Symptoms of Damage: Leaves infested by twospotted spider mites first appear to have areas of white stippling. Later the leaves may bronze, dry, and eventually fall off. This is the result of mites piercing plant cells to remove nutrients and chlorophyll. In heavy infestations the undersides of leaves will also have silken threads spun across the surface. Mites are more prevalent during hot, dry periods, and injury is exacerbated if soil moisture is low. Heavy mite populations may also predispose plants to winter injury.

Identification: The eight-legged adult, about 1⁄50 inch in length, varies in color from pale greenish yellow to green and is usually marked with two dark spots. With the aid of a magnifying lens, nearly clear spherical mite eggs can also be seen.

Life Cycle: These mites overwinter as mature fertile females or young nymphs on fallen leaves and in cracks of posts. The length of the life cycle varies with seasonal and weather conditions but may be completed in about 2 weeks. Reproduction may be continuous from early spring until late fall. The female lays two to six eggs per day—up to about 70 eggs per mite. Eggs hatch in about 4 days, so 10 to 15 generations can occur per year. Hot, dry weather favors rapid population increases.

Monitoring and Controls: Starting in the spring, examine the undersides of leaves weekly for mites using a 10x hand lens. Early in the season, lower leaves are usually infested first, but the mites move up the cane as the season progresses. Overwintered twospotted spider mites will be reddish orange in color. Red raspberry varieties are the most commonly affected. Predatory mites, lady beetles, or lacewings can naturally control mite populations in the field, but broad-spectrum insecticides applied for other pests can accelerate mite problems. Chemicals that kill beneficial predators of mites often do not kill twospotted mites themselves. Miticides that target eggs and nymphs are effective only if used when the twospotted mite population is low. Likewise, predatory mite releases should be made when twospotted spider mite populations are low to minimize the number of predators that must be released and to maximize chances that the predatory mite populations will be able to gain the upper hand. Sometimes a mixture of two species—one that provides a quick knockdown of twospotted spider mite populations, and one that can subsist when twospotted spider mite populations are low—will provide better long-term control. Your supplier can make recommendations as to the best predator species. Since little is available at present for chemical control of mites on brambles, preserving natural enemies is especially important. Learning to identify predatory species to determine whether they are present is worthwhile (see Appendix E for sources of information). When applying miticides, thorough coverage is a must, so use plenty of water (at least 100 gallons per acre) and high enough pressure to treat the undersides of the leaves. Treat with a miticide if a sharp population increase is noted or leaf stippling appears. Resistance to miticides can develop quickly, so they should not be used unnecessarily. When miticides are used, be sure to follow label directions to make the best use of available materials. Populations isolated within a field may be spot treated. The insecticidal soap M-Pede will only suppress mite populations. Multiple applications of M-Pede may be necessary to reduce the mite population.

Potato Leafhoppers, Empoasca fabae *(Homoptera: Cicadellidae)*

Symptoms of Damage: The potato leafhopper feeds near the edge of the leaf, leaving a triangular chlorotic area extending from the feeding site to the leaf edge. If several feeding sites are present on a leaf, the leaf will have a wrinkled appearance and cup downward. Most feeding is at succulent growing tips. If several leaves on a shoot are affected, shoot growth will be greatly slowed. Amount of damage varies from year to year, with greatest damage occurring in midsummer.

Identification: Nymphs and adults are pale green and move very quickly, often in a side-to-side fashion on the leaves, where they are most often found on the underside. The adults (see Figure 6.7) fly quickly when disturbed.

Life Cycle: Potato leafhoppers are a pest of many crops. Potato leafhoppers overwinter as adults in southern states and move northward mainly by the action of storm fronts. The pest's movement and severity depend on many weather-related phenomena and the availability and proximity of alternate food sources. Therefore, the seriousness of this pest is sporadic in northern parts of the region (Pennsylvania and West Virginia) and is common in more southern states.

Monitoring and Controls: Brambles planted near other hosts of the potato leafhopper, such as alfalfa, are much more readily invaded by this pest. Thus, brambles at the edge of a planting near the alternate host will show damage first. Increased pressure from leafhoppers on brambles may be observed after the surrounding vegetation has been harvested or mowed. Apply an insecticide if leafhoppers become a problem. Josephine red raspberry tends to be resistant to leafhopper damage.

Raspberry Sawflies, Monophadnoides geniculatus *(Hymenoptera: Tenthredinidae)*

Symptoms of Damage: Leaf feeding causes holes in leaves, usually on red raspberries, but also on other species.

Identification: Larvae are small (¾ inch), light green, and spiny. The ¼-inch adult female is a black fly with a yellowish band across the abdomen.

Life Cycle: The adults appear in May and the eggs are deposited between the upper and lower surfaces of leaves. As the eggs hatch, the young larvae feed on the outer edge of the leaves. As they grow older, they feed anywhere on the leaf surface. The larvae feed for about 2 weeks before entering the soil, where they remain until the following year.

Monitoring and Controls: Preventive sprays are usually not needed for this pest since significant damage is not common. If larvae cause substantial feeding damage, an insecticide may be applied.

Physiological Disorders

Though physiological disorders are not caused by any pest, they are discussed in this section since their symptoms could be mistaken for those that might be caused by a disease or insect.

Sunscald

Red and yellow raspberries have a tendency to develop white drupelets on the fruits as a result of exposure to high heat and natural UV radiation. In the southern Mid-Atlantic region, most of this damage can be traced back to clear or partly cloudy summer days when temperatures reach the high 90s or even exceed 100°F. Information developed in California suggests that thorough watering the night before each anticipated high-heat day aids natural transpirational cooling of the fruit and fruiting canopy. This practice will reduce most radiation and/or high-temperature damage. Watering during the day of the heat episode or later that evening has little effect in reducing this type of damage. Using a lightweight shade cloth may also aid in minimizing damage. Heritage and yellow sports of Heritage seem especially susceptible. This disorder has also been observed on Triple Crown blackberry.

Red Drupelets on Blackberry

Blackberry fruit pigments, anthocyanins, can break down in storage, resulting in red drupelets. At this point, contributing factors such as UV light, heat damage, pathogens, insects, or chill injury in storage may all play a role in this breakdown.

Table 8.12. Bramble disease control strategies.

All possible control strategies must be used if bramble diseases are to be controlled.
Key: ++ = most important controls; + = helpful controls; — = no effect

Disease Control Considerations	Viruses[a]	Verticillium Wilt	Orange Rust	Cane Blights[b]	Powdery Mildew	Fruit Rots
Good air-water drainage	—	—	—	++	+	++
500+ feet from other brambles	++	—	—	—	—	—
Rotation	+[c]	++[d]	—	+	—	—
Fumigate for fungi	—	+	—	—	—	—
Fumigate for nematodes	+[c]	—	—	—	—	—
Tolerance/resistance	++[e]	++[f]	++[g]	—	+	—
Avoid adjacent plantings	++[j]	—	—	—	+	—
Eliminate wild brambles	++	—	++	—	+	—
Disease-free stock	++	++	++	++	+	—
Aphid control (vectors)	++	—	—	—	—	—
Rogue infected plants	++	—	++	—	—	—
Speed drying (weeds, pruning)	—	—	+	++	—	++
Prune 3 days before rain	—	—	—	++	—	—
Dispose of pruned canes	—	+	+	++	—	—
Maintain plant vigor	—	—	—	++	—	—
Fungicide sprays	—	—	—	++[h]	++[i]	+
Harvest before overripe	—	—	—	—	—	++
Fruit storage conditions	—	—	—	—	—	++

a. Viruses: See text for descriptions.
b. Cane blights for purposes of this table include anthracnose, cane blight, spur blight, and botrytis blight.
c. Rotation is effective for ringspot virus only: two years of a grass crop (e.g., corn) with excellent weed control before planting red raspberry should eliminate need to fumigate for Xiphinema nematode vector.
d. Rotation for verticillium wilt: Avoid fields planted to susceptible crops (tomatoes, potatoes, eggplant, peppers, strawberries, raspberries, and stone fruit) within the past five years. Avoid fields with a history of verticillium wilt unless soil is fumigated.
e. Virus resistance, tolerance, and immunity: Mosaic—blackberries are not affected; black and purple raspberries are more severely affected than red raspberries. Of purple and black raspberries, Black Hawk, Bristol, and New Logan are tolerant; Cumberland is susceptible. Of red raspberries, Canby, Titan, and Reveille are "resistant" because aphid vectors avoid them. Aphid vectors also avoid Royalty. Leaf curl—blackberries are symptomless; all raspberries are affected. Tomato ringspot—red raspberries are affected. Streak—black and purple raspberries are primarily affected. Raspberry bushy dwarf—Esta appears immune.
f. Verticillium tolerance: Some blackberries are resistant; red raspberries are more tolerant than black raspberries.
g. Orange rust resistance: Red raspberries are immune. Other brambles are affected.
h. Fungicide program for cane blights: The lime-sulfur spray is most important for anthracnose (delayed dormant) and cane blight (late fall dormant); apply other effective fungicide sprays when blossoms are in bud and again two weeks later to help control anthracnose, botrytis blight, and spur blight on raspberries. Refer to Table 8.15.
i. Fungicide program for powdery mildew: Refer to Table 8.15.
j. Keep black and purple raspberries away from old plantings of red raspberries because mosaic virus can spread from red raspberries and is more severe on black and purple raspberries; keep all red raspberries away from old plantings of blackberries because blackberries can be a symptomless carrier of curl virus.

Table 8.13. Activity groups and effectiveness of fungicides for bramble disease control.

Not all fungicides listed below are labeled for all the diseases listed. This table is intended to provide information on effectiveness for diseases that appear on the label, plus additional diseases that may be controlled during application. See Table 8.15 for labeled uses.

Fungicide	Activity Group[a]	Phytophthora Root Rot	Orange Rust	Anthracnose	Spur Blight	Gray Mold
Abound	11	0	++	—	—	+
Aliette	33	+++	0	—	—	0
Cabrio	11	0	++	—	—	++
Captan	M	0	0	+	+	++
Captevate	17+M	0	0	—	—	+++
Elevate	17	0	0	—	—	+++
Lime sulfur	M	0	0	++	++	0
Orbit, Tilt	3	0	++	—	—	0
Phostrol	33	+++	0	—	—	0
Pristine	7+11	0	++	—	—	+++
Rally	3	0	++	—	—	0
Ridomil Gold	4	+++	0	—	—	0
Rovral	2	0	0	—	—	+++
Switch	9+12	0	0	—	—	++
Tanos	11	0	0	+	++	—

0 = not effective; + = slight effectiveness; ++ = moderate effectiveness; +++ = very effective; — = insufficient data

a. Chemistry of fungicides by activity groups: 2 = dicarboximides; 3 = demethylation inhibitors (includes triazoles); 4 = acylalanines; 7 = carboxamides; 9 = anilinopyrimidines; 11 = strobilurins; 12 = phenylpyrroles; 17 = hydroxyanilides; 33 = unknown (phosphonates); M = chemical groups with multisite activity. Fungicides with two activity groups listed contain active ingredients from two activity groups.

Table 8.14. Activity groups and effectiveness of insecticides and miticides on bramble pests.

Not all insecticides listed below are labeled for all the insects listed. This table is intended to provide information on effectiveness against insects that appear on the label, plus additional insects that may be controlled during application. See Table 8.15 for labeled uses.

Pesticide	Activity Group[a]	Aphids	Brown Marmorated Stink Bug	Leaf-hoppers	Spider Mites	Japanese Beetle Adults	Tarnished Plant Bugs	Sap Beetles	Spotted Wing Drosophila	Thrips
Acramite	25	—	0	0	+++	0	—	0	0	—
Actara	4A	+++	+++	+++	—[c]	++	++[b]	—	+	0
Admire Pro	4A	+++	++	+++	—[c]	++	—	—	—	0
Altacor	28	—	0	0	—	0	—	—	—	0
Asana	3	++	+	++	—	++	—	—	—	—
Assail	4A	+++	++	+++	—[c]	++	++	+	+	++
Aza-Direct	un	—	0	+	—	+	—	—	—	—
Brigade	3	++	+++	++	+	—	+++	+++	+++	—
Bt Products	11	0	0	0	0	0	0	0	0	0
Confirm	18	0	0	0	0	0	0	0	0	0
Danitol	3	++	+++	++	+	+++	+++	++	+++	—
Delegate	5	—	0	0	—	—	—	—	+++	++
Intrepid	18	0	0	0	—	0	—	—	—	0
Malathion	1B	++	+	++	—	+	++	+	+++	++
M-Pede	—	++	0	—	+	—	—	—	—	—
Mustang Max	3	—	+	++	—	++	—	—	+++	—
Provado	4A	+++	++	+++	—[c]	+++	—	—	+	+++
Pyganic	3	+	0	—	—	+	—	—	++	—
Savey	10	—	0	—	+++[d]	0	—	—	0	—
Sevin	1A	+++	0	++	—	+++	++	++	+	—
Spintor, Entrust, Success	5	—	0	—	—	0	—	—	+++	+++
Zeal Miticide[1]	10	—	—	—	+++[d]	—	—	—	—	—

0 = not effective; + = slight effectiveness; ++ = moderate effectiveness; +++ = very effective, — indicates that insufficient data exists to rank effectiveness of this insecticide or miticide on these pests

a. Chemistry of insecticides by activity groups: 1A = carbamates; 1B = organophosphates; 3 = pyrethrins and synthetic pyrethroids; 4A = neonicotinoids; 5 = spinosyns; 10 = mite growth inhibitors with unknown or nonspecific sites of action; 11 = Bt microbials; 18 = ecdysone agonists/molting disruptors; 25 = neuronal inhibitors; 28 = diamides.

b. Moderate effect on nymphs, but little or no effect on adults.

c. In some studies, spider mite reproduction has increased with the use of low concentrations of insecticides in this product's chemical class (3A, neonicotinoids).

d. Effective on eggs and immatures, but little or no effect on adults.

Table 8.15. Pesticides for bramble disease and insect control.

The recommendations below are correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. If control cannot be achieved with a particular material, it is possible that resistant populations exist. Use a material in a different activity group, which will have a different mode of action. See Table 3.2 for use status, chemical names of active ingredients in products, and reentry intervals. See Table 3.1 for toxicity to non-target organisms, and Tables 8.13 and 8.14 for activity groups and efficacy ratings to help determine products that best suit your situation. See Table 8.16 for other use restrictions, such as quantity allowable per season. Information was current as of July 1, 2012.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
DELAYED DORMANT		
Diseases		
Anthracnose, spur blight, cane blight	When buds begin to break. This is the most important treatment for these diseases. Prune and remove dead and diseased canes prior to primocane emergence. Specified rates vary by manufacturer.	Lime sulfur (—), 10–12 gal per 100 gal of spray solution, applied at 100–160 gal/A
Anthracnose	See cautions on Aliette label concerning its use if applied subsequent to a copper compound application.	Kocide 3000, 0.75 lb (0)
Insects		
Scales	Not a common problem in this region.	Lime sulfur (0), 8 gal/100 gal of spray solution, applied at 100–160 gal/A
CANE EMERGENCE		
Diseases		
Anthracnose, spur blight	When young canes are 8–10 inches tall and again 2 weeks later. Needed only if diseases are present. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Captan 80WDG, 2.5 lb (3), ***or*** Pristine, 18.5–23 oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Abound, 6.0–15.5 fl oz (0), ***or*** Tanos, 6–10 oz (0) plus captan, ***or*** Captevate 68 WDG, 3.5 lb (3), ***raspberries only***
Orange rust	Inspect plantings when plants are 12–18 inches high for symptoms (see text for description). Remove infected plants before orange spores are produced.	Fungicides for orange rust will serve no purpose until orange spores are present. However, plantings should be monitored for presence of orange spores starting in midspring. Once found, fungicides listed under "Prebloom" for orange rust may be used.
Insects		
Raspberry crown borer larvae	In early spring. As a drench in at least 200 gal of water/A. Directed to lower canes and soil; see labels for specific restrictions. This drench will only affect new larvae. Because this insect requires more than one year to complete its life cycle and larvae feeding in the crown are not affected, applications will be needed for more than one year.	Brigade WSB, 16 oz or 2EC, 6.4 fl oz (3), ***or*** Hero, 10.3 fl oz (3), ***or***
	In early spring. Direct to base of canes in 50–100 gallons of water per acre. Apply when at least ½ inch of rainfall is expected or irrigation will be applied. This will move the insecticide into the root zone.	Altacor, 3.0–4.5 oz (3)
Other insects	Monitor for adults of insects listed under "Prebloom." See text for details.	No other sprays are expected to be needed at this time. If adults of insects listed under "Prebloom" are found, insecticides listed under "Prebloom" may be used.

CONTINUED

Table 8.15. Pesticides for bramble disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
PREBLOOM (WHEN BLOSSOMS IN CLUSTERS SEPARATE)		
Diseases		
Anthracnose, spur blight	Sprays for anthracnose and spur blight at this time will also control cane blight. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Captan 80WDG, 2.5 lb (3), ***or*** Pristine, 18.5–23 oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Abound, 6.0–15.5 fl oz (0), ***or*** Tanos, 6–10 oz (0) plus captan, ***or*** Captevate 68 WDG, 3.5 lb (3), ***raspberries only***
Orange rust	For orange rust, while orange pustules are visible, on a 10- to 14-day schedule until temperatures are above 75°F. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Rally 40W , 1.25–2.5 oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Pristine, 18.5–23 oz (0)
Powdery mildew	Sprays for powdery mildew are not usually required but may help on highly susceptible cultivars such as Latham. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Rally 40W, 1.25–2.5 oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Abound, 6.0–15.5 fl oz (0), ***or*** Orbit, 6 fl oz (30), ***or*** Tilt, 6 fl oz (30)
Insects		
Raspberry crown borer larvae	If not applied earlier, as a drench in at least 200 gal of water/A. Direct to lower portion of canes and soil. See text for life cycle information on this pest. Do not make both foliar and drench applications pre-bloom.	Brigade WSB, 16 oz or 2EC, 6.4 fl oz (3)
Aphids	Inspect tender cane growth and undersides of leaves. Aphids may be easily overlooked. Sprays for aphids will also suppress blackberry psyllid. Do not apply Asana within 7 days of pollination, as it repels bees. Actara is highly toxic to bees exposed to direct contact.	Malathion 57EC[b], 3 pt or 8F, 2 pt (1), ***or*** Asana XL, 4.8–9.6 fl oz (7), ***or*** M-Pede, 2% solution (0), ***or*** Actara, 2.0–3.0 oz (3), ***or*** Assail 70WP, 1.0–2.3 oz or 30SG, 2.5–5.3 oz (1)
Rednecked caneborer	This is the time when caneborer and fruitworm adults appear to lay their eggs. One spray just before bloom and another one at the end of bloom should help. Direct sprays toward the base of canes where adults are more likely to be present. Materials with a broad label such as Pyganic, Pyrenone, or Evergreen may help.	
Raspberry caneborer	Just before blossoms open to target adults. No materials are specifically labeled for this pest at this time. However, materials with a broad label such as Pyganic, Pyrenone, or Evergreen may help.	
Raspberry sawflies	When first adults are noted.	Sevin 80S, 2.5 lb or XLR Plus, 2 qt (7), ***or*** Spintor 2SC, 4–6 fl oz (1)
Raspberry fruitworms	Apply when blossom buds separate and again just before blossoms open.	Spintor 2SC, 4–6 fl oz (1)
Tarnished plant bug	See text for thresholds and cultural controls.	Sevin 80S, 1.87–2.5 lb or XLR Plus, 1.5–2 qt (7), ***or*** Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1)
Thrips	Apply just before blossoms open.	Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Malathion 8F[b], 2 pt or 57EC[b], 1.5 pt (1), ***or*** Aza-Direct, 16–56 fl oz (0)
Blackberry psyllid adults	When adults appear on plants. See text for their description. See note above under "Aphids." Materials with a broad label such as Pyganic, Pyrenone, or Evergreen may help, and Surround may provide suppression.	

CONTINUED

Table 8.15. Pesticides for bramble disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
Leafrollers	Not generally a problem. Needed only if past experience has shown leafrollers to be a problem. Confirm and Dipel are also labeled for gypsy moth control. Do not make both foliar and drench applications of Brigade pre-bloom.	Asana XL, 4.8–9.6 fl oz (7), ***or*** Brigade WSB, 8–16 oz or 2EC, 3.2–6.4 fl oz (3), ***or*** Confirm 2F, 16 oz (14), ***or*** Danitol 2.4EC, 10.67–16 fl oz (3), ***or*** Dipel DF, 0.5–1.0 lb (0), ***or*** Spintor 2SC, 4–6 fl oz (1), ***or*** M-Pede, 2% solution (0), ***or*** Mustang, 4.3 oz (1), ***or*** Mustang Max, 4.0 oz (1), ***or*** Delegate WG, 3–6 oz (1)
BLOOM		
Diseases		
Botrytis fruit rot	At 5–10 percent bloom, full bloom, and up to three more times at intervals specified on the label. Bloom sprays also help control anthracnose and spur blight. Do not make more than two sequential applications of Group 11 fungicides before rotating to a fungicide in a different chemical class.	Rovral 4F, 1–2 pt (0), ***or*** Captan 80WDG, 2.5 lb (3), ***or*** Switch 62.5WG, 11–14 oz (0), ***or*** Elevate 50WDG, 1.5 lb (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Captevate 68WDG, 3.5 lb (3), ***raspberries only***
Orange rust	For orange rust, while orange pustules are visible, on a 10- to 14-day schedule until temperatures are above 75°F. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Rally 40W, 1.25–2.5 oz (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Cabrio EG, 14 oz (0)
Powdery mildew	Specific sprays for powdery mildew are not usually required but may help on highly susceptible cultivars such as Latham raspberries. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Rally 40W, 1.25–2.5 oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Abound, 6.0–15.5 fl oz (0), ***or*** Orbit, 6 fl oz (30), ***or*** Tilt, 6 fl oz (30)
Insects		
None at this time		
PETAL FALL THROUGH HARVEST		
Diseases		
Botrytis fruit rot	Three to five days before harvest; repeat at 7- to 10-day intervals through harvest if pressure is high (wet weather, rotting berries on the canes). Resistance development is a concern especially with Rovral and Elevate. Rotate fungicides in different classes.	Rovral 4F, 1–2 pt (0), ***or*** Captan 80WDG, 2.5 lb (3), ***or*** Elevate 50WDG, 1.5 lb. (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Switch 62.5WG,11–14 oz (0), ***or*** Captevate 68WDG, 3.5 lb (3), ***raspberries only***
Late leaf rust	Primarily a problem on fall-bearing raspberries. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Pristine, 18.5–23 oz (0), ***or*** Cabrio EG, 14 oz (0)
Insects and Mites		
Spotted wing drosophila	Monitor for presence of male adults with vinegar traps. Pyrethroids and spinosyns are effective in controlling spotted wing drosophila. Be sure to alternative materials from different pesticide classes for resistance management. 2(ee) labels have been issued for the products listed or the label is broadly written. Success and Entrust have the same active ingredient. Entrust can be used in organic production. Pyganic has a very short period of residual activity; populations with resistance to Pyganic have already been reported in California.	Danitol 2.4 EC, 10.67–16 fl oz (3), ***or*** Delegate WG, 3–6 oz (1), ***or*** Success, 4–6 fl oz (1), ***or*** Entrust, 1.25–2.0 oz (1,) ***or*** Pyganic EC 5.0, 4.5–18 oz (0), ***or*** Mustang Max, 4.0 fl oz (1)

CONTINUED

Table 8.15. Pesticides for bramble disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
Brown marmorated stink bug	Pyrethroids such as Brigade and Danitol are also effective against brown marmorated stink bug. Nymphs should be targeted.	Actara, 3 oz (3)
Aphids	If aphids are present. Watch days-to-harvest limitations. Foliar applications.	Malathion 8F[b], 2–4 pt or 57EC[b], 3 pt (1), ***or*** Asana XL, 4.8–9.6 oz (7), ***or*** M-Pede, 1–2% solution (0), ***or*** Provado 1.6F, 8.0 fl oz (3), ***or*** Actara, 2.0–3.0 oz (3), ***or*** Assail 70WP, 1.0–2.3 oz or 30SG 4.5–5.3 oz (1), ***or***
	Soil application.	Admire Pro, 7.0–14.0 fl oz (7)
Sap beetles	Only if needed. Avoiding a buildup of overripe fruit is the best deterrent.	Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1)
Tarnished plant bugs	See text for thresholds and cultural controls.	Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Sevin 80S, 1.87–2.5 lb or XLR Plus, 1.5–2 qt (7), ***or*** Actara, 3.0 oz (3)
Rednecked caneborer	When adults are observed. Admire Pro is systemic within the plant. It appears in recommendations at this timing, but not prebloom, to avoid possible residual effects on pollinators. Note days-to-harvest limitation.	Admire Pro, 10.5–14.0 fl oz/a (7)
Leafhoppers	As needed. Note long days-to-harvest limitations on some products.	Sevin 80S, 1.25–2.5 lb or XLR Plus, 1.0–2.0 qt (7), ***or*** Malathion 8F[b], 2.0 pt or 57 EC[b], 1.5 pt (1), ***or*** Provado 1.6F, 8.0 fl oz (3), ***or*** Actara, 2.0–3.0 oz (3), ***or*** Assail 70WP, 1.0–2.3 oz or 30SG, 2.5–5.3 oz (1), ***or***
	Admire is applied to the soil.	Admire Pro, 7.0–14.0 fl oz (7)
Japanese beetles	As needed. Note long days-to-harvest limitations on some products.	Sevin 80S, 1.25–2.5 lb or XLR Plus, 1.0–2.0 qt (7), ***or*** Malathion 8F[b], 2.0 pt or 57 EC[b], 1.5 pt (1), ***or*** Actara, 3.0 oz (3), ***or*** Danitol 2.4EC, 10.67–16 fl oz (3), ***or*** Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1)
Green June beetles	Materials effective against Japanese beetles are typically effective for green June beetles. Sevin is the only material currently labeled for June beetles, but the long days-to-harvest limitation is problematic since green June beetles are mainly a problem on ripe fruit. Use of Sevin can also encourage spider mite outbreaks.	Sevin 80S, 2.5 lb or XLR Plus, 2.0 qt (7)
Thrips	If presence is problematic.	Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Provado 1.6F, 8.0 fl oz (3), ***or*** Malathion 8F[b], 2 pt or 57EC[b], 1.5 pt (1), ***or*** Aza-Direct, 16–56 fl oz (0)
Spider mites	Savey and Zeal are effective only against eggs and immatures. Zeal and Savey are in the same chemical class but different subgroups, so whether or not cross-resistance will develop is not yet known. Acramite, Savey, and Zeal are all fairly safe to beneficial predatory mites. Application must be made while mite populations are low. Brigade is effective only at high rates and may increase the likelihood of spider mite population explosions by destroying predatory mites. Insecticidal soaps such as M-Pede may offer some benefit in mite control. Stylet oil is effective against mite eggs.	Acramite 50 WS, 0.75–1.0 lb (1), two applications per year allowed, ***or*** Savey 50WP, 4–6 oz (3), one application per year allowed, ***or*** Zeal Miticide, 2–3 oz (0), one application per year allowed, ***or*** Brigade WSB, 16 oz or 2 EC, 6.4 fl oz (3) see comments, ***or*** Stylet oil, 3–6 qt/100 gal (0)

CONTINUED

Table 8.15. Pesticides for bramble disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
LATE SUMMER/FALL		
Diseases		
Orange rust	Late summer through frost. A second infection period occurs at this time. See text for discussion. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Rally 40W, 1.25–2.5 oz (0), ***or*** Pristine, 18.5–23 oz (0), ***or*** Cabrio EG, 14 oz (0)
Anthracnose	In the fall after old canes are removed. For resistance management, do not make more than two sequential applications of strobilurin (group 11) fungicides before rotating to a fungicide in another chemical class.	Captan 80WDG, 2.5 lb (3), ***or*** Pristine, 18.5–23 oz (0), ***or*** Abound, 6.0–15.5 fl oz (0), ***or*** Cabrio EG, 14 oz (0), ***or*** Tanos, 6–10 oz (0) plus captan, ***or*** Captevate 68WDG, 3.5 lb (3), ***raspberries only***
Insects and Mites		
Japanese beetles	Whenever beetles are causing significant damage.	Sevin 80S, 1.25–2.5 lb or XLR Plus, 1–2 qt (7), ***or*** Assail 70WP, 1.9–2.3 oz or 30SG, 4.5–5.3 oz (1), ***or*** Malathion 8F[b], 1–4 pt or 57ECb, 1.5 pt (1), ***or*** Danitol 2.4EC, 10.67–16 fl oz (3), ***or*** Actara, 3.0 oz (3)
Spider mites	Insecticidal soaps such as M-Pede may offer some benefit in mite control. See additional comments under "Petal Fall through Harvest."	Acramite 50 WS, 0.75–1.0 lb (1). Two applications per year allowed, ***or*** Savey 50WP, 4–6 oz (3). One application per year allowed, ***or*** Zeal Miticide, 2–3 oz (0). One application per year allowed, ***or*** Brigade WSB, 16 oz or 2EC, 6.4 fl oz (3) see comments, ***or*** Stylet oil, 3–6 qt/100 gal (0)
Raspberry crown borer larvae	In early fall. As a drench in at least 200 gal of water/A. Directed to lower canes and soil; see labels for specific restrictions. This drench will only affect new larvae. Because this insect requires more than one year to complete its life cycle and larvae feeding in the crown are not affected, applications will be needed for more than one year.	Brigade WSB, 16 oz or 2EC, 6.4 fl oz (3), ***or*** Hero, 10.3 fl oz (3), ***or***
	In early fall. Direct to base of canes in 50 to 100 gallons of water per acre. Apply when at least ½ inch of rainfall is expected or irrigation will be applied to move insecticide into the root zone.	Altacor, 3.0–4.5 oz (3)
Raspberry crown borer adults	Watch for appearance of adult clear-winged moths after harvest. No materials are specifically labeled for this pest at this time. However, materials with a broad label such as Pyganic, Pyrenone, or Evergreen may help.	
SPECIAL SPRAYS		
Diseases		
Phytophthora root rot	Ridomil Gold SL and Ridomil Gold GR are soil-applied systemic fungicides. Apply to soil surface in a 3-foot band over the row. Make one application in the spring and another in the fall after harvest. Planting on raised beds also significantly reduces phytophthora incidence.	Ridomil Gold GR, 5 lb/1,000 ft of row (45), ***or*** Ridomil Gold SL, 3.6 pt (45), ***or***
	Apply the first foliar spray in the spring when new growth is 1–3 inches long. Reapply on a 45- to 60-day schedule. Phytotoxicity may be an issue with use of phosphorous acid compounds such as Phostrol, especially when applied under high temperatures, when tank-mixed with other materials, and/or when applied on a frequent schedule as with bloom sprays or sprays during harvest.	Aliette 80WDG, 5 lb (60), ***or*** Phostrol, 4.5 pt (—)

CONTINUED

Table 8.15. Pesticides for bramble disease and insect control, continued.

Pest	Timing of Treatment/Comments	Product Labeled Rate/A[a] (Days to Harvest)
Insects		
Spider mites (new plantings)	Savey is effective only against immatures. Application must be made while mite populations are low. Both Acramite and Savey are fairly safe to beneficial predatory mites. Insecticidal soaps such as M-Pede may offer some benefit in mite control. Brigade and Capture must be used at high rates in order to obtain control of spider mites and may increase the likelihood of spider mite population explosions.	Acramite 50WS, 0.75–1.0 lb (1). Two applications per year allowed, ***or*** Savey 50WP, 3–6 oz (3). One application per year allowed, ***or*** Zeal Miticide, 2–3 oz (0). One application per year allowed, ***or*** Brigade WSB, 16 oz or 2 EC, 6.4 fl oz (3) see comments, ***or*** Stylet oil, 3–6 qt/100 gal (0)
Tree crickets	Before or when characteristic egg-laying trails first appear.	Sevin 80S, 1.25–2.5 lb or XLR Plus, 1–2 qt (7)

a. Some pesticides may be phytotoxic to plants. If in doubt, test a small area of the field first. Be sure the sprayer is calibrated properly.

b. Many trade names of malathion are currently available, including Cythion, Malaspray, Malathone, etc. Follow the label for use on bramble crops. Please test a small area before trying a new formulation. Some formulations, especially the emulsifiable concentrates (EC), have caused phytotoxicity on raspberries, particularly in hot weather

Table 8.16. Additional restrictions on bramble pesticides.

The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may be labeled for the same uses. Always consult the label before making pesticide applications.

Abound	For resistance management, do not apply more than two sequential applications of Abound or another strobilurin (group 11) fungicide before alternating with a fungicide that has a different mode of action. See label for several additional resistance management strategies. See Table 8.13 for chemical activity groups of fungicides labeled for use on brambles. Do not allow to drift to McIntosh, Gala, or related apple cultivars (Bancroft, Bromley, Cortland, Cox, Discover, Empire, Jonamac, Kent, Spartan, and Summared). Do not use the same spray equipment for other materials that will be applied to these cultivars, even if thoroughly cleaned.
Acramite 50WS	Do not make more than two applications per year.
Actara	Do not apply more than 6.0 oz of product per acre per season. The minimum interval between application is 7 days.
Admire Pro	Do not apply more than 8.4 fl oz of Admire Pro per acre per season or as specified on the label. Do not apply during bloom or when bees are actively foraging.
Altacor	Do not make more than three applications or apply more than 9.0 ounces of Altacor per acre per season.
Asana XL	Do not apply more than 0.15 lb ai per acre per season.
Assail	Do not make more than 5 applications per season, apply more often than once every 7 days, or exceed a total of 0.5 lb ai per acre per growing season.
Brigade	Do not apply more than 0.2 lb ai per acre per season. One application may be made prebloom and one application made postbloom. Do not make both prebloom foliar and prebloom drench applications.
Cabrio EG	Do not apply more than two sequential applications of Cabrio before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 8.14 for activity groups of insecticides labeled for use on brambles.
Captan 80WDG	Do not apply more than 12.5 lb of 80WDG, or as specified for different formulations, per acre per season.
Captevate 68WDG	Do make more than two consecutive applications of Captevate, or any product containing the active ingredient fenhexamid, before alternating with a fungicide with a different mode of action. Do not apply more than 17.5 lb per acre per season.
Confirm 2F	Do not apply more than 64 fl oz of product per acre per season.
Danitol	Do not make more than two Danitol applications or exceed 32 fl oz per acre per season.

CONTINUED

Table 8.16. Additional restrictions on bramble pesticides, continued.

Delegate	To reduce the potential for resistance development in target pest species, do not make more than 2 consecutive applications of group 5 insecticides (active ingredients of spinetoram or spinosad). If additional treatments are required, rotate to another class of effective insecticides for at least one application. Do not apply more than at total of 19.5 oz of Delegate WG per acre per crop. Do not make more than 6 applications per calendar year or applications less than 4 days apart.
Elevate	Do not make more than two consecutive applications of Elevate. Do not apply more than 6 lb per acre per season.
Hero	Do not make both prebloom foliar and prebloom drench applications. One application may be made prebloom and one application made postbloom. Do not apply more than 27.4 fl oz per acre per season.
Mustang	Do not apply more than 0.3 lb ai (25.8 fl oz of product) per acre per season. Do not make applications less than 7 days apart.
Mustang Max	Do not apply more than 0.15 lb ai (24 oz of product) per acre per season. Do not make applications more than 7 days apart.
Orbit, Tilt	Orbit and Tilt both contain the same active ingredient, propiconazole. Do not apply more than 30 fl oz (0.84 lb of propiconazole) in total of Orbit and Tilt per season. Apply these products in minimum spray volumes of 5 gal/A for ground application and 15 gal/A for aerial application.
Phostrol	Do not make more than four sprays during the growing season.
Pristine	Do not apply more than two sequential applications before alternating with a fungicide with a different mode of action. See label for several additional resistance management strategies. See Table 8.13 for chemical activity groups of fungicides labeled for use on brambles. Pristine may cause injury to foliage of Concord or related grape varieties such as Worden and Fredonia. Do not use Pristine on these varieties and use special care when applying to prevent contact with these sensitive varieties. Thoroughly rinse-spray equipment, including the inside of the tank, hoses, and nozzles after use and before using the same equipment on these sensitive grape varieties.
Provado	Do not apply more than 24 fluid ounces of Provado 1.6F per year. The minimum interval between applications is 7 days. Do not apply prebloom or when bees are actively foraging.
Rally 40W	Apply no more than 10 oz of Rally per acre per year.
Rovral	Do not make more than four applications per season.
Savey 50WP	Limited to one application of Savey per year.
Sevin	Do not apply more than five times, or more often than once every 7 days.
Spintor, Entrust, Success	Do not apply more than a total of 0.45 lb ai of spinosad per acre per crop. Do not make more than 6 applications per year. Do not make applications less than 5 days apart. Whenever Spintor (or Success or Entrust) is applied two times in succession, this should be followed by rotation to another insecticide class for at least one application.
Switch 62.5WG	Do not exceed 56 oz of Switch per acre per year. Do not make more than two applications before using a fungicide in another resistance management group.
Tanos	Do not make more than one application before alternating with a fungicide with a different mode of action. Apply in a minimum of 20 gallons of spray per acre. Do not apply more than 72 oz of product per acre per cropping season. The minimum interval between applications is 5 days.
Zeal Miticide	Do not make more than one application per growing season or use with an adjuvant.

WEEDS

Because blueberry and brambles are both perennial crops, weed management practices and problem weeds are very similar with a few exceptions. See Chapter 4: Weed Control for a discussion of the importance of weed identification and various categories of weed types, cultural practices that minimize weed pressure, a discussion on types of herbicides, how they work, correct application techniques, and factors that influence herbicide effectiveness. See the weed management section of Chapter 7: Blueberries for information on controlling weeds between rows, including the establishment and management of sod row middles, and discussions on cultural and chemical methods of managing specific problem weeds that are likely to become problematic in blueberry fields. As mentioned above, because brambles are perennial, problematic weeds are similar in both situations, though controls may vary between crops.

WEED CONTROL BETWEEN ROWS

A permanent sod such as hard fescue between the rows is effective in controlling weeds in established plantings. Cultivation or herbicide use will be required if a sod row middle is not used. These topics are discussed in detail in Chapter 7.

Practices for Minimizing Weed in Rows

In the row, a weed free zone should be maintained where weed competition with the crop is paramount. Control in-row weeds with mulches and/or herbicides. The use of mechanical cultivation equipment in the row is seldom recommended due to risk of damaging the roots.

The width of the weed-free zone should be about 36 to 48 inches wide, or about 18 to 24 inches on each side of the row. This weed-free strip should be about 40 percent of the distance between the rows. The width may vary, however, depending on soil fertility, water-holding capacity, and exposure to erosion. Do *not* reduce the width of the weed-free zone in young nonbearing fields. Maintain the full width of the vegetation-free zone in new plantings to achieve maximum growth.

In-Row Sod before Planting

Excellent results have been obtained by seeding perennial grass in the row as well as between the rows. Use perennial ryegrass rather than fescue. Rapid establishment and growth and susceptibility to herbicides make perennial ryegrass a better choice than fescue for seeding in the row. Kill the sod in the row before planting and no-till the plants into the dead sod. Use recommended herbicides to control weeds. The sod's roots increase soil organic matter and improve soil structure and water permeability, and the sod acts as a mulch to conserve water and prevent erosion during the establishment year. By fall, the dead sod deteriorates and is not attractive to rodents.

MULCHING AND CULTURAL METHODS

In bramble plantings, tissue-cultured plants are frequently preferred when available. However, many labeled herbicides will injure tissue-cultured raspberry plantlets; therefore, we recommend applying a 4-inch straw mulch or plastic mulch around tissue culture–propagated plants after planting for controlling weeds the first year. Weeds should be removed by hand as often as required to prevent weeds from becoming established. Cultivation should be shallow and done carefully to avoid damaging established plants. Do not continue straw mulching past the first year on wet sites since this practice can exacerbate root rot injury and cause slug infestation. Where nontissue-cultured plants are used (nursery-matured or dormant canes), consider applying one of the preemergence herbicides listed in Table 8.20 after the soil has settled (after irrigation or rainfall), according to labeled rates. These herbicides require ½ to 1 inch of irrigation following application to activate them.

Plastic mulch—and preferably landscape fabric—can be used for controlling weeds in bramble plantings. See "Planting and Establishment—Mulching" in this chapter for details.

HERBICIDES

Choose herbicides for use in the row that are labeled, have adequate crop safety (Table 8.17), and control the weeds in your field (see Table 4.1). The use of a single herbicide repeatedly will lead to an increase in resistant weeds. Use herbicide combinations, herbicide rotations, and sequential or spot treatments in a well-managed weed control program to eliminate or minimize problems. The recommended herbicides covered below have been evaluated for crop safety and effectiveness. Information on all varieties is incomplete. Use herbicides with care on new varieties.

Table 8.17. Crop safety of bramble herbicides.

	New (Nonbearing)	Established (Bearing)
Preemergence, Residual		
Casoron/Norosac	?	G
Devrinol	G	G
Gallery	G	—
Princep	—	F/G
Sinbar	—	F
Snapshot	?	—
Solicam	F/G	G
Surflan	G	G
Postemergence, Selective		
Fusilade DX	G	—
Poast	G	G
Select/Select Max	G	—
Postemergence, Nonselective		
Paraquat products	G	G
Glyphosate products*	G	G

G = good; F = fair (recommended; use with care); P = poor (not recommended); ? = labeled (insufficient data); — = not labeled (do not use)

*Do *not* allow spray to contact young or green (living) canes or leaves.

Remember that weeds also compete with one another besides competing with your crop. Thus, controlling a particular weed or group of weeds may allow other weed species to take over. A combination of two preemergence herbicides gives better weed control than a single herbicide. Combining a "grass herbicide" with a "broadleaf herbicide" results in wider-spectrum control. Consult the label and Table 8.20 for compatible tank mixes.

Herbicide Terminology

Understanding herbicide terminology is important in order to effectively use herbicides and avoid undesirable consequences from herbicide application.

Residual herbicides remain in the soil and kill weeds for up to several months. They are applied before weeds germinate. Weeds begin to compete with most crops within 2 to 4 weeks. Some products are effective only on germinating seeds. If weeds are present, a postemergence herbicide can be combined with a residual herbicide. Residual herbicides are applied incorporated or preemergence.

Incorporated herbicides are mechanically mixed with the soil. This application method is *not* well suited to brambles. It is difficult or impossible to incorporate herbicides near the crown of the bramble plant, and shallow roots may be pruned by the incorporation equipment.

Preemergence herbicides are applied to the soil surface, and are used to prevent weeds from establishing before they emerge from the soil, not to prevent weeds from germinating. Labels often state that preemergence herbicides must be "activated by cultivation or irrigation." As mentioned above, cultivation is not a recommended practice for incorporating herbicides in brambles. However, rainfall or overhead irrigation is needed to move the herbicide into the soil before the weeds emerge, and ideally, just into the zone of weed seed germination. Use a preemergence herbicide in combination with a postemergence herbicide if weeds have emerged, unless the preemergence herbicide also controls weeds postemergence. Of preemergence herbicides labeled for brambles, Devrinol and Surflan work by inhibiting cell division. Casoron inhibits cellulose biosynthesis and also controls emerged plants of certain weed species. Princep and Sinbar work by inhibiting photosynthesis. Solicam inhibits carotenoid synthesis, which exposes chlorophyll to damage by sunlight. Sinbar, besides inhibiting photosynthesis of geminating weeds, also kills recently germinated weeds (those just at the cotyledon stage). Repeatedly using herbicides that act on weeds with the same mode of action may lead to weed populations that are resistant to those herbicide(s).

Postemergence herbicides are used after weeds have emerged from the soil. They are used by carefully applying the herbicide to the weeds without allowing it to contact desirable plants that could be affected, such as caneberries or sod row middles. The best time to apply postemergence herbicides is when weeds are growing rapidly. Do not treat weeds that are dormant or under stress. Most herbicides that enter the plant through the leaves need a minimum rain-free period of at least 1 to 8 hours after application for maximum effectiveness. Postemergence herbicides may be *selective* or *nonselective*. Selective postemergence herbicides kill only certain susceptible weeds. Poast, Select, and Fusilade DX are examples that kill only grasses, and will not control broadleaf weeds or harm the brambles. Nonselective postemergence herbicides kill or injure any treated plant. They may be *contact* or *translocated*. Contact herbicides (Gramoxone Inteon, Scythe) affect only the plant tissue with which they come in contact. Thorough spray coverage is essential for good results. Roots of established annual weeds and perennial weeds often survive. Translocated herbicides (glyphosate products, Fusilade, Poast, Select) move systemically in the weed (or crop plant if contacted) after treatment. Application at the proper growth stage will often result in good control of the roots as well as tops of established annuals and perennial weeds. Results of translocated herbicides may not be evident for several days or weeks.

Herbicides have no activity after application for one of two reasons. Some herbicides are too tightly bound to the soil to be available to plants after application. Care must be exercised in soilless growing environments, where surprising residual activity can be observed from these herbicides. Other herbicides are highly soluble in water and are not bound to soil particles. Residual activity from these herbicides can be observed in the soil, but it often lasts only a few days. They are rapidly leached out of the zone of weed seed germination and degraded by soil microorganisms. See Table 8.18 for solubility and soil absorption characteristics of bramble herbicides. A complete discussion of the

Table 8.18. Bramble herbicide water solubility and soil adsorption characteristics.

	Solubility	Soil Adsorption
Residual Herbicides		
Casoron/Norosac (dichlobenil)	Low	Moderate
Devrinol (napropamide)	Moderate	Strong
Gallery (isoxaben)	Very low	Strong
Princep (simazine)	Very low	Moderate
Sinbar (terbacil)	Moderate	Weak
Solicam (norflurazon)	Low to moderate	Strong
Surflan (oryzalin)	Very low	Strong
Nonresidual Herbicides		
Fusilade DX (fluazifop-P-butyl)	Very low	Very strong
glyphosate products	Very high	Very strong
paraquat products	Very high	Very strong
Poast (sethoxydim)	Moderate to very high[a]	Moderate
Select products (clethodim)	Not available	Weak

Source: Weed Science Society of America (2002), *Herbicide Handbook*, 8th ed. *Controlling Weeds in Nursery and Landscape Plantings (*2007), Penn State College of Agricultural Sciences.

a. pH dependent.

effects that trickle irrigation can have on increasing weed growth under the trickle line, as related to this subject, is included in Chapter 4: Weed Management.

Glyphosate products, including Roundup products, Touchdown products, Glyphomax Plus, and others, and paraquat products, including Gramoxone Inteon, Firestorm, and others, are too tightly bound to the soil to have residual activity. These herbicides are completely unavailable to plants after application in field production. They remain tightly bound to the soil until broken down. Glyphosate can be degraded or digested by soil microorganisms. However, residual activity from glyphosate has been observed when used in greenhouses, on plastic mulch, and near hydroponic growing systems. Paraquat is degraded by sunlight, and is less likely to cause problems when used on plastic mulch, in greenhouses, or near soilless growing systems.

Herbicide Rate Control

Strict rate control is necessary. Improperly applied herbicides or herbicides applied above recommended rates may cause damage to brambles. Using rates that are too low will result in a lack of efficacy, or short duration of control. Residual herbicide rates must be matched with soil type and percentage of organic matter to obtain good weed control and crop safety (see Table 8.19). Determine type and percentage of organic matter for each soil on the farm with a separate soil test.

Most coarse textured soils, such as loamy sands and sandy loams, are low in organic matter, often less than 2 percent. Medium textured soils, such as loams, may have 2 to 4 percent organic matter. Fine textured soils such as silt loams and clay loam soils may have 4 to 8 percent organic matter. Have your soil analyzed for percent organic matter. This is a separate test that must be requested from most soils laboratories. If your soil has an organic matter content higher than the choices listed on the herbicide label for your soil texture, choosing the correct rate may be difficult. See Table 8.19 for recommended rates of specific herbicides for various soil types and organic matter levels. Consult your Cooperative Extension service office for assistance in determining the correct herbicide rate to use on your soil if needed. Adjust by changing tractor speed and maintaining pressure when spraying a field with soil that requires different herbicide rates. Herbicide application and equipment is discussed in Chapter 4.

Herbicide Use in New Plantings

Weed control in a newly planted field should be planned to provide a maximum margin of crop safety. Tillage and/or herbicides prior to planting should control established biennial and perennial weeds. Apply a combination of herbicides to control annual grasses and broadleaf weeds. Devrinol plus Gallery 75DF or Surflan plus Gallery 75DF have been safe and effective residual herbicide combinations for newly planted brambles. Apply in early spring after the soil has settled the soil around the roots of the new plants, but before weeds emerge or the brambles break bud. Waxed paper "milk cartons" are effective and recommended shields. The use of shields adds an additional margin of safety when installed prior to herbicide application.

Table 8.19. Per-acre rates per application for preemergence (residual) herbicides for common soil types for raspberries and blackberries.

Rates for each active ingredient are followed by the corresponding rates of a commonly available product containing the active ingredient listed.

	Soil Type / % Organic Matter												
	Sand		*Loamy Sand*		*Sandy Loam*			*Loam*		*Silt Loam*		*Clay Loam*	
Herbicide	0–1	1–2	0–1	1–2	0–1	1–2	2–4	1–2	2–4	1–2	2–4	1–2	2–4
Napropamide (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Devrinol 50DF (lb)[a]	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8	4–8
Isoxaben (lb ai)[b]	0.75	0.75	0.75	0.75	0.75	0.75	1	0.75	1	1	1	1	1
Gallery 75DF (lb)[b]	1.0	1.0	1.0	1.0	1.0	1.0	1.33	1.0	1.33	1.33	1.33	1.33	1.33
Diclobenil (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Casoron CS (gal)[a]	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8	1.4–2.8
Simazine (lb ai)[b]	—	—	—	—	—	2	2	2	3	2	3	3	4
Princep 90DF (lb)[b]	—	—	—	—	—	2.2	2.2	2.2	3.3	2.2	3.3	3.3	4.4
Terbacil (lb ai)[b]	—	—	—	—	—	1	1.2	1.2	1.6	1.6	1.6	1.6	1.6
Sinbar 80WDG (lb)[b]	—	—	—	—	—	1.25	1.5	1.5	2	2	2	2	2
Norflurazon (lb ai)[b]	—	—	—	2	—	2	2.5	2.5	2.5	2.5	3	3	4
Solicam 80DF (lb)[b]	—	—	—	2.5	—	2.5	3.0	3.0	3.0	3.0	3.75	3.75	5
Oryzalin (lb ai)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
Surflan 4AS (qt)[a]	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4

a. Use the lower recommended rate when tank-mixing with another preemergence herbicide, unless annual grass pressure is severe.

b. Use one-half the recommended rate when tank-mixing with another preemergence herbicide.

— = not labeled or not recommended (do not use).

An alternative to shields is the use of granular formulations when available. Granular formulations fall through the bramble canopy to the soil surface, provided applications are made when the foliage and shoots are dry. The use of nonselective postemergence herbicides such as a paraquat or glyphosate product should be avoided during the year of planting unless shields are in place. Avoidance of contact of these products with the plant is critical.

Herbicide Use in Established Plantings

Apply herbicides to the bramble row in established fields in late fall and also in late spring. Herbicides are applied in late fall or when the soil temperature has dropped to between 40 and 50 degrees to control winter annuals, certain perennials, and early season summer annuals. The spring herbicide application extends summer annual weed control through harvest.

Late fall herbicide applications should all include a residual broadleaf herbicide. Use Princep to control winter annual broadleaf weeds. Consider using Princep in combination with a residual annual grass herbicide. Small seedling annual broadleaf weeds will be controlled by the residual herbicide, but if well-established annuals are present, add a postemergence herbicide such as a paraquat product to the tank. Spot treat with a labeled glyphosate product if perennial weeds are present, preferably in the fall.

When perennial broadleaf weeds are present in addition to annual weeds, use Casoron instead of Princep. Apply when the soil is not frozen in late fall/early winter to control labeled perennial, biennial, and annual weeds or in late winter/early spring before weed growth begins and daily high temperatures exceed 50°F. Perennial weed control following late winter/early spring applications has been less consistent than late fall/early winter applications. Casoron/Norosac is volatile in warm temperatures and must be irrigated or mechanically incorporated after application. Significant herbicide loss may occur if applied in warm weather.

The use of a grass herbicide in the fall depends on the product chosen. Solicam 90DF, Surflan 80WP, and Devrinol 50DF are annual grass herbicides that should be applied in late fall or as a split application—half in the fall and the second half in the spring. Use the split application when grass pressure is heavy for best results. The use of these herbicides in spring only has resulted in inconsistent weed control when dry weather followed the application.

Sinbar 80WDG applications for annual weed control should be applied only in the spring. The relatively high solubility of Sinbar 80WDG results in leaching when applied in the fall. Increased risk of crop injury and poor weed control can result.

In follow-up late spring applications, apply Sinbar 80WDG or the second half of a split herbicide treatment of Solicam 80DF, Surflan 80WP, or Devrinol 50DF for annual grass control. Include a paraquat product if seedling annual weeds are observed. Spot treat with a labeled glyphosate product to control established perennial grasses and broadleaf weeds. Sinbar 80WDG is also effective for seedling weed control postemergence. No other postemergence herbicide may be needed if no established weeds are present and seedling annual weeds are sprayed with Sinbar before they exceed 1 inch in height. See Table 8.20 for a complete listing of recommended herbicides and timings at which they can be used.

PROBLEM WEEDS

Especially in perennial crops, certain problem weeds can become well-established since the field is not worked after crop establishment, and herbicides may have limited or no effectiveness at this point. Many of the weeds that are likely to become problematic are discussed in Chapter 7, along with their life cycle, and cultural and chemical means for management. Many of the herbicides as discussed in the blueberry chapter under "Problem Weeds" are labeled at the identical rates for use in brambles. However, there are some notable exceptions, especially with postemergent nonselective translocated herbicides, such as glyphosate products. Because suckers and canes are often connected to each other through their root system, damage can be more widespread than expected when canes are contacted. For this reason, recommendations vary between crops. See Table 8.20 for labeled herbicide use patterns on brambles.

Table 8.20. Herbicides for bramble weed control.

Note: See text discussion for additional discussion on timing and use of various herbicides in this chapter and Chapter 4. See Table 4.1 for efficacy ratings of herbicides on various weeds. See Table 3.2 for limits on states in which these cannot be used, use status (general vs. restricted), days-to-harvest limitations, and reentry intervals. The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist that may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Information was current as of July 1, 2012.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
NEW PLANTINGS			
Preemergence			
Primarily for annual grasses; suppresses or controls certain annual broadleaf weeds	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or reduced rates of Princep or Sinbar in the spring, if the planting has been established for at least one year to control annual broadleaf weeds. Activate with one-half inch sprinkler irrigation within 24 hours after application. If left on the soil surface, napropamide (Devrinol) is broken down by sunlight. Irrigation moves the herbicide into the soil and prevents breakdown by the sun.	Napropamide, 2.0–4.0 lb	Devrinol 50DF, 4.0–8.0 lb (—)
Primarily for annual broadleaf weeds	Apply in late fall or early spring to weed-free soil to control many broadleaf weeds. If newly planted, allow the soil to settle and fill any depressions around the plant before application. Add a postemergence herbicide to improve the control of emerged weeds. Gallery primarily controls annual broadleaf weeds. Tank-mix with Surflan to control annual grasses. Note: Gallery is not labeled for bearing brambles.	Isoxaben, 0.75–1.0 lb	Gallery 75DF, 1.0–1.33 lb (365)
Primarily for annual broadleaf weeds	Add nonionic surfactant to be 0.25% of the spray volume, or 1 qt per acre crop oil concentrate. Apply in early spring before bud break as a spray directed toward the base of the bush. Broadleaf weeds controlled include horseweed and common lambsquarter. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improved annual grass control. Do not apply more than 6 fl oz of Callisto per acre within one year.	Mesotrione, 1.5–3.0 oz	Callisto 4F, 3–6 fl oz (prebloom)
Primarily for annual grasses	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall, or Sinbar in the spring, if the planting has been established for at least one year, to control annual broadleaf weeds.	Oryzalin, 2.0–4.0 lb	Surflan 4AS, 2.0–4.0 qt (—)

CONTINUED

Table 8.20. Herbicides for bramble weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergence—Selective			
Primarily for annual grass control; may provide partial control of many broadleaf weeds	Note: Planting must have been in the ground for at least 12 months before application in order for this material to be used. Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix with Princep plus a postemergence herbicide in late fall, or Sinbar in the spring, if the planting has been established for at least one year, to improve the control of broadleaf weeds.	Norflurazon, 2.0–4.0 lb	Solicam 80DF, 2.5–5.0 lb (60)
Emerged annual grasses and perennial grasses, depending on rate (see information in column to right)	Add 2 pints crop oil concentrate or nonionic surfactant to be 0.25 percent of the spray solution (1 qt per 100 gallons of spray solution). Use the lower rate on most annual grasses less than 6 inches tall and to control johnsongrass. Use the higher rate to control other perennial grasses, crabgrass, and annual grasses more than 6 inches tall. Do not tank-mix Fusilade DX 2EC with any other pesticide. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Fluazifop-P-butyl, 0.18–0.38 lb	Fusilade DX 2EC, 12.0–24.0 fl oz (365)
Emerged annual grasses	Use the lower rate to control annual grasses less than 6 inches tall. Use the higher rate to control annual grass 6 to 12 inches tall and to control perennial grasses. Do not tank-mix Poast with any other pesticide. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Sethoxydim, 0.2–0.5 lb	Poast 1.5EC, 1–2.5 pt, plus 2 pints crop oil concentrate per acre (45)
Most grass weed species, including certain hard to control grass weeds, such as small grain volunteers and cover crops, and perennials such as hard fescue, tall fescue, bermudagrass, orchardgrass, quackgrass, johnsongrass, and wirestem muhly	Use the lower rate to control annual grasses and the perennial grasses listed to the left. Repeat the application if regrowth occurs. Always add oil concentrate to be 1 percent of the spray solution, or a minimum of 1 pint per acre, to Select 2EC. Always add oil concentrate to be 1 percent of the spray solution, or a minimum of 1 pint per acre, or nonionic surfactant to be 0.25 percent of the spray solution to Select Max. Do not tank-mix with any other pesticide unless labeled. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition. *Select 2EC is currently labeled for nonbearing fields only.* Do not apply within 12 months of harvest.	Clethodim, 0.072–0.125 lb	Select 2EC, 6.0–8.0 fl oz (365), ***or*** Select Max 0.97EC, 9.0–16.0 fl oz (7)

CONTINUED

Table 8.20. Herbicides for bramble weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Postemergence—Nonselective			
Annual weeds	Contact killer only; with no translocation or residual activity. Best results occur when weeds are 2 inches tall or less. Regrowth may occur from the root systems of established weeds. Use a surfactant to be 0.25 percent of the spray solution (1 qt per 100 gallons of spray solution). Combine with recommended preemergence herbicide(s) for residual weed control. Do not allow spray or drift to contact green canes, leaves, or fruit. Crop damage may result. The use of shields, such as grow tubes or paper milk cartons greatly reduces the risk of injury in young plantings. ***Danger: Do not breathe spray mist. Read safety precautions on the label.***	Paraquat, 0.5–1.0 lb	Gramoxone Inteon, 2.0–4.0 pt (—), ***or*** Firestorm 3SC, 1.3–2.7 pt (—)
Annual and perennial weeds	Glyphosate is a translocated, slow-acting herbicide with no soil or residual activity. Results will become evident 1 to 3 weeks after application. Apply lower rates to control seedlings and annual weeds and to suppress established perennial weeds. Use shields and do not allow glyphosate to contact the foliage or green shoots. Optimum rate and time of application depend on weed species and growth stage. Weeds should be growing vigorously when treated. Do not treat weeds that are under stress from drought, extreme heat, cold, or other adverse growing conditions. When using a ropewick applicator, fill the pipe only half full to avoid excessive dripping. Repeated wiping may be needed to provide control equal to broadcast or spot applications. A ropewick applicator offers significant herbicide cost savings. ***Warnings***: (1) Do not allow glyphosate to contact the leaves, young green tissue, fresh cane wounds, or root suckers, or severe crop injury may occur. (2) Do not allow glyphosate to contact any immature part of bramble plants. (3) Do not use galvanized containers; glyphosate may react with the container to produce explosive hydrogen gas.	Glyphosate—no per-acre broadcast rate recommended	Roundup, Touchdown, or other labeled formulations (14). Broadcast applications not recommended in brambles. For spot applications, see label and wet foliage thoroughly. Ropewick Applicator: See label for product/water ratio. One gallon of product will treat 10–100 acres depending on weed density and formulation.
ESTABLISHED PLANTINGS			
Preemergence			
Primarily for annual grasses, suppresses or controls certain annual broadleaf weeds	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or reduced rates of Princep in the spring, or Sinbar in the spring if the planting has been established for at least one year to control annual broadleaf weeds. Activate with one-half inch sprinkler irrigation within 24 hours after application. If left on the soil surface, napropamide (Devrinol) is broken down by sunlight. Irrigation moves the herbicide into the soil and prevents breakdown by the sun.	Napropamide, 2.0–4.0 lb	Devrinol 50DF, 4.0–8.0 lb (—)

CONTINUED

Table 8.20. Herbicides for bramble weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Labeled perennial, biennial, and annual weeds	Apply in late fall/early winter to control labeled perennial, biennial and annual weeds or in late winter/early spring before weed growth begins and daily high temperatures exceed 50°F to control labeled annual weeds. Perennial weed control following late winter/early spring applications has been less consistent than late fall applications. Casoron/Norosac is volatile in warm temperatures and must be irrigated or mechanically incorporated after application. Significant herbicide loss may occur if applied in warm weather.	Diclobenil, 2.0–4.0 lb	Casoron/Norosac 4G, 50–100 lb (—), ***or*** Casoron CS, 1.4–2.8 gal (—)
Primarily for annual broadleaf weed control	Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix at 1.0–2.0 lb ai (1.1–2.2 lb of Princep 90DF) depending of soil texture and organic matter with Surflan, Solicam, or Devrinol. This rate is one-half the labeled Princep rate for use alone for each soil type. Tank-mixing will improve crop safety and the range of weeds controlled.	Simazine, 1.0–4.0 lb	Princep 90DF, 1.1–4.4 lb (—)
Primarily for annual broadleaf weeds	Add nonionic surfactant to be 0.25% of the spray volume, or 1 qt per acre crop oil concentrate. Apply in early spring before bud break as a spray directed toward the base of the bush. Broadleaf weeds controlled include horseweed and common lambsquarter. Tank-mix with an appropriate postemergence herbicide for broad-spectrum control of emerged weeds. Tank-mix with a residual grass herbicide to improved annual grass control. Do not apply more than 6 fl oz of Callisto per acre within one year.	Mesotrione, 1.5–3.0 oz	Callisto 4F, 3–6 fl oz (prebloom)
Controls many annual broadleaf weed species, but may be weak on pigweed species	Apply in the spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix using terbacil at 0.4 to 0.8 lb ai/A (Sinbar 80WP at 0.5–1.0 lb/a), depending on soil texture and organic matter, with Surflan, or Devrinol. Tank-mixing will improve crop safety and the range of weeds controlled.	Terbacil, 0.8–1.6 lb	Sinbar 80WDG, 1.0–2.0 lb (—)
Primarily for annual grass control; may provide partial control of many broadleaf weeds	Apply in late fall or spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Tank-mix with Princep plus a postemergence herbicide in late fall, or Sinbar in the spring, if the planting has been established for at least one year, to improve the control of broadleaf weeds.	Norflurazon, 2.0–4.0 lb	Solicam 80DF, 2.5–5.0 lb (60)

CONTINUED

Table 8.20. Herbicides for bramble weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Primarily for annual grasses	Apply in late fall and/or early spring to weed-free soil, or add an appropriate postemergence herbicide to kill existing vegetation. Use the high rate for long-term control (4 to 8 months) and the low rate for short-term control (2 to 4 months). Tank-mix with Princep plus a postemergence herbicide in late fall or Sinbar in the spring, if the planting has been established for at least one year, to control annual broadleaf weeds.	Oryzalin, 2.0–4.0 lb	Surflan 4AS, 2.0–4.0 qt (—)
Postemergence—Selective			
Emerged annual grasses	Use the lower rate to control annual grasses less than 6 inches tall. Use the higher rate to control annual grass 6 to 12 inches tall and to control perennial grasses. Do not tank-mix Poast with any other pesticide. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Sethoxydim, 0.2–0.5 lb	Poast 1.5EC, 1–2.5 pt, plus 2 pints crop oil concentrate per acre (45)
Most grass weed species, including certain hard-to-control grass weeds, such as small grain volunteers and cover crops, and perennials, such as hard fescue, tall fescue, bermudagrass, orchardgrass, quackgrass, johnsongrass, and wirestem muhly	Use the lower rate to control annual grasses and the perennial grasses listed to the left. Repeat the application if regrowth occurs. Always add oil concentrate to be 1 percent of the spray solution, or a minimum of 1 pint per acre, or nonionic surfactant to be 0.25 percent of the spray solution to Select Max. Do not tank-mix with any other pesticide unless labeled. Do not apply within 1 hour of rainfall. Do not apply to grasses suffering from drought, heat, cold, or any other stress condition.	Clethodim, 0.072–0.125 lb	Select Max 0.97EC, 9.0–16.0 fl oz (7)
Postemergence—Nonselective			
Annual weeds	Contact killer only; with no translocation or residual activity. Best results occur when weeds are 2 inches tall or less. Regrowth may occur from the root systems of established weeds. Use a surfactant to be 0.25 percent of the spray solution (1 qt per 100 gallons of spray solution). Combine with recommended preemergence herbicide(s) for residual weed control. Do not allow spray or drift to contact green canes, leaves, or fruit. Crop damage may result. The use of shields, such as grow tubes or paper milk cartons greatly reduces the risk of injury in young plantings. ***DANGER: Do not breathe spray mist. Read safety precautions on the label.***	Paraquat, 0.5–1.0 lb	Gramoxone Inteon, 2.0–4.0 pt (—), ***or*** Firestorm 3SC, 1.3–2.7 pt (—)

CONTINUED

Table 8.20. Herbicides for bramble weed control, continued.

Weeds	Timing of Treatment/Comments	Active Ingredient Rate/A[a]	Product Rate/A (Days to Harvest)[b]
Annual and perennial weeds	Glyphosate is a translocated, slow-acting herbicide with no soil or residual activity. Results will become evident 1 to 3 weeks after application. Apply lower rates to control seedlings and annual weeds and to suppress established perennial weeds. Use shields and do not allow glyphosate to contact the foliage or green shoots. Optimum rate and time of application depend on weed species and growth stage. Weeds should be growing vigorously when treated. Do not treat weeds that are under stress from drought, extreme heat, cold, or other adverse growing conditions. When using a ropewick applicator, fill the pipe only half full to avoid excessive dripping. Repeated wiping may be needed to provide control equal to broadcast or spot applications. A ropewick applicator offers significant herbicide cost savings. ***Warnings:*** (1) Do not allow glyphosate to contact the leaves, young green bark, fresh trunk wounds, or root suckers, or severe crop injury may occur. (2) Do not allow glyphosate to contact any immature part of bramble plants. (3) Do not use galvanized containers; glyphosate may react with the container to produce explosive hydrogen gas.	Glyphosate—no per acre broadcast rate recommended	Roundup, Touchdown, or other labeled formulations (14). Broadcast applications not recommended in brambles. For spot applications, see label and wet foliage thoroughly. Ropewick Applicator: See label for product/water ratio. One gallon of product will treat 10–100 acres depending on weed density and formulation.

a. Adding a surfactant to these herbicides may improve their effectiveness (see labels). Rates are given in units of commercial product per acre.
b. No days-to-harvest limitation is specified on the label if days-to-harvest is listed as (—).

ADDITIONAL NOTES

- All the rates in this table are given on a full-acre basis. If the material is to be banded along or over the row, use the following formula to calculate the banding rate: rate/A banded = rate/A broadcast x (band width in inches ÷ row spacing in inches).
- With all chemicals, follow label instructions and warnings carefully.
- Use pesticides safely. Consult label for restriction.
- It is unlawful to use recommended chemicals for crops not covered on the label or to use chemicals not cleared for such use on blueberry plantings.
- Formulations, other than those listed, with the same active ingredient may be labeled for the same uses.

CHAPTER 9

Gooseberries and Currants

CONTENTS

Introduction 225
Types of Plants 225
Currants 225
Gooseberries 225
Jostaberries 226
Legality of Culture 226
Culture 226
General 226
Site Selection 226
Soils 227
Cultivars 227
Site Preparation 229
Spacing and Planting Systems 230
Obtaining Plants 230
Planting 230
Establishment 230
Cultivation and Mulching 230
Fertility 230
Notes on Sod Row Middles 231
Irrigation 231
Pollination Considerations 231
Pruning and Training 231
Harvest 232
Propagation 232
Pest Management 232
Diseases 232
Insects 234
Weeds 235

INTRODUCTION

Decisions to commercially produce specialty small fruit crops such as gooseberries and currants should be driven by availability of market outlets for the fruit. A market should be secured before plants are set in the ground. Fresh fruit sales are options for direct marketers, though most consumers are unfamiliar with the fruit and their uses. Consequently, processing the crop into jams, jellies, fresh juice products, and wine may be the best way to utilize these crops. In Europe, significant fresh and processing markets exist, which may be an indication of the undeveloped market potential in this country. Growers near populations of people who are already familiar with the crop may have a ready market.

Successfully producing these unique fruit involves knowledge of cultivars, their horticultural characteristics and requirements, and successful pest management.

TYPES OF PLANTS

Currants and gooseberries are two closely related species within the genus *Ribes*. This genus is diverse with more than 150 known species and hundreds of cultivated varieties (cultivars). Currants and gooseberries can be easily distinguished by the presence or absence of thorns; gooseberries usually have thorns, while currants do not.

Ribes plants are long-lived perennial shrubs that are cold-hardy, some to USDA Zone 2. Species and cultivars vary in plant size and form but are usually upright to spreading in habit (3 to 6 feet). Disease and insect resistance is variable. The fruit is versatile and nutritious and varies in presentation, flavor, shape, size, texture, and color.

CURRANTS

Most cultivated currants are of European origin, though many native North American species also exist. Currant color types include red, white, pink, and black. Plants are thornless and fruit is small (pea sized) and produced and harvested in a grapelike cluster called a "strig." Cultivars may be classified under several species; however, keep in mind that some debate exists as to which species different types of plants belong. Species are *Ribes rubrum* (most red currants and some whites), *R. petraeum* (white), *R. vulgare* (pink, white, and red), and *R. nigrum* and *R. ussurienses* (black). Native currants, sometimes considered more closely related to gooseberries, belong to the species *R. odoratum*, the Buffalo Currant, with some selections known as Clove Currant (for example, the cultivar Crandall) because of the fragrance of their blossoms. Because of their tart flavor, currants are seldom eaten out of hand but are used for processing into juices, jams, and jellies. Black currants are noted for their strong (to some, offensive) odor and astringent flavor, yet they are highly prized in Europe for juice products and their high nutrient content. Vitamin C concentrations can be as high as 250 milligrams per 100 grams of juice, even after 6 months of storage.

GOOSEBERRIES

Cultivated forms of gooseberries are divided into two major types, European (*Ribes grossularia* var. *uva-crispa*) and American (*R. hirtellum)*. European types are native to North Africa and the Caucasus Mountains of eastern Europe and western Asia, while the American types are native to the northern United States and Canada. Within the European types, fruit size varies widely, from pea sized to small egg sized. Color varies widely as well, with fruit colors in shades of green, pink, red, purple, white, and yellow. This diversity is due to the historical popularity of the European gooseberry. Over the past two centuries, hundreds of cultivars have been developed with a focus on prize-winning fruit size and color.

Native American gooseberry species have smaller fruit size and less flavor, but they are more resistant to diseases when compared to European cultivars, which are noted for powdery mildew and leaf spot susceptibility. This problem has limited the culture of most of the European types in this country. However, disease resistance is improving through additional breeding with American types, and several new promising European cultivars have recently been introduced in the United States and Canada. In comparison, most

known American cultivars in the trade today have had some historical infusion of European genetics to improve size and flavor, which can be traced to a handful of crosses made in the 1800s. All gooseberry cultivars have varying degrees of thorniness. Fruit is produced in small groups or singularly on stems and are picked individually.

JOSTABERRIES

Lastly, the jostaberry is an interspecies cross between gooseberries and black currant. Its fruit is larger than currants, similar to gooseberries, and black in color. The stems are thornless. Fruit quality has not gained wide appeal for either fresh or processed use, but it has inspired renewed breeding efforts, with new and improved crosses being developed. It has a vigorous growth habit and is resistant to white pine blister rust. Disease (mildew) resistance is similar to that of black currants.

LEGALITY OF CULTURE

The history of *Ribes* production in America is of significant interest. Cultivated currants and gooseberries were first introduced in America in the Massachusetts Bay colony in 1629. By the mid-1800s commercial acreage of currants and newly developed European and American gooseberry crosses such as Downing and Houghton were common in the eastern United States. In 1899, reported production in the United States reached nearly 7,000 acres. In the early 1900s, *Ribes* species were implicated in the spread of white pine blister rust (*Cronartium ribicola*), a devastating disease for white pine trees brought into this country on imported nursery tree stock.

Ribes, especially black currants, are a secondary host to this disease, which requires both pine and *Ribes* to complete its life cycle. Red and white currants and gooseberries exhibit varying degrees of susceptibility. In 1912, federal and state governments introduced restrictions on importing, planting, and cultivating *Ribes* species to protect the lucrative timber industry. Soon after, a sweeping federal law was passed banning only black currants, while some northern states passed outright bans on all *Ribes* species. A program of eradication of both native stands and domestic plantings was begun, with Civilian Conservation Corp (CCC) crews doing much of the work.

The federal law was rescinded in 1966, but today laws regarding *Ribes* culture remain on the books in many states. While some states allow all species to be cultivated, others continue full or partial bans geographically or by selected species, namely black currant. Laws banning *Ribes* species range from being well to poorly enforced, or in some instances agencies responsible for enforcement no longer exist as originally designated. Restrictions often vary by township within a state. For information on state laws, contact your state's Department of Agriculture.

The early *Ribes* industry was dealt a great setback because of these bans and has yet to recover. Variable and often confusing legal issues are still an effective roadblock to development of a viable industry. Nevertheless, the threat of white pine blister rust remains a reality today, and site selection in new plantings should take into account the presence of nearby susceptible pine species, identifiable by the characteristic of five needles per needle cluster. Most commonly this means consideration of native or planted stands of white pine in the area, but several other susceptible species may be cultivated in nearby nursery operations or your neighbor's yard as ornamentals.

CULTURE

Overall, cultural requirements are similar for all *Ribes* species, and they can be grown successfully in most of the Mid-Atlantic.

GENERAL

Ribes are adapted to cooler climates; therefore, excessive summer heat can be a limiting factor to culture. Temperatures above 85°F can cause currant leaves to begin to flag and extended exposure to direct sunlight can cause leaf sunburn. Temperatures of 95°F sustained for three or more days may cause most of the fruit to drop from the plant, especially if the fruit is nearly ripe. Partial shade, a soil mulch, and adequate water are essential in drier, hotter areas. American gooseberries are more tolerant of direct light and warm temperatures than European types.

Currant and gooseberry plants can be very productive at maturity, with yields of 4 to 6 quarts per plant considered good (by weight, gooseberries produce 8 to 10 pounds per plant and currant, 5 to 8 pounds per plant). Black currant yields are usually 50 percent less. Red currants and gooseberries reach economic bearing capacity in 3 to 4 years, and black currants in 4 to 5 years. With care, the life of currant plantings is about 8 to 15 years, and that of gooseberry plantings is 15 to 20 years. The fruit ripen over a several-week period and, depending on variety, can remain on the plant for extended periods of time in cool weather, allowing harvest schedule flexibility.

SITE SELECTION

Unlike other fruit crops, currants and gooseberries can tolerate partial shade. Northern to northeastern exposure is often ideal because the air and soil will be cooler and moister and plants will be protected from direct sunlight. Full sun exposure in cooler or mountainous climates, however, is desirable and leads to increased yields.

Air circulation and movement is an important consideration in site selection, as foliar disease can be a problem in many cultivars. Consider summer prevailing winds and align rows to take advantage of air movement.

Currants and gooseberries require approximately 1,000 to 1,200 chilling hours to break dormancy, so plants bloom early in the spring. Avoid low areas where late spring frosts can injure the blossoms. Though tolerant to cold, temperatures below 28°F can cause damage to flowers and reduce yields. An additional advantage of cooler, northern slopes is slow spring warmup and delayed plant growth, which can further reduce frost risk.

Plants have shallow, fibrous roots and should be situated where irrigation can be provided. They should be grown beyond the canopy of shade trees, away from competition for moisture.

Though currants and gooseberries are not excessively damaged by white pine blister rust, their proximity to susceptible pine species (those with five needles per needle cluster) should be considered. Locate plantings at least 1,500 feet away from valuable ornamental plantings,

commercial nurseries, commercial pine crops or native stands.

SOILS

Currants and gooseberries are fairly tolerant of a wide range of soil conditions and less than perfect sites. They perform best in well-drained silt to sandy loam soils with an organic matter content greater than 1 percent and good water-holding capacity. Planting in light sandy or heavy clay soils should be avoided, as well as areas in which water stands for any length of time. If your area is poorly drained, improve the site by tiling or building raised beds. Both heavy and light soils can be improved by additions of organic matter. The ideal soil pH is slightly acidic, from 5.5 to 6.5. Micronutrient deficiencies may occur at a pH greater than 7.0. Saline or salty soils near coastal areas should be avoided.

CULTIVARS

Several factors should be considered when choosing a cultivar. Adaptability, availability of nursery stock, productivity, ripening time, fruit size, appearance, flavor, ease of harvest, and disease resistance are just a few important considerations.

Selection for cold-hardiness is usually not an issue, though bloom time and bloom hardiness should be considered in areas where late spring frosts commonly occur. More importantly for the Mid-Atlantic, relative tolerance to summer heat, foliar disease, and insect pressure should be considered. Documentation of the performance of cultivars in our region is limited, and test plantings of cultivars are strongly recommended before larger plantings are committed.

Currants

Most currants are self-fruitful; therefore, only one cultivar is needed for fruit production, unless otherwise noted in cultivar descriptions. However, currants will produce better and larger fruit crops when more than one cultivar is planted. A few cultivars may be locally available through nurseries and garden centers, but specialty mail order nursery suppliers are the primary source of stock. See Appendix C for a listing of nurseries that carry *Ribes*.

Red Currants

CASCADE

- Early.
- Fruit is large, medium dark red, and produced on short strigs.
- Plants are erect to slightly sprawling and of medium productivity and vigor.
- Berries are susceptible to sunscald and should be picked promptly.

DETVAN

- Midseason.
- A selection from Slovakia.
- Plants are very large, robust, and upright.
- Fruit is large and produced on very long strigs, often with as many as 25 to 30 berries per strig.
- Should be planted on at least 5-foot row centers.
- Very high yielding.
- Good resistance to gray mold (also called runoff).

JONKEERS VAN TETS

- Popular early to midseason selection from Holland.
- Fruit is dark red and soft, has very good flavor, and is on medium-sized strigs.
- Plants bloom early and are heavy producers.
- Growth habit is not uniform.
- Plants are mildew and aphid resistant, but gray mold can be a problem for fruit production in wet years.

RED LAKE

- Mid- to late season.
- Fruit is large, firm, light red, subacid, and is on easy-to-pick long strigs with high juice content.
- Easily found in nurseries.
- Plants are productive, upright, dense and hardy.
- Has a low tolerance to frost.
- Susceptible to mildew.

ROVADA

- Late season.
- Fruit is large and produced on long, compact strigs.
- Dependable bearer and productive.
- Blooms late, so frost can be less of a problem than with other cultivars.
- Resistant to mildew and other leaf diseases.

TATRAN

- Late season.
- A sister selection of Detvan, with many similar characteristics.
- Plants are robust and upright.
- Fruit is very large and produced on long strigs of 25 to 30 berries.
- Very high yielding and resistant to runoff.
- Should be planted at least 5 feet apart both within the row and between rows.
- Canes become very heavy with fruit and may need some support.

WILDER

- Mid- to late season.
- Fruit is large, dark red, subacid, and produced on large compact clusters.
- Plants are productive, large, and upright to spreading.
- Resistant to leaf spots.

White and Pink Currants

White and pink currants are more difficult to find. They grow like red currants but have a less acidic, sweeter, unique flavor. The fruit is small, white to yellowish to pinkish, and opaque to translucent.

BLANKA

- Mid- to late season.
- Known for heavy yields and dependability.
- Produces long strigs of large, opaque, off-white fruit.
- Plants are vigorous and spreading and easy to grow.

PINK CHAMPAGNE

- Midseason.
- Quality and flavor are good.
- Fruit is a translucent pink color.
- Yields are generally low.
- Plants are vigorous, upright, and resistant to leaf diseases.

PRIMUS

- Late season.
- Has white to yellowish fruit on upright, vigorous plants.
- Similar to Blanka in fruit quality, but yields may be slightly lower.

WHITE IMPERIAL

- Midseason.
- One of most commonly available white varieties.
- Lowest acidity of currant cultivars.

- Produces small fruit on long strigs.
- Yields are moderate.
- Plants have a spreading growth habit.

Black Currants

Black currants are prized for their strong aroma, flavor and high vitamin C content. Some varieties, particularly those that are purely *Ribes nigrum*, are highly susceptible to white pine blister rust. Resistance has been developed in cultivars through crossing of *R. nigrum* and *R. ussurienses*. Cultivars resistant to white pine blister rust are available and should be selected.

Juice and processing quality of initial crosses to incorporate white pine blister rust resistance (Consort, Coronet, Crusader) are considered substandard as compared to standard nonresistant cultivars. However, recent backcrosses (crosses back to a parent), such as the cultivar Titania, have retained near immunity to white pine blister rust. These backcrosses also have improved commercial traits such as tolerance of adverse weather at flowering, and suitability for machine harvest. In addition, they have a long hang time, even fruit-ripening within clusters, high yield, improved resistance to mildew and leaf diseases, and better juice quality. Black currants nonresistant to white pine blister rust, though sometimes listed, are not recommended and usually are in the target group still prohibited by law.

BEN LOMOND

- Known for even ripening and high yields of large, firm fruit that have a long hang time and high vitamin C content, despite high pectin levels.
- Plants are compact yet spreading and have good frost tolerance at flowering.
- Plants have variable resistance to mildew and slight resistance to white pine blister rust.

BEN SAREK

- Early to midseason.
- Known for strong set of very large fruit, ease of hand harvest, and tolerance to frost and cold injury.
- Growth habit is very compact.
- Recommended for small-scale growers with limited land area.
- Has slight to moderate resistance to white pine blister rust.

BLACKDOWN

- Untested in the region.
- Fruit is said to be large and flavorful.
- No resistance to white pine blister rust.

BLACK SEPTEMBER

- Late season variety.
- Fruit is large and firm with a mild flavor.
- Yields are poor.
- No resistance to white pine blister rust.

CONSORT

- Early to midseason.
- Fruit is medium to small with medium firmness.
- Juice quality is fair.
- Does not machine harvest well.
- Plants are self-fertile with dependable set but are rated fair in productivity.
- Susceptible to leaf spot and mildew.
- Resistant to white pine blister rust.

CORONET AND CRUSADER

- Similar to Consort but both require pollinators.
- Yields and quality are poor.
- Resistant to white pine blister rust.

TISEL

- Midseason.
- New cultivar that is a progeny of Titania.
- Productive.
- Fruit ripens evenly and has very high vitamin C levels.
- Has reported immunity to white pine blister rust and also is resistant to mildew.
- Not yet available in the United States.

TITANIA

- Midseason.
- Fruit is large and of high quality.
- Yields are high.
- Plants are vigorous, growing up to 6 feet tall, come into full production by the third year, and are well-suited for machine harvest.
- Nearly immune to white pine blister rust, but is susceptible to a cane blight disease, possibly from the genus *Botryosphaeria*.

CURRENT BREEDING EFFORTS

A few Russian seedling selections are being increased in number for distribution and will become available in the near future. These selections vary in resistance to mildew and white pine blister rust. Many of these selections are large fruited and, in general, much more palatable for fresh use than black currant cultivars currently available.

Gooseberries

American gooseberry cultivars are more foliar-disease resistant, more productive, healthier, and more adaptable to varied climatic conditions than European cultivars, which have the advantages of large fruit size, good color, and sweet flavor. Lack of disease resistance and marginal hardiness has limited European cultivar use in North America and a stringent disease management program is required to grow them. Despite the huge number of European cultivars in existence, few are commonly available in the United States. Newer cultivars with American genetic disease resistance are being developed and introduced; however, at this time, few new commercial American cultivars are on the market. Most currently available have been around for many years. While the true genetic lines are somewhat blurred between American and European gooseberries, a distinct separation of the two types still remains.

The following cultivars are of American origin:

CAPTIVATOR

- Late season.
- American-European hybrid.
- Fruit is large, pink to red, teardrop shaped, and sweet.
- Yields are moderate.
- Plants are mildew resistant with few thorns.

JAHNS PRAIRIE

- A selection from a native population in Alberta, Canada.
- Belongs to the species *R. oxyacanthoides* L.
- Fruit is red pink and of very good eating quality.
- Resistant to botrytis, powdery mildew, and white pine blister rust.

OREGON CHAMPION

- Midseason.
- Fruit is small to medium in size, round to oval, and pale white to greenish yellow at maturity.
- The fruit has a thin skin and is juicy and tart.

- Plants are large, vigorous, upright to spreading, and productive.
- Plants are somewhat susceptible to mildew.

PIXWELL

- From North Dakota.
- Fruit is of medium size, pink, in clusters, and of fair quality.
- Plants are vigorous, productive, hardy, and have few thorns.
- Recommended for home garden use.
- Best if used slightly underripe.
- Mildew resistant.

POORMAN

- Early to midseason.
- Fruit is red, of medium size, and oval shaped.
- Fruit ripens over a long period and is of high quality.
- Flavor is sprightly sweet.
- Plants are vigorous, the largest of American cultivars, productive, upright, dense with few short thorns, and mildew resistant.

TIXIA

- Midseason.
- Red fruit is large and relatively mild in flavor.
- Plants are vigorous, have few thorns, and are resistant to mildew.

WELCOME

- Released by the University of Minnesota.
- Fruit is a dull red and of medium to large size.
- Plants are hardy and have few spines.

The following cultivars are of European origin:

CARELESS

- Midseason.
- Fruit is large, oval, and pale green to milky white when ripe with a smooth transparent skin.
- Plants are moderately vigorous, upright to spreading, and very susceptible to mildew.

CLARK

- Mid- to late season.
- Fruit is very large, red, and of high quality.
- Plants are thorny, dense, short with branches close to the ground, moderate in vigor, and productive.
- Thought to be a natural American-European cross.
- Plants are very susceptible to mildew.

HINNONMAKI RED AND HINNONMAKI YELLOW

- Developed in Finland.
- Fruit is red and green yellow, respectively.
- Hinnonmaki Red fruit is medium size, while Hinnonmaki Yellow fruit is smaller.
- With both, the skin is tart, but the flesh is sweet, aromatic, and has very good flavor.
- Both are thorny.
- Hinnonmaki Red is also known as Leppa Red (erroneously).
- Plants are short, moderate in vigor, and upright to slightly spreading.
- H. Red is more mildew resistant than H. Yellow.
- Sometimes characterized as an American type.

INDUSTRY

- An older, large, red-fruiting cultivar with slightly hairy fruit.
- Finding a source of this cultivar may be difficult.
- Plants are very susceptible to mildew.

INVICTA

- Midseason.
- Fruit is large and pale green with a bland flavor.
- Used for processing, where it provides an even color and flavor.
- Plants are large and productive and have numerous spines.
- Resistance to mildew is good, but resistance to other leaf spots is not.

SITE PREPARATION

Site preparation should begin by eradicating perennial weeds in the planting area to the fullest extent possible. This can be achieved by applying translocated herbicides in mid- to late summer or by diligent cultivation. A soil test should be taken to determine the soil pH, phosphorus, and potassium levels and needs. These nutrients should be amended to moderate levels, with available phosphorus brought to a range of 50 to 75 pounds per acre and potassium to 150 to 200 pounds per acre. Lime should be added to bring the soil pH to 6.1 if pH levels are below 5.5. Along with lime, phosphorus can be incorporated in the fall; however, potassium and nitrogen (25 to 35 pounds per acre) should be incorporated in the spring to avoid the loss of nutrients to leaching. Currants and gooseberries are sensitive to the chloride contained in muriate of potash (0-0-60), so another form of potassium, such as sulfate of potash, should be used. If plants are to be planted in the fall, nitrogen should not be applied until the following spring.

Currants and gooseberries respond well to organic amendments, which improve aeration and drainage and also increase water-holding capacity in all soil types. Organic matter can be applied in the fall or spring before planting. Well-aged manure at 4 to 5 bushels per 100 square feet (1,750 to 2,200 bushels per acre) is a good option; other suitable sources are finished compost, leaves, rotted hay or straw, shredded peat, or sawdust. Any additions should be free of weed seeds and insects.

For larger plantings, a cover crop (green manure) can also be grown and turned in to increase organic matter. See Chapter 2 for more information on green manure crops. Two or possibly three green manure crops can be grown during the course of one growing season if the first crop is planted early. At blossom, till or disk down the cover crop and replant immediately. A winter cover (e.g., cereal rye, vetch) should be sown after fall site preparation. At least 3 weeks prior to spring planting, overwintered cover crops should be burned down with herbicides and/or mowed or chopped and incorporated. Be sure to disk or rototill organic materials deeply into the soil to ensure adequate breakdown and soil loosening. If large amounts of non-decomposed materials are added, ammonium nitrate can be applied at 1 pound per 100 square feet (450 pounds of ammonium nitrate per acre) to aid in decomposition. A different nitrogen source can be used, applied at an equivalent rate (150 pounds of actual nitrogen per acre).

In areas of questionable drainage, permanent raised beds 3 to 4 feet wide and 4 to 6 inches tall should be formed. A second option to improve drainage is to install drain tiles at least 25 inches deep near the row.

SPACING AND PLANTING SYSTEMS

Plant spacing is dependent on cultivar vigor and growth habit, site fertility, planting system, and equipment size. In general, red or white currants and gooseberries should be planted 3 to 4 feet apart in rows a minimum of 6 to 8 feet apart. Black currants are more vigorous and should be spaced 4 to 5 feet apart in rows 8 to 12 feet apart. Avoid overcrowding plantings because adequate air circulation and movement are critical in reducing foliar disease incidence. Equipment access is also an important preplant consideration, and adequate room must remain between rows when plants mature.

Plants can be established as freestanding bushes at the above spacing or planted at closer densities to form a hedgerow—a common practice for black currant production. A third, less common method is to keep plants pruned as a tree form or as a standard with a trunk kept at a chosen height and supported by a trellis. This is sometimes practiced with gooseberries, which increases air circulation and reduces disease. In this system, spacing is the same as that of freestanding bushes.

While trellising the plants is not a requirement, it improves fruit exposure and makes harvesting easier, especially with gooseberries. A simple series of horizontal wires placed about 6 inches apart to which canes can be tied will suffice.

OBTAINING PLANTS

Plants should be one or two years old, vigorous, and well rooted. Reliable disease-free stock can be purchased from a nursery, or nonpatented stock can be easily propagated by means of layering and by cuttings (see section on propagation). Only disease- and insect-free stock should be propagated and planted. Nursery-grown plants will usually come as bare-root stock. Request that the plants be shipped as close to the planting date as possible.

After receiving the plants, check the roots for moistness, moisten if necessary, and store plants in a plastic bag in cold storage (separate from apples or other sources of ethylene, as this is lethal to plants) until the site is ready to plant. If storage is necessary for longer than two weeks, plants can be heeled in with roots covered with soil in a temporary outdoor trench.

PLANTING

Because *Ribes* plants break dormancy early, very early spring planting is recommended. A plant that has just leafed out can easily tolerate 20°F, so do not be afraid to plant as soon as the soil can be worked. If dormant nursery stock is available, fall planting should be used; however, avoid nitrogen fertilizer application, which may decrease winter hardiness. In addition, plants should be mulched to reduce winter frost heaving effects.

Avoid excessive root drying and exposure as plants are set out. The roots of bare-root plants should be soaked in a bucket of clean water 2 to 3 hours prior to planting. Plants should be set about an inch deeper than they were growing in the nursery. Covering one to three buds on the lower part of canes will encourage a larger root system and increase renewal cane production. Avoid excessive planting depths. Damaged and straggling root parts should be trimmed; the roots should be spread out, covered with soil, and pressed firmly to remove air pockets. Water the plants to settle the soil, but avoid "water logging."

ESTABLISHMENT

Newly set plants should be pruned back to 6 to 10 inches above the ground, depending on root system vigor. This will encourage development of new canes. With fall planting, this pruning should be delayed until spring. When practical, blossoms or any set fruit should be removed the year of planting. This helps plants to become well established and make better vegetative growth.

CULTIVATION AND MULCHING

Mechanically cultivate or hand hoe from early spring until harvest to control weeds between rows. Practice level, shallow cultivation to avoid harming roots. After planting and throughout the life of the plants, maintain an organic mulch of straw, decomposed hardwood sawdust or bark, pine needles, compost, or other suitable material around the base of each plant or as a band over the row. Mulching helps to conserve soil moisture, cools the soil, and suppresses weeds. The mulch should be 2 to 4 inches deep, with additional annual applications made to maintain this depth as decomposition occurs. Fresh or undecomposed materials such as woodchips or sawdust can tie up available nitrogen as they break down, and additional nitrogen above recommended rates may be needed. Signs of nitrogen deficiency include yellowing older leaves and poor growth. Rodents may infest mulched areas and should be controlled before winter sets in.

FERTILITY

Currants and gooseberries are heavy feeders and respond to a regular fertilizer program. Established plants should be fertilized each spring as growth begins. Depending on site fertility and plant vigor, fertilizer applications can be made only once in early spring or split to encourage better growth. Because the plants have shallow roots and fertilizer may quickly leach below the root zone, splitting applications, especially in light textured soils, is recommended.

Both currants and gooseberries are sensitive to chloride. Therefore, when applying a balanced fertilizer such as 10-10-10, use a fertilizer made with potassium sulfate rather than potassium chloride. You may need to blend your own. Keep in mind that some fertilizers and certain mixtures absorb moisture very quickly, so the blend should be applied immediately after it is mixed. Other potassium-containing fertilizers that can be used are potassium magnesium sulfate (Sul-Po-Mag), if magnesium is also needed, and potassium nitrate. For second-year plantings, apply approximately 4 to 5 ounces of 10-10-10 fertilizer per plant (or an equivalent rate of a similar fertilizer). A broadcast application should be made, spread under the branches and just beyond the drip line. In third-year plantings, rates should be increased slightly. Fourth-year and mature plantings should receive a maximum of 6 to 8 ounces of 10-10-10 fertilizer per plant (0.6 to 0.8 ounces of actual nitrogen per plant or 25 to 50 pounds of actual nitrogen per acre). Depending on growth, up to double these rates may be needed where fresh sawdust or bark chip mulch is used (using fresh mulch materials is not recommended).

When available, manure or other composted materials with a high nitrogen content are the best nutrient sources for *Ribes,* which respond well to the slow-release nature of organic nitrogen sources. These materials can be substituted for all or part of the fertilizer requirement. They should be applied in early spring to allow time for nutrient movement into the root zone. In general, inorganic nitrogen additions can be reduced by one-half or more with the use of manure. Applying either manure or chemical fertilizers in summer or early fall can make plants more susceptible to winter injury.

NOTES ON SOD ROW MIDDLES

A permanent sod such as creeping red fescue or orchardgrass may be grown between rows. This area should be lightly cultivated and fertilized prior to sowing or drilling seed for best results. Sod eliminates the need for cultivation between rows and provides a clean walking area for hand-picking. Sod should not be allowed to grow closer than one foot from the drip line and should be kept closely mowed and irrigated. Avoid legumes in a sod seed mix because they may provide untimely nitrogen. Plantings under sod culture tend to be more prone to frost injury as compared to cultivated soil since bare soil warms more quickly in the spring and releases more heat on cold nights.

IRRIGATION

For quality fruit, currants and gooseberries require about one inch of water per week from bloom to the end of harvest. This ensures good plant growth, high yields, and large berry size. In most areas, rainfall is usually adequate, especially if mulch is being used. However, if rainfall is insufficient, supplemental irrigation is advised. Drip or trickle irrigation is preferable to overhead irrigation, which can increase foliar disease problems. During prolonged dry periods after harvest, plants should be watered periodically until late August or early September. Add enough water to moisten the soil to 6 to 8 inches deep, allowing it to dry out somewhat before watering again. Roots can be injured by overirrigation.

As with strawberries, sprinkler irrigation can help to prevent frost injury during bloom. As temperatures fall just below freezing, low volumes of water are applied using special low-delivery nozzles. A protective film of ice forms over the plant and blossoms and, as water is converted to ice, heat is released, which protects blooms and newly set fruit. Trickle systems are not useful for frost protection. See Appendix A for additional information on frost protection.

POLLINATION CONSIDERATIONS

Since currants and gooseberries (except for a few black currants) are self-fruitful, cross-pollination by a second cultivar is not needed. However, cross-pollination can result in bigger fruit and a larger harvest. Larger plantings may benefit from inclusion of multiple cultivars and nearby placement of beehives to facilitate pollination. Bumble bees and solitary bees are more efficient in most cases due to the early bloom when weather is colder and honey bees are not as active. As always, only insecticides not harmful to bees should be used during bloom.

PRUNING AND TRAINING

Currants and gooseberries should be pruned in the dormant season—during late winter and early spring. Red currants and gooseberries are similar in their fruiting characteristics; black currants are different and should be pruned accordingly.

Red, White, and Pink Currants and Gooseberries

Plants of these types produce most of their fruit from short spurs located on one- , two- , or three-year-old canes. Spurs decline in productivity by the fourth year. Hence, older canes should be removed at ground level. In pruning for bush production, a goal for a mature plant is to have nine to twelve main stems (three to four each of one-, two- , and three-year-old canes). All stems older than three years should be removed. This is called renewal pruning and will keep the bushes productive. A seasonal pruning schedule should follow this pattern:

- At planting: After planting, head back plants to 6 to 10 inches tall to encourage root and basal shoot growth.
- After the first season: During late winter or early spring, remove all but six to eight of the most vigorous shoots, making pruning cuts close to the ground.
- After two seasons: Leave four or five new one-year-old shoots and keep three or four of the two-year old-canes.
- After three seasons: Leave three to four canes from new one-year-old growth, and keep three or four each of the two- and three-year-old canes.
- Mature plantings: After the fourth and following years, remove the oldest canes and keep three to four new one-year-old canes to replace the older canes you removed.

When pruning, also remove branches that lie too close to the ground. Heading back is not necessary; however, removal of diseased tips and weak or otherwise damaged branches is advised. Excessively crowded and vigorous canes should be thinned to create an open center to increase light exposure for fruit bud formation and to increase air circulation. Do not make the common mistake of leaving the bushes too thick. Plants may also be thinned in summer by removing many of the side branches on the canes so that the canes are better able to support a heavy fruit load and to facilitate harvest.

Pruning red currants to a tree or standard form is also possible. This requires judicious removal of suckers and stem growth and/or the use of grafted plants. Trellising or some means of support is usually required. The advantages of this system are increased yields and air circulation. Disadvantages are increased hand labor in pruning and training, cost of wire support, and decreased plant longevity. This method is recommended for those who have had experience with dwarf tree fruit systems or are interested in specialized or unique methods of production or ornamental aspects. Trellising of large red currant plants reduces wind damage in early spring.

Black Currants

Black currants produce best on one- and two-year-old wood. They do not fruit on spurs as do red currants and goose-

berries. Strong one-year-old shoots and two- and three-year-old stems that have an abundance of strong one-year-old shoots are the most productive.

Because of their bearing habit, black currants can be pruned by two different methods. These two methods can be used in both free-standing and hedgerow systems.

Method 1

In a method similar to pruning red currants and gooseberries, plants should have two- and three-year-old canes, along with one-year-old shoots, with a total of 10 to 15 canes per mature bush. Black currants are somewhat more vigorous than red currants; hence the number of canes kept is higher. The proportion of one-year-old canes kept to older canes is also different, with approximately one-half of all canes kept being one-year-old canes. Remove all shoots more than three years old at ground level.

Method 2

An easier method of pruning black currants takes advantage of its fruiting habit. This system uses only one-year-old canes and an alternate-year production system.

- Year 1: Plants are pruned to the ground immediately following the harvest, then lightly fertilized and watered. Small immature canes may be allowed to grow. This will usually provide 12 to 18 inches of growth by dormancy. These canes do not set flower buds.
- Year 2: The previous year's canes remain vegetative and additional canes are produced.
- Year 3: A large crop is produced. Plants are again pruned to the ground after fruiting.

The cycle repeats with vegetative growth only the next year. As plants are out of production for a season, the planting should be divided into differently pruned blocks to ensure a crop each year. This method greatly simplifies pruning of black currants and reduces insect and disease carryover. The hedgerow planting system is ideal for this time-saving pruning method.

Black currants can also be trained as a standard. This requires diligent pruning to promote one-year-old shoot production on older wood.

HARVEST

Black currants, jostaberries, and gooseberries are harvested as individual berries; red, white, and pink currants are picked in whole strigs. Red currants are smaller and more tightly bunched than black currants. Gooseberry fruit is borne singularly or in small clusters on spurs.

Fruit is harvested in midsummer. Currants ripen over a two-week or longer period, while gooseberries take from 4 to 6 weeks to ripen, depending on weather. Once a berry fully ripens, it can be left on the bush for a week or more without becoming overmature; but in some varieties, fruit acidity can drop. This allows fruit that matures more slowly to ripen and condenses harvest to two to three pickings. Red currants turn red long before they are fully ripe. They should be allowed to remain on the plant as long as possible to develop additional flavor and sweeten with time.

Gooseberry harvest generally requires the use of gloves, especially with thornier varieties. If desired, a canvas may be spread out under the bush and fruit knocked off onto it. Berries can be harvested when they are full size but not yet ripe. This is preferred for pies and jam. For fresh and juice use, fruit should be allowed to reach full ripeness and color expression.

Both currants and gooseberries can be frozen and kept for later use.

PROPAGATION

To increase your plantings, currants and gooseberries are easily propagated by means of cuttings or layering, as long the varieties you intend to propagate are not patented.

Cuttings should be taken during the dormant season from new one-year-old wood. Make cuttings 6 to 8 inches long, with the bottom and top cuts made near nodes. Stick in rooting media in the late fall or take later and keep in moist sand, sawdust, or peat moss in a cool place (refrigerator) until they are set in early spring. Cuttings should be set about 6 inches apart in a well-drained nursery bed. They should be inserted so that one to two buds extend out of the soil. Fall stuck cuttings should be mulched with straw or stuck through black plastic. They should be cut and placed as soon as the plants are dormant, which will allow several weeks for rooting to start before the ground freezes.

Gooseberries—in particular the European types—can also be propagated by layering. This can be done using a "stooling bed" (mound layering) or by individual branch layering (ground layering). Stool beds require the use of a stock plant that should be cut back before growth starts in the spring. By early summer a large number of vigorous shoots will have been produced. Soil is mounded around these shoots about halfway to the tips, with care taken to work the soil down among the shoots. The covered parts of the shoots usually become rooted by fall. Cut the newly rooted plant from the parent in the spring and plant in a permanent site or in nursery rows.

Branch layering is similar to mound layering and is accomplished by bending down branches while they are still attached to the plant and partly covering them with soil. Pegs may be necessary to hold down the stems. This can be done fall or spring. Plants are kept covered for one growing season. Roots and shoots form along the branch; several plants can often be obtained from one branch. These can be dug and separated after the growing season.

PEST MANAGEMENT

Both currants and gooseberries can be affected by several insect and disease problems. Powdery mildew and leaf spot (anthracnose) are two common disease problems. Careful site selection, choosing resistant cultivars, and proper pruning often give adequate control; chemical use is an additional means of management (see Table 9.1).

DISEASES

Botrytis (Runoff), Dieback, and Fruit Rot

Symptoms: The gray fuzz characteristic of botrytis on other crops covers the leaves and fruit. Tips of branches turn dark and die. Fruit drops from the plant before ripening.

Causal Agent: The fungus *Botrytis cinerea.*

Epidemiology: The fungus has a wide host range and can survive on either living or dead tissue. It overwinters in dead leaves and plant debris and on stems. Inoculum is produced from fruiting structures on canes, from dead leaves, and from mummified berries in the spring.

Controls: To help control the disease, choose a planting site with good air movement and prune out weak canes to speed the drying of plants. Also eliminate weeds to aid in quicker drying of foliage and fruit and harvest fruit before it is overripe. Fungicides should be applied during bloom, with additional applications made during harvest, if necessary. Refer to Table 9.1 for fungicide recommendations.

Anthracnose Leaf Spot

Symptoms: Dark-brown or black spots that appear on the leaves at any time during the growing season. The spots grow larger over time to a size of about 1/8 inch, remain dark, and may develop a purplish margin. Eventually leaves turn yellow and drop from the plant. The spots look like fly specks on berries. Berries may split open and drop from the plant.

Causal Agent: *Drepanopeziza ribis.*

Epidemiology: The fungus overwinters in old leaves on the ground. Spores are produced on the dead leaves and are released, infecting new leaves. A different type of spore is later produced that is spread by splashing rain. Wet spring weather aids in disease development.

Controls: Rake away and destroy affected leaves. Mulch can be applied in the fall after the leaves drop to bury them. Any practice that aids in plant drying will be helpful. Fungicides may be applied.

Septoria Leaf Spot

Symptoms: Spots on leaves develop in early summer. Septoria leaf spots are similar in appearance to anthracnose leaf spots, except that septoria leaf spots develop a light center as the spots enlarge. Leaves drop from the plant.

Causal Agent: *Mycosphaerella ribis* (anamorph *Septoria ribis*)

Epidemiology: The fungus overwinters in old leaves on the ground.

Controls: Good sanitation and practices that improve foliage drying. Fungicides may be applied.

Powdery Mildew, Gooseberry Mildew, American Gooseberry Mildew, and American Powdery Mildew

Symptoms: Powdery, "frosty" patches on shoots, branch tips, and young leaves, eventually causing dead tissue in the affected area or deformation of leaves and shoots. On the fruit, white patches may occur, but eventually the mildew turns a dark brown, making the fruit rough and unmarketable. Infected fruit might also split open. In severe cases, infection decreases fruit production the following year.

Causal Agent: *Sphaerotheca mors-uvae* is referred to as American gooseberry mildew since it originated in the United States. *S. mors-uvae* causes more severe symptoms on *Ribes* than other types of powdery mildew. *Sphaerotheca macularis* is another species of powdery mildew that occasionally affects *Ribes* in the United States and causes similar symptoms. Control for both species is the same.

Epidemiology: *S. mors-uvae* affects gooseberries and black currants. The fungus overwinters in buds and infects the shoots produced from those buds in the spring. Spores are produced on infected foliage and spread by wind. The fungus grows most prolifically under conditions of high humidity.

Controls: Because mildew is most problematic under conditions of high humidity, any cultural control that decreases humidity in the vicinity of the leaves will be helpful. Avoid damp planting sites; growing *Ribes* in shady locations to decrease heat stress may make the occurrence of powdery mildew more likely. Do not use closer plant spacings than those recommended above. Keep plantings well pruned and well weeded. Captivator, Glendale, Hinnomaki Yellow, Hinnomaki Red, and Poorman are resistant.

White Pine Blister Rust and Currant Blister Rust

Symptoms: In the spring, small, yellow spots appear on the leaves. Yellow-orange fruiting bodies ("rust") are visible on the leaf undersides. Damage to *Ribes* plants is of little concern; the main concern is the damage and death of susceptible five-needled pine species (in the east, primarily white pine).

Causal Agent: *Cronartium ribicola.*

Epidemiology: Initial infection occurs in the spring when fungal spores from diseased white pines land on the leaves of the *Ribes* bush and germinate. After 1 to 3 weeks, fruiting bodies on the undersides of the leaves produce spores that infect more *Ribes* tissue. A second type of spore is produced in late summer and fall that can be wind-carried great distances. These spores then infect white pines. After 1 to 2 years, spores are produced from the pine tree, starting the cycle over. Black currants are the most susceptible *Ribes* species.

Controls: Resistant black currant varieties are listed in the section on cultivars. Avoid planting near white pines.

Currant Cane Blight

Symptoms: Shoots wilt and die. The whole plant may be affected. Pith is discolored, ranging from light tan in young infected shoots to black in mature canes that are nearly dead. Canes may become hollow and snap off.

Causal Agent: *Botryosphaeria ribis*.

Epidemiology: Disease cycle is thought to be similar to that of *Botrysphaeria dothidea*, which causes *Botryosphaeria* cane blight on blueberries. Inoculum survives the winter and is probably produced in dead, infected canes and shoot tips in the spring and early winter.

Controls: Remove infected branches and dead shoot tips in the spring, wilting canes in the summer, and entire plants if dead or severely infected. Stobilurin fungicides can help protect uninfected plants but will not cure infected plants. According to research at Cornell, the most effective practices for management have been application of dormant sprays of copper hydroxide and sulfur combined with diligent pruning.

INSECTS

Aphids, Various Species, especially Currant Aphid, *Cryptomyzus ribis* (Homoptera: Aphididae)

Symptoms of Damage: Foliage is distorted, crinkled, curled, and sometimes reddened, brought about by aphid feeding on the leaf undersides.

Identification: Small (less than 1/10 inch), slow-moving, pear-shaped, yellow-green insects with cornicles (tubes) extending backwards from their posterior.

Life Cycle: Aphids overwinter as tiny, glossy, black eggs on the stems. Green female aphids hatch from these eggs about the time the leaves appear and give birth to live aphids. Winged forms are produced when overcrowding occurs, allowing the aphids to distribute themselves more easily. Male and female forms are produced in the fall and mate, after which the females deposit eggs for overwintering.

Monitoring and Control: Especially troublesome on red currants. Predatory insects are helpful in control, and aphid populations may decrease later in the season once populations of predators build. Insecticides as listed in Table 9.1 may be applied.

Brown Marmorated Stink Bug, *Halyomorpha halys* (Stal) (Hemiptera: Pentatomidae)

Symptoms of Damage: Direct feeding on fruit by adults and all stages of nymphs. This pest is listed for this crop as a precaution; extensive damage has not been reported on Ribes.

Identification: Adults are mottled brown, about ¾ inch long, and nearly as wide. They are similar in shape to other stink bugs exhibiting a shield shape. Adults can be differentiated from common brown stink bugs by alternating brown and white bands on their antennae and along the edges of their abdomens. Nymphs are smaller and, like adults, exhibit white bands on brown antennae. Their coloration varies with instar, but each has some yellow or red coloration, and their eyes are red. Eggs are yellowish green, oval, and laid in clusters that are attached side to side on leaf undersides.

Life Cycle: One generation per year is expected in this region, but at least two can occur with warmer temperatures. Adults overwinter in protected locations and emerge in spring. They lay eggs from May through August. Nymphs progress through five instars.

Monitoring and Controls: Direct observation; other monitoring techniques are in development. Pyrethroids are the most effective chemical class. Nymphs should be targeted during pesticide applications as they cannot fly away; a direct hit of nymphs or adults is necessary for efficacy. Natural enemies are present, but they have a wide host range and thus currently provide insufficient control.

Currant Fruit Fly (Gooseberry Maggot, Currant Maggot), *Euphranta (formerly Epochra) canadensis* (Diptera: Tephritidae)

Symptoms of Damage: A dark spot on the berry possibly surrounded by a reddened area. White larvae may be found in affected fruit. Infested berries usually drop prematurely, but when they don't, harvested fruit can be contaminated.

Identification: Adults are a fly about 1/3 inch long. Their bodies are yellow with shading and their wings are banded.

Life Cycle: Adults emerge from soil in the spring and lay eggs under the skin of fruit. Eggs hatch in 5 to 8 days, and larvae then feed in the fruit for 11 to 16 days. Larvae may continue to feed once berries have fallen to the ground. Larvae enter the soil and pupate over the winter.

Monitoring and Control: Early varieties may escape damage. Collecting and destroying fallen fruit regularly before larvae hatch may have some effect on populations. Monitor for adults—usually found in shady areas of the plant—starting at petal fall. Treat if adults are seen.

Currant Borer, *Synanthedon tipuliformis (Lepidoptera: Sesiidae)*, also Known as Currant Stem Borer, Clearwing Borer, and Clearwinged Moth

Symptoms of Damage: Withering or yellowing of leaves. Affected canes may die. Watch for a dark hollow stem pith when pruning, as this is evidence of damage. Borers are particularly troublesome on red currants.

Identification: The ½-inch-long adult resembles a wasp, though this pest is actually a moth with clear wings and a wingspan of about ¾ inch. The larva is white with a light-brown head.

Life Cycle: Adult moths emerge from the canes in the spring and lay their eggs on the canes in early summer. In a little more than a week, the larvae hatch and enter the cane where they feed while tunneling through the pith. They overwinter as larvae, cause little damage while feeding briefly during the spring, pupate, and emerge as adults.

Monitoring and Control: These branches should be pruned below the damage and destroyed. Adults fly well and can be seen hovering around the canes. Insecticides should be applied to target adults and young larvae before they enter the canes. Insecticides applied after the larvae are protected inside the cane will have no effect.

Imported Currant Worm, *Nematis ribesii* (Hymenoptera: Tenthredinidae)

Symptoms of Damage: Damage is from the larvae, which have voracious appetites and can completely defoliate a plant in a few days.

Identification: Adults are sawflies the size of a housefly. The head and thorax are dark, and the abdomen is a yellow-red. The caterpillar larvae are green with black spots in early instars but become a solid light green in their last instar.

Life Cycle: Adults emerge from the soil soon after bud break. Translucent white eggs are laid along the leaf veins, from which the larvae hatch in 7 to 10 days. They feed on the leaves for 2 to 3 weeks and then pupate in litter on the ground. A second generation of adults appears in midsummer, but it tends to be much lower in numbers, possibly because of predation by natural predators. This second generation overwinters as pupae.

Monitoring and Control: Watch for larvae starting just after bloom as the fruits start to enlarge. Cultural control involves being observant of growing conditions and keeping plants vigorous. Insecticides may be applied, if necessary.

Gooseberry Fruitworm, *Zophodia convolutella* (Lepidoptera: Pyralidae)

Symptoms of Damage: Hollowed-out berries that change color prematurely and dry up or fall to the ground. Clusters of berries and part of the stem may be wrapped in a silken webbing.

Identification: The adult is a grayish moth with a wingspan of about an inch. Larvae are about ¾ inch long with a brownish head and green body with dark stripes along the sides when fully grown.

Life Cycle: Shortly after fruit set, adults emerge from cocoons under dead leaves on the ground, where they overwintered. The female lays eggs on the fruit. The larva enters the berry and feeds on the pulp. The larva may eat several berries and web them together. After the larva is fully grown, it moves down to the ground and pupates.

Monitoring and Control: Hand-picking infested berries provides some control. An insecticide may be needed starting at early fruit development and again 10 days later.

San Jose Scale, *Quadraspidiotus pernicious (Homoptera: Diaspididae)*

Symptoms of Damage: In cases of light infestations, plant vigor may be decreased from the scale removing plant juices. In severe infestations, canes or plants may be killed.

Identification: Small, gray, circular specks about 1/10 inch across, usually on the canes.

Life Cycle: The scale insect overwinters under its shell on the plant's branches. In the spring, the males emerge as tiny yellow-winged insects and mate with females. The females give birth to live young (crawlers), which move to a new location, begin feeding, and form their own shells. The scale insects reach maturity in 25 to 30 days. Two generations occur per year.

Monitoring and Control: Superior oil at bud break will help, as will an insecticide targeting the crawlers.

See Chapter 3 for general guidance on using pesticides safely.

Spotted Wing Drosophila, Drosophila suzukii Matsumura (Diptera: Drosophilidae)

Symptoms of Damage: Tiny white larvae found in otherwise marketable fruit. Tiny holes surrounded by sunken tissue may be found where oviposition wounds were made. Spotted wing drosophila is a new pest; it will feed on *Ribes,* but it is not known whether *Ribes* fruit are preferred.

Identification: This pest is similar in appearance to other vinegar flies or fruit flies. Most adult males have one large black spot on each wing, forward of the tip. The definitive feature that differentiates this vinegar fly from other species is two black bands (sex combs) on each front leg on the males. Adult females lack wing spots and black bands on the legs, but they have a large sawlike ovipositor. Larvae are 2–3 millimeters long, white, and have no obvious head.

Life Cycle: Due to this pest's recent arrival, its local life cycle is still uncharacterized. It is likely that a small number of adults will survive the winters. The pest can also be transported into the region in fruit at any time. Each female can lay between 200 and 600 eggs. Eggs hatch in 1 to 3 days depending on temperature, after which larvae feed in the fruit for 5 to 11 days. Pupation lasts for 4 to 15 days. Eight to nine generations per growing season are likely.

Monitoring and Controls: Vinegar traps can be bought or made and are used to monitor for pest presence, but they are not a method of control. Traps containing vinegar should be hung in the crop as the fruit begins to color. Pyrethroids and spinosads are efficacious on the adults; neonicotinoids and some other broad-spectrum materials are less so.

WEEDS

Good weed control begins years before planting. Begin by identifying perennial weed problems in the field. Eliminate these weeds before planting by rotating to crops in which the target perennial weed can be controlled and by using herbicides registered for the crop that control the target weeds. After harvest of these preceding crop(s), spend extra effort to continue control strategies. Early to mid-fall applications of glyphosate products or Banvel can be very effective. Use caution when applying residual herbicides including Banvel and Stinger, as carryover can affect crops the following year. Use cover crops to aid in suppressing weed growth.

A permanent sod such as hard fescue between the rows is effective in controlling weeds in established plantings. Within-row weeds can then be controlled with appropriate herbicides or landscape fabric.

Herbicides labeled for use in bearing and nonbearing currants and gooseberries are Casoron, certain glyphosate products (Roundup, Touchdown, and others), Gramoxone Max 3SC and Gramoxone Inteon 2.76SC, Scythe, Rely, and Surflan AS. Devrinol 50DF is labeled for use on bearing and nonbearing currants. Fusilade DX, Select 2EC, Gallery 75DF, and Snapshot 2.5TG are labeled for use only on nonbearing currants and gooseberries (plants that won't be harvested for at least one year). Other formulations with the same inactive ingredients may exist that are labeled for the same uses.

Glyphosate products and Gramoxone, Scythe and Rely are nonselective postemergence materials. Glyphosate products are translocated within and therefore kill the entire plant, even though only a portion of the plant may have come in contact with the herbicide. Fusilade, Select, and Select Max are selective postemergence materials that are also translocated in the plant, but are effective only on grasses. Gramoxone and Scythe are nontranslocated contact herbicides, and kill only the portion of the plant with which they come in contact. Because of this feature, the roots of treated weeds

survive, and control of perennial weeds is only temporary. Good coverage is a necessity, as untreated portions of the leaves and stems will continue to live. Rely is partially translocated. Casoron, Gallery, Surflan, Devrinol, and Snapshot are preemergence materials, so they must be applied before weeds have germinated. Gallery is effective against annual broadleaves, while Surflan and Devrinol are effective against annual grasses and certain annual broadleaves. Casoron and Snapshot are effective against both annual grasses and annual broadleaf weeds. Casoron also controls some perennials. Before use, always consult the herbicide labels for precautions, reentry intervals, and preharvest intervals.

Remember that weeds compete with each other, not just with crop plants. Therefore, controlling a particular weed or group of weeds may allow another weed species to take over, requiring adjustments to your control strategies.

Table 9.1. Pesticides for *Ribes* disease and insect control.

The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. If control cannot be achieved with a particular material, resistant populations could exist. Use a material in a different activity group, denoted by different designations in the "Group" column. Materials from different activity groups have different modes of action, See Table 3.2 for limits on states in which these cannot be used, use status (general versus restricted), chemical names of active ingredients, and reentry intervals. See Table 3.1 for toxicity to nontarget organisms. Information was current as of July 1, 2012.

Pest	Timing of Treatment/Comments	Group[a]	Product Labeled Rate/A[b] (Days to Harvest)
DISEASES			
Botrytis	During bloom, with additional applications made during harvest, if necessary. Omega can be used only during bloom due to its long days-to-harvest limitation.	17	Elevate 50 WDG, 1.5 lb (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0), ***or***
		2	Rovral 4F, 1–2 pt (0), ***or***
		9, 12	Switch 62.5WG, 11–14 fl oz (0), ***or***
		29	Omega 500DF, 1.25 pt (30), ***or***
		3	Quash, 2.5 oz (7)
Anthracnose leaf spot	At bud break.	M	Lime sulfur (0), 2.5 gal per 100 gal of spray solution, applied at 100–160 gal/A
	When disease symptoms appear, then as needed. Rally is labeled for anthracnose on gooseberries only.	3	Rally 40W, 5.0 oz (0)
Septoria leaf spot	When disease symptoms appear. Watch days-to-harvest limitations on Orbit and Tilt.	11	Abound, 6.0–15.5 fl oz (0), ***or***
		11	Cabrio EG, 14 oz (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0), ***or***
		3	Orbit, 6 fl oz (30), ***or***
		3	Tilt, 6 fl oz (30)
Powdery mildew	Prebloom or postbloom.	NC	Stylet oil, 3–6 qts/100 gal (0), ***or***
		M	Lime sulfur, 1.5 qt per 100 gal of water (0)
	As needed.	3	Rally 40W, 5.0 oz (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0), ***or***
		11	Abound, 6.0–15.5 fl oz (0), ***or***
		11	Cabrio EG, 14 oz (0)
White pine blister rust	When pustules are visible on leaf undersides.	NC	Stylet oil, 3–6 qts/100 gal (0), ***or***
		3	Rally 40W, 5.0 oz (0)

CONTINUED

Table 9.1. Pesticides for *Ribes* disease and insect control, continued.

Pest	Timing of Treatment/Comments	Group[a]	Product Labeled Rate/A[b] (Days to Harvest)
INSECTS			
San Jose scale	At bud break.	—	Superior oil, see label for rate (—)
	When crawlers are present.	*3*	Mustang Max, 4 fl oz (1)
Aphids	Foliar application. Whenever aphids are found. Do not apply Provado prebloom or during bloom. Admire may be applied to the foliage at a low rate.	*1B*	Malathion 57EC, 2 pt (3), ***or***
		—	M-Pede, 1–2% v/v (0), ***or***
		4A	Provado, 3.0–4.0 fl oz (3), ***or***
		4A	Actara, 3.0–4.0 oz (3), ***or***
		4A	Assail 70WP, 1.0–2.3 oz or 30SG, 2.5–5.3 oz (1), ***or***
		3	Brigade WSB, 5.3–16.0 oz (1), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0), ***or***
		4A	Admire Pro, 1.0–1.4 fl oz (3)
	Soil application. Do not apply until bloom is over or when bees are actively foraging.	*4A*	Admire Pro, 7.0–14.0 fl oz (7)
Imported currant worm	Target adults starting soon after bud break, then larvae as fruits start to enlarge.	*1B*	Malathion 57EC, 3.2 pt (3), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)
Currant fruit fly	As adults are noted, starting at petal fall. Delegate is for suppression.	*5*	Success, 4–6 fl oz (3), ***or***
		5	Spintor 2SC, 4–6 fl oz (3), ***or***
		5	Entrust, 1.25–2.0 oz (3), ***or***
		5	Delegate WG, 3–6 oz (3), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)
Currant borer	Late spring to early summer. Pyganic should target adults and Bt products should target larvae before they enter the cane. Insecticides will have no effect once larvae are protected inside the cane.	*3*	Pyganic EC 5.0, 4.5–18 oz (0), ***or***
		11	Bt products, various rates (0), ***or***
		3	Danitol, 10.67–16 fl oz (21)[c]
Gooseberry fruitworm	Target adults at early fruit development and again 10 days later.	*3*	Brigade WSB, 5.3–16 oz (1), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)
Brown marmorated stink bug	If feeding on fruit is causing crop losses.	*3*	Danitol, 10.67–16 fl oz (3, 21)[d]
Spotted wing drosophila	When adult males are found in vinegar traps.	*3*	Danitol, 10.67–16 fl oz (3, 21)[d], ***or***
		5	Delegate WG, 3–6 oz (3), ***or***
		5	Success, 4–6 fl oz (3), ***or***
		5	Entrust, 1.25–2.0 oz (3), ***or***
		3	Mustang Max, 4 fl oz (1), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)

a. Fungicide groups are listed in normal type; insecticide groups are italicized. Chemistry of fungicides by activity groups: 2 = dicarboximides; 3 = imidazoles or triazoles; 7 = carboxamides; 9 = anilinopyrimidines; 11 = strobilurins; 12 = phenylpyrroles; 17 = hydroxyanilides; 29 = activity group not named, chemical group = 2,6-dinitroanilines; M = chemical groups with multisite activity; NC = not classified. Fungicides with two activity groups listed contain active ingredients from two activity groups. Chemistry of insecticides by activity groups: 1B = organophosphates; 3 = pyrethrins and synthetic pyrethroids; 4A = neonicotinoids; 5 = spinosyns; 11 = Bt microbials.

b. Some pesticides may be phytotoxic to plants. If in doubt; test a small area of the field first. Be sure sprayer is calibrated properly.

c. Currant borer is listed only for currants on the Danitol label.

d. The PHI for Danitol is 3 days for gooseberries and 21 days for currants.

APPENDIX A

Expanded Special Topics

CONTENTS

Frost and Freeze Protection 239
Critical Temperatures for Frost Damage .. 239
Types of Frosts and Freezes/Conditions Causing Their Occurrence 239
Environmental Parameters Affecting Frost Occurrence and Protection 240
Effects of Environment on Frosts/Freeze Occurrence 240
Methods for Protecting Plants from Frosts and Freezes 240
Taking Temperature Measurements..... 242
Calibrating Temperature Instruments..... 242
Placement of Temperature Instruments .. 242
Accuracy versus Resolution 242
Types of Thermometers..... 242
Other Gadgets..... 243
How to Conduct a Bioassay to Test for Herbicide Carryover 243
Green Manures 244

FROST AND FREEZE PROTECTION

With most small fruit plants, damage from freezes and frost is a concern from bud break in the spring through flowering and fruit set. The blossoms are of most concern since they are tender and are the plant part most commonly damaged by low temperatures. Depending on the small fruit crop and the site on which it is grown, damage from frosts and freezes may be of concern nearly every year or only occasionally. The likelihood that frost protection will be needed varies because bloom time and critical temperatures are different for each crop. Frost protection will be needed during nearly every year for plasticulture strawberries; in most years for matted-row strawberries; in only some years for blueberries, gooseberries, and currants; and was rarely needed for brambles until recently.

CRITICAL TEMPERATURES FOR FROST DAMAGE

There is no one temperature at which frost damage occurs uniformly. The main cause of frost damage to plants in nature is extracellular ice crystal formation that causes secondary water stress to the surrounding cells. The temperature at which damage occurs varies with the crop and growth stage. Usually there is minimal difference among cultivars. Table A.1 lists commonly accepted critical temperatures for strawberry and blueberry blossoms at different stages of bud development. Note that these values are not absolute and erring on the side of safety is better when protecting crops from frost damage. The length of time that a plant's tissues are exposed to low temperatures has little effect on damage; the critical factor is the low temperature reached, even if it was reached only briefly.

TYPES OF FROSTS AND FREEZES/CONDITIONS CAUSING THEIR OCCURRENCE

Two different situations occur that can cause temperatures to drop to damaging levels:

Radiant frosts and freezes occur on calm, clear nights with no cloud cover. After sunset, the soil and plants lose heat, which radiates back to the sky. This usually occurs a day or two after the passage of a cold front. Since cloudiness accompanies fronts, heat frequently has little opportunity to build up during the hours prior to clearing, thus compounding the problem.

Advective freezes are caused when a cold air mass moves into the region, represented by the classic Alberta clipper, a cold front with a lot of cold air and wind. Therefore, advective freezes are sometimes called windborne freezes. This type of freeze is the most difficult against which to protect. The large air mass that moves in with this type of freeze is dry; therefore, frequently the dew point is considerably below freezing. Since frost or dew does not form until the temperature drops to the dew point, the white crystals typically seen in a frost or freeze may not form. If no frost crystals are visible, this type of event is sometimes referred to as a "black frost." This color also can describe the appearance of the plants that were not sufficiently protected in this type of event.

Table A.1. Critical temperatures for cold damage of flower buds based on stage of development.

Note that with blueberries there is considerable variability in temperatures at which damage was reported for these growth stages.

Strawberries	Critical Temperature (°F)	Blueberries	Critical Temperature (°F)
Bud Emergence	10	Bud Swell	15–20
Tight Bud	22	Tight Cluster	18–23
"Popcorn"	26	Separate Flowers Visible	22–25
Open Blossom	30	Late Closed Blossom	25–26
Green Fruit	28	Open Blossom	27
		Petal Fall	28

Adapted from K. Perry, B. C. Poling, and Richard Funt, *Strawberries,* North Carolina State University; and E. Hanson, and M. Longstroth, "Protecting Blueberries from Frost," *Blueberries: Fruit Crop Advisory Team Alert* 18: 3, Michigan State University.

ENVIRONMENTAL PARAMETERS AFFECTING FROST OCCURRENCE AND PROTECTION

Air temperature is the measurement used for initiating or stopping frost control practices; it can be taken with either a dry-bulb or wet-bulb thermometer. Dry-bulb temperatures are the type commonly referenced in literature and in weather forecasts. Wet-bulb temperatures are obtained from a thermometer that is covered with a wet wick. Air is moved over the bulb either by a fan or by whirling the thermometer through the air. The wet-bulb temperature is useful to know because it is essentially what the plant temperature will be once the irrigation is started and evaporative cooling has taken place.

Wind speeds of more than a few miles per hour can make frost protection difficult, especially in an advective freeze. Light breezes, however, tend to mix the air and can increase temperatures at ground level in the case of radiational frosts. Temperatures tend to be more uniform even across a distance of miles when windy conditions exist.

Dew point is the temperature at which the relative humidity reaches 100 percent as the air cools. At this point, water vapor contained in the air condenses into fog or dew, which gives off heat, slowing the temperature drop. Consequently, on nights when the dew point is in the upper forties or higher, it is unlikely that temperatures will drop to damaging levels. The risk of frost becomes greater as the dew point becomes lower. When dew points are in the mid-30s, frost is very likely. Condensed moisture droplets that freeze or water vapor that sublimes (directly freezes into the solid form without condensing as a liquid first) release heat in doing so. Therefore, if the dew point is below freezing—so that this heat release does not take place until below freezing—temperatures can drop to damaging levels extremely rapidly. Table A.2 can be used for determining the approximate dew point temperatures as calculated from air temperature and relative humidity, the parameters most commonly available.

Relative humidity is the amount of moisture contained in the air relative to the maximum amount that could be held. It changes with temperature and can change quickly with the air mass.

EFFECTS OF ENVIRONMENT ON FROSTS/ FREEZE OCCURRENCE

Site selection is the first and most important step for protecting a small fruit crop from frost or freeze. The best site for frost protection and environmental modification is a site downwind or closely surrounded by a large body of water, such as being within a few miles of the eastern shore of Lake Erie or the Chesapeake Bay, or on necks of land that jut out into the water. In the fall and early winter, the water stays warmer than the surrounding land, making the early winter low temperatures less severe, thus giving plants a chance to acclimate. In the late winter and early spring, the water remains cold, which keeps nearby air temperatures low, delaying early bud development on sensitive crops so that the incidence of damaging frosts is reduced. In these areas, less temperature variation also occurs between the daily minimum and maximum temperatures than elsewhere.

Topography also affects frost occurrence. Cold air is heavier than warm air and, therefore, flows downhill. Temperatures are often higher at the tops of slopes, while cold air collects in the lower areas (frost pockets). Often the temperature will be 4 to 5 degrees lower in these frosty areas compared to higher surrounding areas. Areas surrounded by a continuous timberline of trees can also form a frost pocket, even though the site is elevated or has a slight slope because the "high walls" of the tree line prevent the free flow of cold air off of the site. At some point, though, elevation becomes problematic, especially in the more mountainous areas of western Maryland and Pennsylvania, where cold air is routinely encountered due to high elevation. In these regions, because bud break occurs later in the season when nights are shorter, frosts are often less severe.

Table A.2. Approximate dew points calculated from air temperature and relative humidity values.

	Relative Humidity (%)			
Dry-Bulb Temperature (°F)	25	50	75	100
	Dew Point (°F)			
20	-8	6	14	20
25	-4	10	19	25
30	2	15	24	30
35	5	20	28	35
40	9	24	33	40
45	13	28	38	45
50	17	32	42	50

Adapted from Myers, *G.E.S. Handbook No. 1*, University of Georgia Cooperative Extension Service.

Southern slopes are generally warmer than those facing north, but plants on southern slopes will also come out of dormancy earlier, possibly negating this benefit in many instances.

Soil moisture is an important component of frost protection since a moist soil will retain the heat of the day better than a dry soil. Moist soil will radiate captured heat back to the environment over a longer period of time. If the soil is dry, plantings should be irrigated a day or two ahead of an expected cold snap in order to allow time for heat to be captured.

Soil texture and compaction are also factors since heavier soils with more clay retain heat better than sandy soils. Sandy soils are also often lighter in color and hence tend to reflect more sunlight, rather than absorbing it in the form of heat.

Ground cover affects the amount of heat absorbed and released from the soil surface. A bare, undisturbed moist soil with no ground cover can release sufficient heat to raise temperatures 2 to 3°F in the plant canopy as compared to a sod-, grass-, or straw mulch-covered soil.

METHODS FOR PROTECTING PLANTS FROM FROSTS AND FREEZES

Floating row covers are especially useful for small acreages of low-growing crops and/or when water for overhead irrigation (see below) is not available. The amount of frost protection obtained from using row covers varies with the weight and fiber arrangement of the row cover. The amount of protection usually increases with the weight, though differences in the texture of row covers from different manufacturers make this correlation less than perfect. Row covers weighing 0.6 ounces per square yard typically can give 2 or 3 degrees of

protection during a radiational frost. At the Wye Research and Education Center in Maryland, as much as 11 degrees of protection has been obtained with 1/8-inch thick nursery foam covers, but these covers are not readily available nor are they especially economical. A double layer of lighter-weight row covers provides a similar effect. Weather conditions prior to the frost also affect the amount of protection obtained from row covers. Less heat will be able to accumulate under the covers on cloudy or windy days, so the amount of protection obtained may be only 1 or 2 degrees, especially in the unfortunate situation when the sky remains cloudy until after sunset. When row covers are used for frost protection, they should be pulled onto the crop during mid-afternoon to allow heat to build up under the cover. Row covers can also be used in conjunction with sprinkler irrigation (see below) set up on top of the row cover to minimize the amount of water needed. Row covers used in this way have cut the amount of overhead irrigation needed for frost protection by about 50 percent on average.

Heating or burning may require burning permits issued by local fire departments. It is the oldest method for frost protection, but it is not practical for low-growing small fruit crops like strawberries and is infrequently used in this region. However, if fires or heaters are used, several small ones are better than one large one. Twice as much heat will need to be produced to protect border rows as compared to interior rows.

Wind machines work if a temperature inversion occurs (warm air present above a cold layer) and if there is no wind as with radiant-type freezes. They mix the air by pulling down the warm air from above to replace the colder air trapped near the soil surface. They only provide a few degrees of protection and, therefore, are sufficient protection primarily for crops that bloom relatively late when frosts are usually less severe. Sprinkler irrigation works well on all small fruit crops, but needs to be approached carefully. When used improperly the crop injury level can be greater than if it were not used at all, especially when conditions such as those associated with advective freezes (high wind and low dew point) develop and evaporative cooling occurs at crop level. However, used properly, irrigation can save a crop. Because sprinkler irrigation use can result in the application of large volumes of water to the crop, use should be delayed until greater than 10 percent of the blossoms are in danger of being damaged.

Sprinkler irrigation for frost protection works because when water changes from a liquid to a solid (i.e., freezes) it gives off heat (called the heat of fusion) at the rate of 144 BTUs per pound. Enough water must be applied uniformly over the entire crop area so the heat of fusion offsets evaporative cooling as well as radiational and convective heat losses to maintain the temperature near 32°F. As long as a film of water is over the ice that encases the stem and flowers, the plant will be protected against frost damage. Because of the effect of evaporative cooling, once irrigation is started for frost protection, do not stop it until the sun is up on the crop, temperatures are safely rising above critical temperatures, and ice is sloughing off, or damage can occur.

Frost protection using irrigation works only if the system is already set up and fully functional prior to the frost event, so it should be tested to ensure that it works. An adequate supply of water is also needed. An acre-inch of water equals 27,154 gallons. To protect a 10-acre planting with solid set sprinklers applying 0.2 inches per hour, 54,308 gallons of water are needed for each hour of operation, or 271,540 gallons over a 5-hour protection period. At some growth stages, the critical temperature is very low, and startup of irrigation perhaps could be delayed until temperatures drop quite far. Even when this is the case, irrigation should still be started before ice freezing in the pump or lines can be a problem. Do not shut off the system if there is any chance water will freeze in the pump. Knowing the temperature at the pump or water source is helpful.

A common recommendation is to start the system when the temperature at plant level falls to 4 degrees above the critical temperature (for example, 34°F for open strawberry blossoms). If the dew point is below freezing, irrigation must be started sooner—at a higher temperature. Table A.3 shows temperatures suggested for starting irrigation systems for cold protection for various critical plant temperatures and dew points.

Damage may occur when the air temperature is several degrees above the freezing point because of evaporative cooling. When conditions of wind plus low humidity exist, the droplets could be below 32°F by the time they reach the plant, so some injury could occur when the system is first started. Because of this, the wet bulb temperature appears to be a better indication of when the irrigation system should be used rather than dry bulb (standard thermometer) temperature. Irrigation should be fully operating when the wet bulb temperature equals the critical temperature.

Most overhead sprinkler systems are designed to deliver 0.1 to 0.2 acre-inches of water per hour and are useful for radiant freeze or frost protection when wind speeds are light and temperatures are not below the mid-twenties. Microsprinklers provide more uniform distribution than those having larger droplets and/or those covering a larger area.

Table A.3. Recommended temperatures for starting irrigation at various critical temperatures and dew points.

Critical Temperature (°F)	Dew Point (°F)	Suggested Starting Air Temperature (°F)
30	30	32
30	29	33
30	27	34
30	25	35
30	24	37
30	22	38
30	20	39
30	17	40
32	32	34
32	31	35
32	29	36
32	28	37
32	26	38
32	24	40
32	22	41
32	20	42
32	18	43

Source: *Irrigation* (formerly *Sprinkler Irrigation)* (1983), 5th edition, Arlington, Va.: The Irrigation Association.

The rate at which water freezes, however, depends on several environmental factors, including air temperature, humidity, and wind speed. Generally, the lower the air and dew point temperatures, and/or the higher the wind speed, the greater the rate of freezing. A higher rate of water application is then required for adequate protection. Table A.4 provides a guide for determining the application rates for frost protection at various temperatures, wind speeds, and relative humidity levels. Note that the relative humidity makes a large difference in needed application rates. When breezy conditions (5 mph) are forecast overnight, water supply lines should be moved closer together (from 60- to 40- or 30-foot centers) and the volume of sprinkler heads may still need to be increased by 0.15 to more than 0.25 inches per hour. At 5 to 10 mph, protection will be spotty and damage is a possibility despite your efforts. When wind speeds exceed 10 mph, the risks for crop damage from evaporative cooling due to inadequate water supply or uneven distribution of the water may outweigh the potential benefits.

As mentioned above under the discussion of row covers, overhead irrigation pipes and sprinklers can be set up on row covers and irrigation started after the temperature under the row covers drops near the critical temperature. This is the safest way to protect crops in the case of advective freezes and greatly reduces the amount of water used regardless of the type of frost event. Water can either remain running or be turned off, as long as temperatures under the row cover are monitored with water turned on again if necessary. Because of the necessity of and time required for removing and reapplying the row covers (they can just be gathered into the row middles in which the irrigation pipes are located), this method is best suited for small-acreage plantings. Be sure to uncover the plants as early in the day as possible so that drying of the foliage and pollination can take place.

TAKING TEMPERATURE MEASUREMENTS: ACCURATELY DEPICTING CROP CONDITIONS

Without an accurate determination of conditions in the crop canopy, costly errors can easily be made during frost protection. Obtaining accurate measurements entails making sure that instruments are reading correctly, taking measurements where they reflect the conditions the plant is experiencing, and understanding the limitations of monitoring equipment used.

CALIBRATING TEMPERATURE INSTRUMENTS

Temperature sensors must be calibrated to ensure that you are reading an accurate temperature. Calibrate them by immersing the sensor in a 32°F, gently stirred water and crushed ice slurry. It is best to have more ice than water. Be sure to allow enough time for the device to equilibrate fully, even if you need to keep adding ice to the mixture to keep the temperature at 32°F. Make sure that the sensor or thermometer bulb is submerged in the water. Note that with liquid-in-glass min-max thermometers, the bulb is probably located at the top of the thermometer.

While the thermometer is still in the slurry, note the temperature for use in correcting future readings. If the reading is above 32°F, subtract the difference between 32 and the current reading from future readings. If the reading is below 32, add the difference to future readings. For example, if the ice bath temperature reads 30°F, 2 degrees must be added to future outdoor or canopy temperatures measurements when using that particular thermometer. It helps to write the correction factor on a waterproof tag affixed to each thermometer using waterproof ink (for example "add 2 degrees") in order to avoid confusion at critical times.

PLACEMENT OF TEMPERATURE INSTRUMENTS

With low-growing plants such as strawberries, the coldest temperature in a field is often near the surface where the strawberry plants grow. The difference between air temperature measured at a standard height of 5 feet and plant level can be as much as 5°F. If sensors are placed at the standard height of 5 feet, be sure to account for the possible temperature difference between this height and the ground. Electronic sensors (thermocouples, thermistors) can be placed just at the plant canopy level. Thermocouple tips are sometimes inserted into flower blossoms for a measurement of blossom temperature. In blueberry plantings, several measurements should be taken at different places in the field at the various heights of the plant canopy.

ACCURACY VERSUS RESOLUTION

Recognizing the difference between resolution and accuracy is important when taking measurements. Digital readouts give the impression that because the reading can be noted to the closest tenth or hundredth of a degree, the device measuring the temperature must be accurate. This is not necessarily the case. The reading may be very exact, but it may also be very wrong. Resolution is how fine the divisions are to which the thermometer can be read. Accuracy is how correct the device is. For example, a certain digital thermometer may be advertised as having a resolution of 0.1 degrees but an accuracy of plus or minus 2 degrees. Accuracy is the important figure. Sometimes you'll see a notation that a thermometer is accurate to a certain percentage within its range. For example, if the device is listed as being accurate to within 0.5 percent in its range, and its range is -60 to 140°F, it would be accurate to within 0.5 percent of this 200-degree range, or to within plus or minus 1 degree of any temperature read between -60 and 140°F. This does not mean that it is accurate to within 0.5 percent of any given temperature.

TYPES OF THERMOMETERS

- Liquid-in-glass thermometers, usually relatively inexpensive in price, can vary in their readings. However, they usually vary less than dial thermometers and are a good value. Just be sure to calibrate them as described above. The thermometer can be laid horizontally in the ice slurry. Wet-bulb thermometers tell to what temperature the plant will drop when irrigation is first started. Irrigation should be started when the wet-bulb temperature is 1 to 2 degrees above

Table A.4. Irrigation application rates (inches/hour) for adequate protection of strawberries at various air temperatures, wind speeds, and relative humidity levels.

Air Temperature, Canopy Level (°F)	Wind Speed (mph) 0–1	2–4	5–8	10–14	18–22
AT 50% RELATIVE HUMIDITY					
27	0.10	0.20	0.30	0.40	0.45
24	0.10	0.30	0.35	0.45	0.60
20	0.15	0.35	0.45	0.60	0.75
18	0.20	0.40	0.50	0.65	0.85
AT 75% RELATIVE HUMIDITY					
27	0.05	0.10	0.20	0.20	0.25
24	0.10	0.20	0.30	0.35	0.40
20	0.10	0.25	0.40	0.45	0.60
18	0.15	0.30	0.45	0.55	0.70

Adapted from Perry, (1986), *FROSTPRO Application Rate Model,* North Carolina State University.

the critical temperature, depending on how long it takes to get your irrigation system fully operational. The irrigation should be fully running by the time the wet-bulb temperature drops to the critical temperature.

- Thermocouple thermometers are generally capable of measuring a wide range of temperatures and have very good accuracy, such as being within plus or minus 0.05 percent of the temperatures in their ranges. However, because some types may be capable of reading temperature ranges of hundreds of degrees, the accuracy in terms of degrees may not be much different than that of a liquid-in-glass thermometer, though generally their accuracy is extremely good. So, calibration in an ice-water bath is still recommended before use. The thermocouple probes themselves are quite cheap, but the device to which they connect that produces the readable output can be pricey.
- Thermistor themometers are probably the best option for accuracy, as they are designed to read a relatively narrow temperature range, and have good accuracy. There are models that will be accurate to within plus or minus 0.5° with prices in the moderate range. Calibration is still recommended.

OTHER GADGETS

Electronic devices and plug-in probes offer some useful advantages over standard thermometers. For example, if row covers are being used and the probe is positioned under the row cover with connecting wires outside of it, the temperature under the row cover can be measured without needing to pull the row cover off or crawl under the row cover to check the temperature. Also, once irrigation is turned on, the temperature in the field can be monitored. This may provide peace of mind on windy nights when growers question whether their irrigation rate is sufficient, though little can be done at this point if it is not. One last important note about electronic devices is that the number display on many digital units is not meant to withstand temperatures below freezing, so the display could "black out" when you need it the most! So, you should not plan on leaving the electronic part of the device outside. Instead, use it in the field only when actually obtaining the reading.

Frost alarms and alerts are especially valuable if your field is farther than walking distance away from where you live. Once the temperature drops to a certain point, the alarm sounds a buzzer, calls you on the phone, or flashes a light, depending on the model. If you get a model that calls you, it will likely need to be located where there is access to a phone line. If there is no access to needed utilities near your field, the frost alarm can be installed elsewhere, with the "alert temperature" set high enough to allow for differences between its location and the field.

A useful addition to the equipment that can be used is a device that flashes a light color-coded to the temperature and visible from more than a mile away. This means that it is possible to track the temperature in your field from some distance away or monitor fields in several locations at one time.

HOW TO CONDUCT A BIOASSAY TO TEST FOR HERBICIDE CARRYOVER

Sometimes herbicides that berry crops don't tolerate are used on rotational crops. For example, corn is a desirable crop to include in small fruit rotations because it has almost no pests or diseases in common with berry crops. In addition, growing corn affords an opportunity for weeds to be controlled because corn is tolerant of atrazine, an herbicide that controls a broad range of weeds. However, atrazine residue may still be present at damaging levels in the soil when it is time to plant the berry crop. Other residual herbicides may cause phytoxicity as well. Rotational restrictions are listed on the herbicide label and are an indication of when herbicide carryover problems might be expected.

The most reliable way to tell whether the next crop to be planted might be damaged, regardless of whether the next crop will be berries or another susceptible crop, is to conduct a bioassay. A bioassay simply means that you are using something living—in this case, sensitive plants—to indicate whether it is safe to plant. In this example, growth of the sensitive plants in atrazine-treated soil will be compared to growth of plants in a nontreated (control) soil.

First, collect a representative soil sample from the field treated with atrazine. The soil should be taken from the top few inches of soil. Make sure you include any areas that might have higher concentrations of atrazine, such as areas where you turned the tractor around or higher ground that might be rockier. The sample should be made up of soil from at least eight locations in the field and weigh about 5 pounds.

Second, collect soil of a similar type from an area that was not treated with atrazine or other residual herbicides. If you do not have a suitable area, you can use potting soil or other soil, but

be aware that the time it will take for indicator seedlings to germinate may be different from that in the field soil. Another option is to divide the soil sample from the atrazine-treated field in half and mix in activated charcoal at a rate of 1 teaspoon of activated charcoal per 5 pounds of soil. The activated charcoal will bind with the atrazine and make it inactive. Activated charcoal can be found in drugstores or aquarium supply stores.

Place the soil in gallon-size pots and label the pots. If the soil is too wet, it may be spread out to dry for a few hours, but in any event seeds should be planted within a day or two. Oats, soybeans, or green beans can be used for the test. Sow ten seeds ¼ inch deep or less in each container, water the containers, cover them loosely with plastic wrap to keep them moist, and place them in a warm location where they will get sunlight. Sunlight is needed for development of herbicide injury symptoms. After germination, beans should be thinned to three per pot by snipping off extra plants so excess plant growth doesn't "dilute" the herbicide effect. The target plant population is three snap bean or soybean plants per 5 pounds of soil or ten oat plants per 5 pounds of soil.

Compare plant growth between the herbicide-treated and non-herbicide-treated pots over the next 2 to 3 weeks and watch for symptoms to develop on plants in the herbicide-treated soil. Symptoms develop faster with higher herbicide concentrations. If the temperature is below 70°F, plant growth and symptom development will be slowed. Symptoms will consist of marginal yellowing or browning in the case of atrazine. Symptoms of damage from other herbicides may include misshapen or crinkled leaves, stunted growth, or tissue bleaching, depending on the herbicide used.

The above information was condensed from "A Quick Test for Herbicide Carry-Over in the Soil," Publication G1891, by R. N. Klein, M. L. Bernards, and P. J. Shea, University of Nebraska-Lincoln.

GREEN MANURES: A SAMPLE TWO-YEAR PREPLANT SOIL CONDITIONING PROGRAM

One protocol for managing dagger nematodes with green manures was discussed in Chapter 2. A somewhat more involved program that both builds organic matter and manages nematodes is discussed below for growers who are willing to commit the time and planning to this type of program.

Best results for using green manures for soil conditioning are obtained when they are grown for more than one year prior to planting the small fruit crop. Table A.5 outlines a sample two-year preplant soil-conditioning program for sites where small fruit crops are to be grown. If the plot is to be left fallow for several years, two perennial native bunch grasses—eastern gamagrass and switchgrass—are very deep rooted, will improve soil quality, and will decrease the weed seed pressure. The preplant site conditioning program outlined here is based on research results obtained from various sources throughout the Mid-Atlantic region.

While planting small fruit crops after other fruit crops is not recommended, this is sometimes necessary where space is limited. This is also the situation in which a rotation such as this one is most needed. Therefore, this scenario assumes that a site is used where a previous fruit crop had been grown and dagger nematode populations may have had time to build.

Note: If this is an old bramble, blueberry, or grape planting, apply Roundup, a translocating contact herbicide, to the old crop in September or early October prior to starting this program.
Crops may then be planted as discussed in crop-specific chapters of this guide.

Table A.5. Sample two-year preplant soil conditioning program.

Timing	Site Treatments and Cover Crops	Soil pH and Fertility Adjustments
TWO YEARS BEFORE PLANTING (YEAR BEFORE PLANTING FOR FALL-PLANTED PLASTICULTURE STRAWBERRIES)		
March to early May	Remove old trees, bushes, or vines and their roots. Plow the site thoroughly to expose additional woody roots and large rocks for removal. Collect and submit soil samples drawn from the top 12–16 inches of soil for pH and basic fertility determinations.	Apply lime to adjust soil pH to 6.0–6.5 (pH 4.5–4.8 if site is for blueberries). Incorporate these materials by deep plowing. If more than two tons of lime is required, apply half before plowing and incorporate the remaining half after plowing by disking.
Mid-May	Plant sudex (sorghum x sudan grass hybrid variety of Sorghum bicolor) at 20–25 pounds of seed per acre. Note: Sudex is the crop of choice because it produces a large amount of biomass in a short time and its roots will penetrate at least 4 feet deep or more.	Before planting sudex, broadcast 50 pounds of actual nitrogen per acre and the required amounts of potassium and phosphorus needed for forage crops based on soil test results.
Mid-July through late August	Mow this crop down in mid to late July before seed heads mature. In late August, an additional mowing may be necessary with a flail mower to reduce regrowth before plowing it down thoroughly with a moldboard plow.	An additional 30 pounds of actual nitrogen using ammonium sulfate should be applied after the first mowing to support the bulk of the plant residue of the sudex cover crop while providing some sulfur to subsequent rapeseed crop.
Late August	Plant Dwarf Essex rapeseed at 8 to 10 pounds of seed per acre. In addition to adding more organic matter to the soil, rapeseed produces chemicals that are toxic to plant-parasitic nematodes. Two successive rapeseed crops plowed under as green manure reduce nematode populations equivalent to that achieved with a chemical soil fumigant.	Retest soil pH throughout the top 12–16 inches and add lime to adjust pH to 6.5 if needed. Add 15–20 pounds of additional nitrogen per acre as ammonium sulfate to support rapid, early growth of rapeseed crop. ***Note:*** The sulfur in the ammonium sulfate may acidify the soil slightly at this level, but the added availability of sulfur should increase the amount of toxicants produced within the plant.
ONE YEAR BEFORE PLANTING (YEAR OF PLANTING FOR FALL-PLANTED PLASTICULTURE STRAWBERRIES)		
Mid-April	Mow rapeseed using a flail mower and plow down this plant residue immediately. Note: Mowing injures the plants and initiates a process that releases nematicidal chemicals into the soil. Never mow more area than can be plowed within 1–2 hours. Two weeks after plowing, plant a second crop of Dwarf Essex rapeseed at the same rate noted above.	Retest soil for basic fertility adjustments and then broadcast 50 pounds of actual nitrogen per acre (as ammonium sulfate) and sufficient phosphorus and potassium to support rapeseed based on test results.
Mid-August	Mow the second rapeseed crop using a flail mower and plow down this plant residue immediately as done previously.	After plowing down the second rapeseed crop, use a pH test to determine how much additional lime will be required to adjust the overall soil pH to 6.5. The soil pH on sites intended for blueberries should be 4.5–4.8 at this stage.
Early September	For brambles and blueberries: Approximately 2 weeks after plowing down the second rapeseed crop, plant 20 pounds of certified Kentucky-31 seed and 10 pounds of winter oats per acre. For matted-row strawberries: Plant rye or barley as a winter cover crop unless soil fumigation is used to reduce weed problems. If soil is to be fumigated, plant winter cover crop after labeled treatment safe replant date. ***For plasticulture strawberries:*** Plant as discussed in the strawberry plasticulture section.	Broadcast lime along with 15–20 pounds of actual nitrogen (use calcium nitrate, not ammonium sulfate as nitrogen source). Disk the site deeply to incorporate these materials before planting the fescue cover crop. ***Note:*** Some Kentucky-31 seed is marketed as "endophyte enhanced." The presence of these endophytes (fungi that live within the grass plant) improves growth and may improve nematode control. However, some endophytes are capable of producing toxins that are hazardous to livestock, so this seed and sod should be used only for this purpose, and not as a feed for livestock.
YEAR OF PLANTING (except for plasticulture strawberries)		
April	***For brambles:*** Two weeks before planting, apply glyphosate (Roundup) herbicide as a directed spray to kill the K-31sod cover in 4-foot-wide strips marking the planting rows. ***For matted-row strawberries:*** Proceed with planting as discussed in the strawberry chapter. ***For blueberries:*** Use a two-bottom moldboard plow to open a 4-foot-wide planting strip. See details on final soil preparation in the blueberry chapter.	Leave the killed sod in place and set plants using a mechanical planter or suitable auger. *Note:* Killed sod does not compete with new plants, traps more rain than bare ground, reduces soil loss through erosion, and provides 1–4 weeks of weed suppression.

APPENDIX B

Diagnostic Services

CONTENTS

Introduction 247
Collecting Meaningful Samples and Shipping 247
Soil Samples for Nutrient Analysis 247
Plant Samples for Nutrient Analysis 247
Plant Samples for Disease Diagnosis 248
Insect Identification 248
Soil Samples for Nematode Testing 248
Other Types of Samples 248
University Laboratories 248
Penn State 248
Rutgers University 249
University of Delaware 249
University of Maryland 249
Virginia Tech 249
West Virginia University 250
Private Laboratories in the Mid-Atlantic Region 250
Virus Testing 250
Tissue Analysis Results 250
Specific Element Recommendations for Strawberries at Renovation 251
Specific Element Recommendations for Brambles 252
Specific Element Recommendations for Blueberries 253
University Nematode Assay Forms/ Instructions 254
Rutgers University 255
University of Delaware 257

INTRODUCTION

Various services exist to assist you in making management decisions. These include soil and tissue analysis; disease, insect, or weed identification; and nematode assays. Your extension educator can assist you in determining which service(s) you need. Both university and private laboratories are listed below, along with information on how to obtain sample submission materials.

When university-operated labs provide a free service, samples are usually only accepted from clients within the state. When the service is provided at a reduced cost, labs may accept samples from both in-state and out-of-state clients but with a different fee structure. In other cases, labs can accept samples from any state for the same charge. Contact your extension office or visit each laboratory's Web site for current pricing. In any event, when using a university lab, use the one within your home state to the extent possible. Recommendations are likely to be based on research conducted within the state, specific to local conditions and problems. For problem diagnosis, it is strongly recommended that growers work with their county extension offices, as your local extension educator may be able to help with identifying the problem and provide suggestions for avoiding the problem in the future, as well as correcting existing issues. Your county extension office should have sample submission materials available, or be able to provide you with information on how to obtain them for university-operated labs within your state. Most labs also have this information on their Web sites.

Private labs should be contacted directly for requirements for sending in samples. Omission of laboratories within the region from the listings below implies only a lack of information about the omitted lab, not a lack of suitability or accuracy.

COLLECTING MEANINGFUL SAMPLES AND SHIPPING

Samples must be collected, packaged, and shipped correctly. Sampling from the wrong places, from the wrong parts of the plants, or at the wrong times can waste time and money and result in either inconclusive or erroneous determinations.

SOIL SAMPLES FOR NUTRIENT ANALYSIS

Soil samples obtained should be representative of the area to be tested. There can be a considerable variability among individual small cores of soil within a field, so at least 12 to 15 cores should be taken from the area to be tested. Samples should be air-dried at room temperature before they are sent in. They should not be heated in order to dry them, as this can affect various soil characteristics.

PLANT SAMPLES FOR NUTRIENT ANALYSIS

Nutrient levels in the plant vary greatly during the season; they also vary greatly among leaves of different ages and positions on the same plant. Times to sample as listed below are those when nutrient levels are relatively stable and should always be used for routine monitoring of samples. If sampling must be done at other times of the year, collect separate samples of similar leaves (same age and position on the plant) from plants showing the most and least severe symptoms. Submit these samples for separate analyses so the results can be compared.

What to Sample and When

Matted-row strawberries: Sample the most recently fully expanded leaves as soon as the plants have regrown after renovation.

Plasticulture strawberries: Sample the most recently fully expanded leaves in spring during early to mid-bloom for first harvest-year plantings, or after renovation (as for matted-row strawberries) for plantings that will be carried over.

Brambles: For summer bearers, sample the most recently fully expanded leaves on nonfruiting canes between mid- and late summer. For primocane bearers (fall- or everbearers), sample the most recently fully expanded leaves as late in the summer as possible prior to bloom.

Blueberries: Sample the most recently fully expanded leaves immediately after harvest.

How Many Leaves to Sample

A minimum of 30 leaves of raspberries, blackberries, and strawberries, or 60

leaves of blueberries should be selected for each sample. All leaves comprising each sample should preferably be from the same cultivar, although they should be taken from different plants.

Handling Samples

Detach leaves and remove the petioles. Place leaves in a dry paper bag and send immediately.

Note: In the unusual situation that you suspect very variable soil conditions are causing localized nutrient deficiencies, sample the plants from the problem area(s) independently and use another kit to sample leaves from healthier plants.

PLANT SAMPLES FOR DISEASE DIAGNOSIS

Plant disease labs isolate and identify disease organisms, if present, from plant tissue. Provide information requested on submission forms as accurately as possible, and carefully follow the instructions on packaging and sending your sample. A good packaging job will prevent soil from covering the leaf and stem surfaces in transit, which can obscure diagnostic symptoms. If your plant sample dries out too much before arrival at the lab, disease organisms may not survive, preventing them from "growing out" in culture—a necessary step in identification. Conversely, samples that are too moist may begin to decompose in transit. In both cases, isolating the causal organisms may become impossible, and you will not get the accurate diagnosis you need. When sending in an entire strawberry plant, place the root system in small plastic bag, then tie a rubber band around the crown to keep the soil and plant from drying out and the foliage from becoming covered with soil. Complete instructions for sending various types of samples are detailed on disease clinic websites or can be obtained from laboratory personnel. Send samples in a manner that will avoid their being held over the weekend in transit.

INSECT IDENTIFICATION

Various departments and/or clinics at universities in the region provide insect identification services. Kits provided usually consist of an information form, a container for your insect, and a pre-addressed mailer. Usually soft-bodied insects should be sent in 70 percent alcohol, and hard-bodied insects should be sent in dry. Check with your lab, however, as preferences may differ. Be sure to send your insect in quickly.

SOIL SAMPLES FOR NEMATODE TESTING

Procedures for obtaining and sending in samples for a nematode assay are covered briefly here, in detail in Chapter 1, and in instructions from individual state's labs. Samples should be taken when the soil temperature is above 40°F and the soil is moist. Separate samples should be taken from areas that have been under different management practices, that are of different soil types, or that will be planted to different types of crops. Use a soil sampling tube or similar object taking at least 20 cores to an 8- to 10-inch depth. Sample near feeder roots of plants. If a problem is suspected, sample near plants in early decline since this is where the greatest numbers of nematodes will be found. Do not sample near dead plants since nematodes will have already migrated to other nearby healthy (or slightly affected) plants. Nematodes must remain alive until the sample is processed by the laboratory, so do not allow the samples to overheat and send them to the lab quickly. Include some roots in the sample so that the nematodes will have a food source until the sample is processed.

Make certain that all information requested is included on the nematode assay form that you receive. This information is needed to identify the sample and to aid in interpreting assay data. If you collect more than one sample, you must assign a field number to each area sampled and place that number in the appropriate area of the form. Each plastic bag of soil should be tightly sealed. Keep samples out of direct sunlight to avoid overheating. Samples may also be damaged by heat if they are stored in the trunk of a car or another hot location. Use a Styrofoam cooler to keep samples cool. Heat kills nematodes, and dead nematodes are unsuitable for identification.

OTHER TYPES OF SAMPLES

Additional services such as compost and manure analysis, greenhouse media analysis, plant and weed identification, screening for *Neotyphodium* endophytes, and fungicide resistance screening services are occasionally available. See listings below to get further details.

UNIVERSITY LABORATORIES

PENN STATE

Soil Testing and Plant Analysis (Nutrient Levels)

Agricultural Analytical Services Laboratory
The Pennsylvania State University
Tower Road
University Park, PA 16802

Phone: 814-863-0841
Fax: 814-863-4540
E-mail: aaslab@psu.edu
Web site: www.aasl.psu.edu

Sample submission forms are available from county extension offices in Pennsylvania, from the lab, or can be downloaded from the Web. Testing of compost, greenhouse media, manure, drinking water, irrigation water, and biosolids are also offered.

Plant Disease Identification

Plant Disease Clinic
Department of Plant Pathology
The Pennsylvania State University
220 Buckhout Laboratory
University Park, PA 16802-4507

Phone: 814-865-2204
Web site: plantpath.psu.edu/facilities/plant-disease-clinic

Kits consisting of an information sheet, instructions, and mailing envelope are available at Pennsylvania county extension offices. Information sheets and instructions may also be downloaded from the clinic's Web site as listed above. If samples are forwarded to a commercial lab for certain viruses or other specialized testing after consultation with the client, the cost of that testing is passed on to the client.

Insect Identification

Insect Identification Lab
Department of Entomology
The Pennsylvania State University
501 Agricultural Sciences and Industries Bldg.
University Park, PA 16802

Phone: 814-865-1896

Kits are available at Pennsylvania county extension offices.

Nematode Assays

The nematode diagnostic service at the Fruit Research and Extension Center in Biglerville has been discontinued. Information on nematode testing programs at Virginia Tech, Rutgers, and the University of Delaware are listed below. Contact listed lab personnel before sending samples to find out whether they are accepting out-of-state samples and what the fees are. Other laboratories providing this service can be found on Google by searching "Nematode Testing Services" or "Nematode Diagnostic Service."

RUTGERS UNIVERSITY

Rutgers has a soil and tissue testing laboratory, and a plant diagnostic laboratory.

Soil and Tissue (Nutrient Levels) Testing

Rutgers Soil Testing Laboratory
Rutgers, the State University of New Jersey
57 US Highway 1
New Brunswick, NJ 08901-8554

Phone: 732-932-9295
E-mail: soiltest@njaes.rutgers.edu
Web site: njaes.rutgers.edu/soiltestinglab

Plant Diagnoses

At Rutgers' Plant Diagnostic Laboratory and Nematode Detection Service, services available are disease and insect pest diagnosis and identification, plant and weed identification, fungus and mold identification, nematode assays, fungicide resistance screening, and more. Fee schedules and information forms are available from the lab's Web site, through Rutgers Cooperative Extension offices, or the lab will fax them to you in response to your phone or fax request. The nematode sampling form and instructions are included at the end of this appendix as well. Check with the lab before sending in nematode samples in case prices have changed since this printing.

Mailing Address

Plant Diagnostic Laboratory
Rutgers NJAES
PO Box 550
Milltown, NJ 08850-0550

Street Address (for delivery services other than U.S. Mail):

Plant Diagnostic Laboratory
Rutgers NJAES
Ralph Geiger Turfgrass Education Center
20 Indyk-Engel Way
North Brunswick, NJ 08902

Phone: 732-932-9140
Fax: 732-932-1270
E-mail: clinic@njaes.rutgers.edu
Web site: njaes.rutgers.edu/plantdiagnosticlab

UNIVERSITY OF DELAWARE

Soil Testing

University of Delaware Soil Testing Program
152 Townsend Hall
531 S. College Avenue
Newark, DE 19716-2170
Phone: 302-831-1392
Fax: 302-831-0605
E-mail: soiltest@udel.edu
Web site: ag.udel.edu/dstp

Kits may be obtained from extension offices in New Castle, Kent, and Sussex counties, at the soil testing lab, or by mail from the soil testing lab.

Plant Diseases and Nematode Assays

University of Delaware Plant Diagnostic Clinic
151 Townsend Hall
University of Delaware
Newark, DE 19716-2170

Phone: 302-831-1390
Fax: 302-831-0605
E-mail: bobmul@udel.edu
Web site: ag.udel.edu/Extension/pdc/index.htm

Samples are accepted from in-state clients. Plant submission forms, used primarily for disease diagnosis, are available in PDF format at **ag.udel.edu/Extension/pdc/pdf/UD_Plant_Diagnostic_Form.pdf.**

For nematode assays, forms and sample bags are available for purchase from extension offices in New Castle, Kent, and Sussex counties. Sampling instructions and an information sheet in PDF format are available at **ag.udel.edu/Extension/pdc/pdf/Nematode_Assay_taking_samples.pdf** and are also included at the end of this appendix. Check with the lab before sending in a sample to obtain the current pricing.

UNIVERSITY OF MARYLAND

Diagnosis of Plant Diseases and Plant and Insect Identification

Plant Diagnostic Laboratory
Department of Entomology
Room 3171 Plant Sciences Building
University of Maryland
College Park, MD 20742-4454

Phone: 301-405-1611
Fax: 301-314-9290
E-mail: rane@umd.edu
Web site: www.plantclinic.umd.edu

In-state samples should be submitted through county extension offices, though they may also be mailed in directly. Specimen submission forms may be downloaded from the lab's Web site.

VIRGINIA TECH

Soil Testing

Samples must be submitted through county extension offices, from which submission forms are available. Fee structure varies between commercial and noncommercial samples. Samples are accepted from out-of-state clients for a higher fee.

Virginia Tech Soil Testing Lab
145 Smyth Hall (0465)
Blacksburg, VA 24061

Phone: 540-231-6893
Fax: 540-231-9263
E-mail: soiltesting@vt.edu
Web site: www.soiltest.vt.edu

Plant Disease Identification

Samples must be submitted through county extension offices, from which submission forms are available. Information on selecting and packaging plant specimens is available from the clinic's Web site.

Plant Disease Clinic
106 Price Hall
Virginia Tech
Blacksburg, VA 24061-0331

Phone: 540-231-6758
Fax: 540-231-7477
E-mail: clinic@vt.edu
Web site: www.ppws.vt.edu/~clinic

Insect Identification

Insect Identification Laboratory
Eric R. Day, Manager
Department of Entomology
Virginia Tech
Blacksburg, VA 24061

Web site: www.idlab.ento.vt.edu

Samples may be submitted only through Virginia Cooperative Extension local offices.

Nematode Identification

Nematode Assay Laboratory
115 Price Hall
Virginia Tech
Blacksburg, VA 24061-0331

Phone: 540-231-4650
Fax: 540-231-7477
E-mail: jon@vt.edu
Web site: www.ppws.vt.edu/~clinic/nematode.php

Use the *Nematode Predictive Assay Report* (Pub. 450-098) or *Nematode Diagnostic Assay Report* (Pub.450-901) for submitting samples. Forms are available through Virginia county extension offices. Instructions on how to sample are available from the lab's Web site.

Weed Identification

Weed ID Clinic
Department of Plant Pathology, Physiology, and Weed Science
Virginia Tech
Blacksburg, VA 24061-0331

Web site: www.ppws.vt.edu/~clinic/weedid.php

The form to include with weed samples (Pub. 450-138) is available through county extension offices.

WEST VIRGINIA UNIVERSITY

General information is available at **anr.ext.wvu.edu/pests/identification** on submitting insect, weed and disease specimens.

Soil Testing

WVU Soil Testing Laboratory
Division of Plant and Soil Sciences
PO Box 6108
Morgantown, WV 26506-6108

Phone: 304-293-6023, ext. 4312
Fax: 304-293-2960
E-mail: jgorman@wvu.edu
Web site: www.caf.wvu.edu/plsc/sidemenu/wvu soil lab/soiltest.html

Disease and Insect Identification

Samples may be sent to the Plant Diagnostic Clinic at West Virginia University or to the West Virginia Department of Agriculture.

West Virginia University Plant Diagnostic Clinic
G-151 South Agricultural Sciences Building
PO Box 6108
Morgantown, WV 26506-6108

Phone: 304-293-8838
Fax: 304-293-6954
Web site: anr.ext.wvu.edu/pests/identification

Plant Industries Division
Pest Identification Laboratory
West Virginia Department of Agriculture
1900 Kanawha Blvd. East
Charleston, WV 25305-0191

Phone: 304-558-2212

Weed Identification

Rakesh S. Chandran
1076 Agricultural Sciences Building
PO Box 6108
West Virginia University
Morgantown, WV 26506-6108

Phone: 304-293-6131 ext. 4225
Web form: anr.ext.wvu.edu/r/download/46342

PRIVATE LABORATORIES IN THE MID-ATLANTIC REGION

The labs below primarily offer testing of materials for the concentration of various elements, whether nutrients or contaminants. They typically test a wide range of materials from water to fertilizers. Contact individual labs for details.

A & L Eastern Laboratories, Inc.
7621 Whitepine Road
Richmond, Virginia 23237

Phone: 804-743-9401
Fax: 804-271-6446
E-mail: supportale@aleastern.com
Web site: al-labs-eastern.com

A & L offers analysis of soil, plant tissue, feed and mineral supplements, fertilizers and lime, water, and manure.

Agri Analysis, Inc.
280 Newport Road
Leola, PA 17540

Phone: 717-656-9326 or 1-800-464-6019
Fax: 717-656-0910
E-mail: www.agrianalysis.com/contact-us.php
Web site: www.agrianalysis.com

Agri Analysis tests soil, plant tissue, water, fertilizers and lime, manure, compost and organic material, nutrient solutions, and soilless media. This lab also offers a sample pick-up service in Pennsylvania and parts of Maryland for a fee.

J. R. Peters Laboratory *(primarily for greenhouse and nursery industry)*
6656 Grant Way
Allentown, PA 18106

Phone: 866-522-5752
E-mail: info@jrpeterslab.com
Web site: www.jrpeterslab.com

J. R. Peters analyzes plant tissue, nutrient solutions, and soilless media and offers a media physical analysis.

VIRUS TESTING

Testing for viral pathogens is relatively expensive, and requires following strict protocols. The lab should be called in order to discuss protocols to be followed before sampling or shipping.

Agdia, Inc.
30380 County Road 6
Elkhart, IN 46514 USA

Phone: 574-264-2615 or 800-62-AGDIA (800-622-4342)
Fax: 574-264-2153
E-mail: info@agdia.com
Web site: www.agdia.com

TISSUE ANALYSIS RESULTS: CRITICAL VALUES AND RECOMMENDATIONS

While many labs offer a tissue testing, not all provide interpretations. The values in the following tables are a composite of the best nutrition information currently available for small fruit and are the ones currently used at Penn State's Agricultural Analytical Lab. These values assume that the plant root system is healthy and that the soil pH is within optimal ranges for each crop

(strawberries and brambles: 5.5 to 6.5, blueberries: 4.5 to 5.0). If either of these assumptions is not true, do not attempt to use this information. Information for plasticulture strawberries is presented in the tables below; however, specific recommendations to accompany these values are still under development. If your individual state's lab gives a different interpretation, use your state's information instead, as it may be better suited to your conditions and climate.

Critical Nutrient Values for Strawberries at Renovation

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.50	1.80	2.00	2.80	>3.25
P (%)	0.20	0.25	0.35	0.40	>0.50
K (%)	1.20	1.50	2.00	2.50	>3.00
Ca (%)	0.60	0.70	1.50	1.70	>2.00
Mg (%)	0.25	0.30	0.45	0.50	>0.65
Mn (ppm)	40	50	150	200	>250
Fe (ppm)	50	60	150	250	>325
Cu (ppm)	5	7	10	20	>25
B (ppm)	20	30	60	70	>85
Zn (ppm)	15	20	35	50	>65

SPECIFIC ELEMENT RECOMMENDATIONS FOR STRAWBERRIES AT RENOVATION (Courtesy of Cornell University)

Nitrogen (N)

- *Low N (if N is below 1.8 percent):* Increase rate of N application by 10 percent for each 0.1 percent that the sample is below 2.0 percent. Apply N at renovation and again in mid-September.
- *N is within desired range, but nitrogen to potassium (K) ratio is greater than 1.5:* To improve the balance between N and K in your plants, reduce your N application by 10 percent. Apply N at renovation and again in mid-September.
- *High N (if N is above 2.8 percent):* Reduce rate of N application by 10 percent for each 0.1 percent that the sample exceeds 2.8 percent. Apply N at renovation and again in mid-September.

Phosphorus (P)

- *Low P (if P is below 0.25 percent):* Apply superphosphate at 200 pounds per acre (45 percent P_2O_5) at any time to the soil surface.
- *High P (if P is above 0.4 percent):* Omit phosphate from fertilizer program.

Potassium (K)

- *Low K (if K is below 1.5 percent):* Apply actual potassium at 45, 50, 70, 90, or 100 pounds per acre for soil management groups I (clay), II, III, IV, and V (sand), respectively. If magnesium (Mg) is also low, sulfate of potash-magnesia (Sul-Po-Mag) can be used as a source of K at five times the above rates.
- *High K (if K is above 2.5 percent):* Discontinue use of K fertilizer for one year.
- *K is within range, but N to K ratio is greater than 1.5 and K to Mg ratio is less than 3.0:* To improve the balance between N and K, increase K to a total of 80 pounds actual K.
- *K is within range, but N to K ratio is less than 1.0 and K to Mg ratio is greater than 4.0:* To improve the balance between K and Mg, omit K from your fertilization program.

Calcium (Ca)

- *Low (if Ca is below 0.7 percent):* Apply lime if pH is less than 6.0. See soil test recommendation for adjusting soil pH. If pH is greater than 6.0, apply calcium sulfate at 1,000 pounds per acre.
- *High (if Ca is above 1.7 percent):* May indicate improper soil pH. See soil test recommendation for adjustments.

Magnesium (Mg)

- *Low (if Mg is below 0.3 percent)*—four alternatives:

1. Apply magnesium sulfate (Epsom salts) to the soil surface in late fall or spring at 200 pounds per acre.
2. Sulfate of potash-magnesia (Sul-Po-Mag) can be used if potassium is also low. Use at same rate as magnesium sulfate.
3. Apply dolomitic limestone according to soil test recommendations if pH is below 5.5.
4. Three foliar sprays of magnesium sulfate at two-week intervals beginning after renovation will temporarily correct deficiency (15 pounds per 100 gallons per acre).

- *Mg is in range, but K to Mg ratio is greater than 5.0:* To improve the balance between K and Mg, increase Mg application to a total of 80 pounds per acre actual Mg.
- *High Mg (if Mg is above 0.5 percent):* Omit addition of Mg.

Critical Nutrient Values for Early Season Plasticulture Strawberries

Element	Deficient	Adequate	High
N (%)	<2.8	2.8–3.0	>3.0
P (%)	0.2	0.2–0.4	>0.4
K (%)	1.1	1.1–2.5	>2.5
Ca (%)	<0.4	0.4–1.5	>1.5
Mg (%)	<0.2	0.2–0.4	>0.4
Mn (ppm)	<25	25–100	>100
Fe (ppm)	<50	50–100	>100
Cu (ppm)	<5	5–10	>10
B (ppm)	<20	20–40	>40
Zn (ppm)	<20	20–40	>40

Source: "Hill System Plastic Mulched Strawberry Production Guide for Colder Areas," Virginia Tech, VCE Pub. 438-018.

Manganese (Mn)

- *Low Mn (if Mn is below 50 ppm):* Apply a foliar spray of manganese sulfate (2 pounds per 100 gallons per acre) or manganese chelate (6 pounds per 100 gallons per acre) before September 15. Check for high soil pH.
- *High Mn (if Mn is above 200 ppm):* May indicate a low soil pH or contamination by fungicide or irrigation water. Consult soil test recommendation to determine need for lime. Contamination from sprays may give artificially high readings.

Iron (Fe)

- *Low Fe (if Fe is below 60 ppm):* Apply ferrous sulfate at 4 pounds per 100 gallons per acre or iron chelate at 8 pounds per 100 gallons per acre as a foliar spray before September 15. If condition persists for several consecu-

tive years and soil pH is within desired range, apply 25 pounds per acre iron chelate or 15 pounds per acre ferrous sulfate to soil in early spring.

- *High Fe:* May be toxic if levels exceed 500 ppm. Contamination from sprays may give artificially high readings.

Copper (Cu)

- *Low Cu (if Cu is below 7 ppm):* Apply copper chelate (4 pounds per 100 gallons per acre) in a foliar spray before May 15. If condition persists for several consecutive years and soil pH is within desired range, apply copper sulfate at 20 pounds per acre to soil in late fall.
- *High Cu (if Cu is above 20 ppm):* May indicate low soil pH or contamination from sprays. Consult soil test recommendation to determine the need for lime.

Boron (B)

- *Low B (if B is below 30 ppm):* Apply solubor to the soil at the rate of 4 pounds per acre in early spring or late fall, *or* apply a foliar spray of Solubor (20 percent actual boron) at the rate of 1.5 pound of product per 100 gallons per acre in early spring and again after renovation.
- *High B (if B is above 70 ppm):* Discontinue use of boron. May be toxic if levels exceed 100 ppm.

Zinc (Zn)

- *Low Zn (if Zn is below 20 ppm):* Apply zinc chelate (2 pounds per 100 gallons per acre) once after renovation and again in early May of the following year. If condition persists for several consecutive years and soil pH is within desired range, apply 10 pounds per acre zinc sulfate to soil in fall.
- *Zn is in desired range, but P to Zn ratio is greater than 140:* To improve the balance between phosphorus and zinc, apply 2 pounds of zinc chelate per 100 gallons per acre four times during the growing season. Follow label instructions.
- *High Zn (if Zn is above 50 ppm):* May indicate fungicide contamination. Toxicity can occur if levels exceed 300 ppm.

SPECIFIC ELEMENT RECOMMENDATIONS FOR BRAMBLES

Nitrogen (N)

- *Low N (if N is below 2.0 percent):* Increase rate of nitrogen application by 10 percent for each 0.1 percent that the sample is below desired level. Ammonium nitrate is the best source of nitrogen. Fall fruiting types should be near the high end of the range (3.0 percent). Apply nitrogen before April 20.
- *High N (if N is above 3.0 percent):* Reduce rate of nitrogen application by 10 percent for each 0.1 percent that sample exceeds desired level.

Phosphorus (P)

- *Low P (if P is below 0.25 percent):* Apply 200 pounds per acre superphosphate (45 percent P_2O_5) at any time to soil surface.
- *High P (if P is above 0.40 percent):* Omit phosphate from fertilizer program.

Potassium (K)

- *Low K (if K is below 1.5 percent):* Apply potassium sulfate at 90, 100, 140, 180, or 200 pounds per acre for soil management groups I, II, III, IV, and V, respectively (I = clay, V = sand). If Mg is also low, sulfate of potash-magnesia (Sul-Po-Mag) may be used at 2.5 times the above rates. Do not use muriate of potash.
- *High K (if K is above 2.5 percent):* Stop using potassium fertilizer.

Calcium (Ca)

- *Low Ca (if Ca is below 0.6 percent):* Apply lime as needed if pH is less than 6.0. See soil test recommendation for adjusting soil pH. If pH is greater than 6.0, apply 1,000 pounds per acre calcium sulfate.
- *High Ca (if Ca is above 2.5 percent):* May indicate improper soil pH. See soil test recommendation for adjustments.

Magnesium (Mg)

- *Low Mg (if Mg is below 0.30 ppm):* If pH is below 6.0, apply dolomitic limestone according to soil test recommendation. If not, apply 200 pounds per acre magnesium sulfate (epsom salts) *or* sulfate of potash-magnesia (Sul-Po-Mag) to soil surface in late fall or early spring. Three foliar sprays of magnesium sulfate at 15 pounds per 100 gallons per acre at leaf expansion, after harvest, and in late summer will temporarily correct the deficiency.
- *High Mg (if Mg is above 0.90 ppm):* Omit use of magnesium.

Manganese (Mn)

- *Low Mn (if Mn is below 50 ppm):* Apply a spray of manganese sulfate (2 pounds per 100 gallons per acre) or manganese chelate (6 pounds per 100 gallons per acre) after harvest but before September 15. Check soil pH. For fall fruiting types, apply in June.
- *High Mn (if Mn is above 200 ppm):* May indicate a low soil pH or contamination by fungicide or irrigation water. Consult soil test recommendations to determine need for lime.

Iron (Fe)

- *Low Fe (if Fe is below 50 ppm):* Apply ferrous sulfate at 4 pounds per 100 gallons per acre or iron chelate at 8 pounds per 100 gallons per acre as a foliar spray between harvest and September 15. For fall fruiting types, apply in June. If condition persists for several consecutive years and soil pH is within desired range, apply 25 pounds per acre iron chelate or 15

Critical Nutrient Values for Brambles

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.80	2.00	2.50	3.00	>3.50
P (%)	0.23	0.25	0.35	0.40	>0.50
K (%)	1.45	1.50	2.00	2.50	>3.00
Ca (%)	0.57	0.60	1.70	2.50	>3.00
Mg (%)	0.27	0.30	0.70	0.90	>1.15
Mn (ppm)	45	50	150	200	>250
Fe (ppm)	48	50	150	200	>250
Cu (ppm)	6	7	30	50	>60
B (ppm)	28	30	40	50	>60
Zn (ppm)	18	20	35	50	>65

pounds per acre ferrous sulfate to soil in early spring.

- *High Fe (if Fe is above 200 ppm):* May be toxic if levels exceed 250 ppm. Contamination from sprays may give artificially high readings.

Copper (Cu)

- *Low Cu (if Cu is below 7 ppm):* Apply copper chelate (4 pounds per 100 gallons per acre) in a foliar spray during leaf expansion in May. If condition persists for several consecutive years and soil pH is within desired range, apply 20 pounds per acre copper sulfate to soil in late fall.
- *High Cu (if Cu is above 50 ppm):* May indicate low soil pH or contamination from sprays. Consult soil test recommendation to determine the need for lime.

Boron (B)

- *Low B (if B is below 30 ppm):* Apply Solubor to soil in early spring at 4 pounds per acre, *or* apply a foliar spray of solubor (20 percent actual boron) at the rate of 1.5 pounds product per 100 gallons per acre in early spring. For summer bearers, apply again after harvest.
- *High B (if B is above 50 ppm):* Discontinue use of boron. May be toxic if levels exceed 100 ppm.

Zinc (Zn)

- *Low Zn (if Zn is below 20 ppm):* Apply zinc chelate at the rate of 3 pounds per 100 gallons per acre in a foliar spray at leaf expansion and after harvest. For fall fruit types, apply in May and early July. If condition persists for several consecutive years and soil pH is within desired range, apply 10 pounds per acre zinc sulfate to the soil in fall.
- *High Zn (if Zn is above 50 ppm):* May indicate fungicide contamination. Toxicity may occur if levels exceed 300 ppm.

SPECIFIC ELEMENT RECOMMENDATIONS FOR BLUEBERRIES

Nitrogen (N)

- *Low N (if N is below 1.7 percent):* Increase rate of N application by 10 percent for each 0.1 percent that sample is below desired level. If soil pH is above 5.0, use ammonium sulfate; if below 5.0, use urea. Do not use ammonium nitrate or chloride fertilizers. Apply half of the nitrogen fertilizer at bud break and the remaining half four weeks later.
- *High N (if N is above 2.1 percent):* Reduce rate of nitrogen application by 10 percent for each 0.1 percent that sample exceeds desired level. If soil pH is above 5.0, use ammonium sulfate; if below 5.0, use urea. Do not use ammonium nitrate or chloride fertilizers.

Phosphorus (P)

- *Low P (below 0.06 percent):* Apply 180 pounds per acre superphosphate (45 percent P_2O_5) at any time.
- *High P (above 0.18 percent):* Omit phosphate from fertilizer program.

Potassium (K)

- *Low K (below 0.40 percent):* Apply 400 pounds per acre potassium magnesium sulfate or 160 pounds per acre potassium sulfate in fall or early spring.
- *K is in range and K to Mg ratio is greater than 4.0:* To improve the balance between K and Mg in your plants, omit K from your fertilization program.
- *High K (above 0.65 percent):* Omit K from fertilizer program.

Calcium (Ca)

- *Low Ca (below 0.4 percent):* Refer to soil test and apply lime as needed if soil pH is below 4.0. Apply 1,000 pounds per acre calcium sulfate in fall or early spring if pH is above 4.0.
- *High Ca (above 0.8 percent):* Refer to soil test for pH adjustment.

Magnesium (Mg)

- *Low Mg (below 0.2 percent):* Refer to soil test and apply dolomitic limestone if pH is below 4.0. If pH is above 4.0, apply 250 pounds per acre magnesium sulfate or use Sul-Po-Mag (400 pounds per acre) if K is also low. Apply in fall or early spring.
- *Mg is in range and K-to-Mg ratio is greater than 5.0:* To improve the balance between K and Mg, increase Mg application to a total of 80 pounds per acre actual Mg.
- *High Mg (above 0.3 percent):* May indicate high soil pH. Refer to soil test.

Manganese (Mn)

- *Low Mn (below 50 ppm):* Apply a foliar spray of manganese chelate at 6 pounds per 100 gallons per acre twice during the growing season. If product label offers a different recommendation, follow label recommendation.
- *High Mn (above 500 ppm):* Refer to soil test for possible pH adjustment.

Iron (Fe)

- *Low Fe (below 70 ppm):* Apply a foliar spray of iron chelate at 6 pounds per 100 gallons per acre in late summer and again after bloom the following year, but check product label and follow its recommendation. If conditions persist for several consecutive years and soil pH is within desired range (4.5 to 5.0), apply 25 pounds per acre iron chelate or 15 pounds per acre ferrous sulfate to soil in early spring. If product label offers a different recommendation, follow label recommendation.
- *High Fe (above 300 ppm):* No application necessary.

Critical Nutrient Values for Blueberries

Element	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	1.65	1.70	1.90	2.10	>2.50
P (%)	0.05	0.06	0.10	0.18	>0.22
K (%)	0.35	0.40	0.55	0.65	>0.80
Ca (%)	0.35	0.40	0.60	0.80	>1.00
Mg (%)	0.18	0.20	0.25	0.30	>0.40
Mn (ppm)	45	50	250	500	>650
Fe (ppm)	65	70	200	300	>400
Cu (ppm)	4	5	11	15	>20
B (ppm)	29	30	40	50	>65
Zn (ppm)	14	15	25	30	>40

Copper (Cu)

- *Low Cu (below 5 ppm):* Apply a postbloom and postharvest spray of copper chelate at 2 pounds per 100 gallons per acre. If product label gives a different recommendation, follow label recommendation.
- *High Cu (above 30 ppm):* No application necessary.

Boron (B)

- *Low B (below 30 ppm):* Apply solubor at 1.5 pounds per 100 gallons per acre as a foliar spray in late summer and again during early bloom. If product label gives a different recommendation, follow label recommendation. If condition persists for several consecutive years and soil pH is within desired range (4.5 to 5.0), apply Solubor at 5 pounds per acre to soil surface in early spring.
- *High B (above 50 ppm):* Consult your county extension fruit educator if B is higher than 100 ppm.

Zinc (Zn)

- *Low Zn (below 15 ppm):* Apply zinc chelate at 2 pounds per 100 gallons per acre postbloom, postharvest, and late summer. If product label gives a different recommendation, follow label recommendation. If condition persists for several consecutive years and soil pH is within desired range (4.5 to 5.0), apply 10 pounds per acre zinc sulfate to soil surface in early spring.
- *High Zn (above 30 ppm):* No application necessary.

UNIVERSITY NEMATODE ASSAY FORMS AND INSTRUCTIONS

Provided below are nematode assay forms and instructions for Rutgers University and the University of Delaware. For instructions and forms from other universities, contact the appropriate county extension office in your state.

RUTGERS UNIVERSITY

(See pages 255–56.)

UNIVERSITY OF DELAWARE

(See page 257.)

RUTGERS
New Jersey Agricultural Experiment Station

NEMATODE SOIL ASSAY SUBMISSION FORM

Plant Diagnostic Laboratory
Rutgers NJAES
PO Box 550
Milltown, NJ 08850-0550
www.njaes.rutgers.edu/services

Submitter _____
Address _____
_____
Zip _____ County _____
Phone # _____
Fax # _____
E-mail _____

Reason for sample submission:
- ☐ nematode identification only (pre-plant)
- ☐ nematode identification only (post-plant monitoring)
- ☐ association with plant problem

Previous crop: _____
Present crop & variety: _____
Crop to be planted: _____
Sample / Field I.D. : _____
Date symptoms first appeared: _____
Date sample collected: _____

Office Use Only
Lab # _____
Date _____
Received by _____
Chk# _____
Amt.

METHOD OF PAYMENT:
- ☐ Bill me (commercial clients only)
- ☐ Cash ☐ Check or Money Order
- ☐ Credit Card ☐ VISA ☐ MasterCard

Credit Card No. ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
Exp. Date ☐☐-☐☐ Zip Code _____
Signature:

Please Check All Appropriate Boxes

Location					
Athletic Field	Fallow	Farm Field	Garden	Golf Course	Greenhouse
Landscape	Landscape Turf	Nursery	Orchard	Tree Farm	Vineyard

Other: _____
_____

Plant Part Affected					Distribution on Plant	
Leaves	Branches	Roots	Fruit	Flowers	Top	Bottom

Other: _____
_____

Symptoms									
Leaf Spot	Leaf Yellowing	Leaf Scorch	Leaf Drop	Wilt	Canker	Dieback	Stunting	Abnormal Growth	Root Rot

Other: _____
_____

Soil Information

Distribution in Planting					Soil Type			Soil Drainage				Cultural Practices				Terrain			
Single Plant	Most Plants	In a Group	Down Row	Random	Sandy	Loam	Clay	Good	Moderate	Poor	pH	No-Till	Conventional Till	In-ground Bed	Container	Slope	High Area	Low Area	Level

Size of Planting: _____

Chemicals Applied to Plant or Area

	Product	Rate	Date
Fertilizer			
Fungicide			
Herbicide			
Insecticide			
Nematicide			
Other			

Exposure			Weather Prior to Symptoms					Irrigation		
Full Sun	Partial Sun	Shaded	Avg. Temp.		Average Rainfall			Frequency per Week	Amount (inches)	Time of Day:
			day	night	past week	month	humidity			
							☐high ☐medium ☐low			Type:

062408

Have samples been sent for nutritional analysis? ☐ Yes ☐ No

Have samples been sent for disease analysis? ☐ Yes ☐ No

HOW TO SELECT AND SEND NEMATODE SAMPLES

I. SAMPLING: **(See FS757 'Proper Sampling of Soil and Plant Tissue for Detection of Plant Parasitic Nematodes' for more details.)**

a) Soil from *row and field crops, fallow fields, and home gardens:*

• For each field, take samples from areas with a common crop history. Areas that are different in slope, drainage, and soil type should be sampled and tested separately. Sampling areas should not exceed four acres. Larger fields should be divided into subsections and sampled separately.

• Sample root zones of affected plants at least 6-8 inches below the soil surface. Take a uniform core or thin slice of soil with a spade or soil probe. Follow a systematic pattern (Fig. 1), and sample at least 20 different locations within the sample area. Deposit the soil in a clean bucket, mix well, and submit a 1 qt. subsample in a plastic bag.

b) Soil from *established plantings (i.e., trees, shrubs, fruit crops, and turfgrasses):* Sample each plant species separately. Collect soil from the root zone of declining plants, not dead plants.

• *Fruits and nursery crops:* Remove at least three soil cores per plant, 12 to 15 inches deep, from the fibrous root zone under the canopy of declining plants. Soil samples should be collected from blocks not exceeding four acres and containing plants of a similar species, variety, cultivar, and age. Follow a systematic sampling pattern in the block (Fig. 1), and submit a 1 qt. subsample.

• *Turfgrass:* Collect samples around the margin of the affected patch. Systematic sampling (Fig. 1) from the transition zone ensures optimum results. Soil cores should be collected from the root zone at a depth of 3-5 inches. Submit a 1 qt. subsample.

• *Individual trees and shrubs:* Following a zig-zag pattern around the dripline of each plant, collect soil from the fibrous root zone in several locations (Fig. 2). Sample at a depth of 12-15 inches. Take 10 cores for large specimens and 15 cores for row plantings. Submit a 1 qt. subsample.

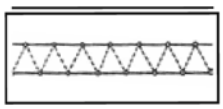


Figure 1. Sampling pattern for row and field crops, home gardens, fallow fields, turf, vineyards, or fruit and nursery blocks.

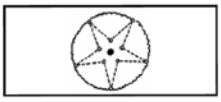


Figure 2. Sampling pattern for trees and shrubs.

II. TIMING OF SOIL SAMPLING:

Soil samples may be taken at any time when the soil temperature exceeds 40 °F. Nematode populations are generally highest in the fall. Samples should be taken when the soil is moist, but not excessively wet or dry.

III. PACKING/SHIPPING:

a) Place a 1 qt. subsample of soil in a plastic bag and seal tightly to prevent drying.
b) Select a strong container, such as a corrugated box or tube, that will not crush in transit.
c) Mail samples early in the week. Samples mailed on Thursday or Friday generally remain in the post office over the weekend where high temperatures can stimulate decay.
d) Complete and enclose this sample submission form and the **appropriate payment (see below) for each sample to be analyzed.** Make checks or money orders payable to **Rutgers, The State University.** See reverse for credit card payment. (Fees are subject to change.)

V. PAYMENT: **(All fees are per sample.)**

Nematode Assay Only:		**Disease/Insect & Nematode Assay (Fine & Sports Turf Only):**	
In-state (except fine turf)	$30	In-state	$120*
In-state fine turf	$60	Out-of-state	$170*
Out-of-state	$95		

* Combination fee applies only to samples from same green, field, etc.

IV. MAILING ADDRESS: Be sure to use appropriate address to help ensure timely delivery.

U.S. POSTAL SERVICE only:
Plant Diagnostic Laboratory
Rutgers NJAES
PO Box 550
Milltown, NJ 08850-0550

Physical address for OTHER DELIVERY SERVICES only:
Plant Diagnostic Laboratory
Rutgers NJAES
Ralph Geiger Turfgrass Education Center
20 Indyk-Engel Way
North Brunswick, NJ 08902

Cooperating Agencies: Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer.

062408

UNIVERSITY OF DELAWARE NEMATODE ASSAY INFORMATION SHEET

(PLEASE PRINT)

COUNTY	PHONE NUMBER
GROWER'S NAME	
ADDRESS	
CITY STATE ZIP	

Fill out this sheet and attach to sample. Samples sent in without information and fee requested on this sheet CANNOT be processed. See reverse for care of samples and how to sample for nematodes.

(NEW CASTLE COUNTY)
461 Wyoming Rd
Newark,DE 19716
(302) 831-2506

(KENT COUNTY)
Phillip Sylvester
Paradee Center
Dover, DE 19901
(302) 730-4000

(SUSSEX COUNTY)
Cory Whaley
Elbert N & Ann V Carvel
Research & Ed Center
16483 County Seat Hwy
Georgetown, DE 19947
(302) 856-7303

*You will receive a Nematode Assay Report, and copies can be sent to your County Extension Agent. *Make sure the numbers in the column "Your Field Number" correspond to the numbers on the soil samples. These numbers are the only means by which our samples can be accurately identified in the laboratory. The other information requested on this sheet is needed to aid in interpreting assay data and making a recommendation.

***If you would like faster service – please provide Fax number or e-mail address.**

Sampled by _____ **Fax #** _____ E-mail: _____ **Date:** _____

Address: _____ **City** _____ **State** _____ **Zip** _____

FIELD HISTORY

Lab Number (Leave Blank)	Your Field Number	Crop To Be Grown Crop-Variety	Crop Last Year Crop-Variety	Crop Before Last Year	Field Size Acres	Additional comments

APPENDIX C

Nursery Sources of Berry Plants

As a service to our readers, we have cross-referenced various small fruit crops with the nurseries where they may be purchased (see table below). No endorsement of the nurseries is intended. Nurseries not listed that can supply quality plants in commercial quantities are requested to contact the coordinator of this publication if they wish to be included in this listing.

Aarons Creek Farms, Inc.
380 Greenhouse Dr.
Buffalo Junction, VA 24529
Phone: 434-374-2174
Fax: 434-374-2055
E-mail: Contact form is at acfplugs.com/contact-us.htm
Web site: acfplugs.com

A. G. Ammon Nursery, Inc.
1610 Rte. 532
Chatsworth, NJ 08019-9707
Phone: 609-726-1370
Fax: 609-726-1270

Awald Farms
2195 Shirley Road
North Collins, NY 14111
Phone: 716-337-3162
E-mail: Sales@awaldfarms.com
Web site: awaldfarms.com/index.html

Barwacz Farm
05146 59th St.
Grand Junction, MI 49056
Phone: 269-253-4419
Fax: 269-253-4495
E-mail: info@barwaczfarm.com
Web site: www.barwaczfarm.com

Blueberry Croft Farm and Nursery
710 Jericho Church Road
Cub run, KY 42729
Phone: 270-908-0703
E-mail: Contact form is at www.blueberrycroft.com/cms/contact-us
Web site: www.blueberrycroft.com/cms/index.php

Boston Mountain Nurseries
20189 N. Hwy. 71
Mountainburg, AR 72946
Phone and Fax: 479-369-2007
E-mail: pense@valuelinx.net
Web site: www.alcasoft.com/bostonmountain

Briggs Plant Propagators, LLC
715 South Bank Rd.
PO Box 658
Elma, WA 98541
Phone: 800-444-1515
Fax: 360-482-6187
E-mail: sales@briggsnursery.com
Web site: www.briggsnursery.com

Cedar Valley Nursery, Inc.
3833 McElfresh Rd. SW
Centralia, WA 98531
Phone: 360-736-7490
Fax: 360-736-6600
(Custom propagating of *Rubus* cultivars in addition to standard production)

Cottle Strawberry Nursery, Inc.
2488 West NC Hwy 403
Faison, NC 28341
Phone: 910-267-4531 or 910-267-1836
Fax: 910-267-0156
E-mail: See www.cottlestrawberry.com/contact.php
Web site: www.cottlefarms.com/plants.php

Daisy Farms
28355 M-152
Dowagiac, MI 49047
Phone: 269-782-6321
Fax: 269-782-7131
E-mail: daisyfarms@qtm.net
Web site: www.daisyfarms.net

DeGrandchamp Farms
76241 14th Avenue
South Haven, MI 49090
Phone: 269-637-3915 or 1-888-483-7431
Fax: 269-637-2531
E-mail: Contact form is at degrandchamps.ipower.com/contact
Web site: www.degrandchamps.com

DiMeo Fruit Farms
3101 Nesco Road
Hammonton, NJ 08037
Phone: 609-561-5905
E-mail: Contact form is at www.dimeofarms.com/contact.html
Web site: www.dimeofarms.com

Fall Creek Farm and Nursery, Inc.
39318 Jasper-Lowell Rd.
Lowell, OR 97452
Phone: 541-937-2973
Fax: 541-937-3373
E-mail: Contact form is at www.fallcreeknursery.com/about/contact/about contact
Web site: www.fallcreeknursery.com

Finch Blueberry Nursery
5526 Finch Nursery Lane
Bailey, NC 27807
Phone: 800-245-4662 or 252-235-4664
Fax: 252-235-2411
E-mail: finchnursery@bbnp.com
Web site: www.danfinch.com/berrys.htm

G. W. Allen Nursery, Ltd.[a]
7295 Hwy 221, RR #2
Centreville, NS, Canada B0P 1J0
Phone: 902-678-7519
Fax: 902-678-5924
E-mail: sales@gwallennursery.com
Web site: www.gwallennursery.com

Hartmann's Plant Co.
PO Box 100
Lacota, MI 49063-0100
Phone: 269-253-4281
Fax: 269-253-4457
E-mail: info@hartmannsplantcompany.com
Web site: www.hartmannsplantcompany.com

Indiana Berry and Plant Co.
2811 US 31
Plymouth, IN 46563
Phone: 800-295-2226
Fax: 574-784-2468
E-mail: info@indianaberry.com
Web site: indianaberry.com
(Also carries an interesting assortment of berry-related items such as promotion supplies, picking containers, and bird-repellent devices; carries some equipment)

Jersey Asparagus Farms, Inc. (see Walker Bros.)

J. W. Jung Seed Company
335 S. High St.
Randolph, WI 53956-0001
Phone: 920-326-5672 or 800-297-3123
Fax: 800-247-5864
E-mail: Contact form is at www.jungseed.com/ContactUs.asp
Web site: www.jungseed.com

Koppes Plants, LLC
PO Box 441
Watsonville, CA 95077-441
Phone: 831-724-6009
Fax: 831-724-5123
E-mail: koppesplants@sbcglobal.net
Web site: www.koppesstrawberryplants.com

Krohne Plant Farms, Inc.
65295 CR342
Hartford, MI 49057
Phone: 269-424-5423
Fax: 269-424-3126
E-mail: info@krohneplantfarms.com
Web site: www.krohneplantfarms.com

Kube Pak Corp.
194 Rt. 526
Allentown, NJ 08501
Phone: 609-259-3114
Fax: 609-259-0487
E-mail: sales@kubepak.com
Web site: www.kubepak.com

Lassen Canyon Nursery, Inc.
1300 Salmon Creek Rd.
Redding, CA 96003
Phone: 530-223-1075
Fax: 530-223-6754
E-mail: info@lassencanyonnursery.com
Web site: www.lassencanyonnursery.com

Lewis Nursery and Farms, Inc.
3500 NC Hwy. 133
Rocky Point, NC 28457
Phone: 910-675-2394
Fax: 910-602-3106
E-mail: infess@bizec.rr.com

Norcal Nursery, Inc.
11810 Highway 99E
PO Box 1012
Red Bluff, CA 96080
Phone: 530-527-6200
Fax: 530-527-2921
Web site: norcalnursery.com

Northwoods Wholesale Nursery
28696 S. Cramer Rd.
Mollala, OR 97038
Phone: 800-651-3738 or 503-651-3737
Fax: 503-651-3882

Nourse Farms, Inc.
41 River Rd.
S. Deerfield, MA 01373
Phone: 413-665-2658
Fax: 413-665-7888
E-mail: info@noursefarms.com
Web site: www.noursefarms.com

Schlabach's Nursery
2784 Murdock Rd
Medina NY 14103
Phone: 585-798-6198

Simmons Berry Farm
11542 North Hwy. 71
Mountainburg, AR 72946
Phone and Fax: 479-369-2345
E-mail: simmonsplantfarm@hotmail.com
Web site: www.simmonsplantfarm.com

Southmeadow Fruit Gardens
10603 Cleveland Ave.
PO Box 211
Baroda, MI 49101
Phone: 269-422-2411
Fax: 269-422-1464*51
E-mail: smfruit@aol.com
Web site: www.southmeadowfruitgardens.com

Stokes Berry Farm
2822 Center Road
Wilmington, OH 45177
Phone: 937-382-4004
Fax: 937-383-0317
E-mail: info@stokesberryfarm.com
Web site: www.stokesberryfarm.com

Strawberry Tyme Farms, Inc.[a]
1250 St. John's Road West, RR #2
Simcoe, Ontario, Canada N3Y 4K1
Phone: 519-426-3099
Fax: 519-426-2573
E-mail: info@strawberrytyme.com
Web site: www.strawberrytyme.com

Tower View Nursery
70912 CR-388
South Haven, MI 49090
Phone: 269-637-1279
Fax: 269-637-6257

V. Kraus Nurseries, Ltd.[a,b]
PO Box 180, 1380 Centre Rd.
Carlisle, Ontario, Canada L0R 1H0
Phone: 905-689-4022
Fax: 905-689-8080
E-mail: sales@krausnurseries.com
Web site: www.krausnurseries.com

Walker Bros.
105 Porchtown Road
Pittsgrove township, NJ 08318
Phone: 856-358-2548
Fax: 856-358-6127
E-mail: Contact form is at www.walkerplants.com/info/contact.php
Web site: www.walkerplants.com

Walter K. Morss & Son
76 Lakeshore Rd.
West Boxford, MA 01921
Phone: 508-352-2633

Waters J9 Blueberry Farm
600 Ditney Road
Madisonville, KY 42431
Phone: 270-322-9222
E-mail: dj@watersfamily.com
Web site: www.watersj9blueberryfarm.com

Weeks Berry Nursery
6494 Windsor Island Road North
Keizer, OR 97303
Phone: 503-393-8112
Fax: 503-393-2241
E-mail: plants@weeksberry.com
Web site: www.weeksberry.com

Whitman Farms
3995 Gibson Road NW
Salem, OR 97304
Phone: 503-585-8728
Fax: 503-363-5020
E-mail: Lucile@whitmanfarms.com
Web site: www.whitmanfarms.com

Windermere Orchards & Nursery[a]
199 Windermere Road, RR #1
Berwick, NS B0P 1E0
Canada
Phone: 902-538-3213
Fax: 902-538-0244

Zilke Bros. Nursery
8924 Cleveland Ave.
Baroda, MI 49101
Phone: 269-422-2666

---

a. Phytosanitary certificates are required for importation of all small fruit crops from Canada. This may mean additional charges by Canadian nurseries; contact individual nurseries for details. In addition, importation of Rubus into the United States from Canada requires Form PPQ587 (application for permit to import plants), which may be obtained from individual states' Department of Agriculture offices. Form may also be downloaded from the USDA APHIS Web site. Go to **www.aphis.usda.gov/plant_health/permits/downloads/forms/ppqform587.pdf.**

b. Distributes plants only through other nurseries. Call for information on distributors.

Source	Strawberry		Blueberry	Raspberry				Blackberry	Gooseberry	Currants	Elderberry	Hardy Kiwi	Cranberry	Misc.
	Dormant	Plugs		Red	Gold	Black	Purple							
Aarons Creek Farms		•												
A. G. Ammon Nursery			•											
Awald Farms				•	•	•		•						
Barwacz Farm			•											
Blueberry Croft Farm & Nursery			•											•
Boston Mountain Nurseries			•	•		•		•	•		•			
Briggs Plant Propagators			•					•						
Cedar Valley Nursery				•	•	•		•						
Cottle Strawberry Nursery		•[a]												
Daisy Farms	•		•	•		•		•						
DeGrandchamp Farms			•										•	•
DiMeo Fruit Farms			•	•		•		•						•
Fall Creek Farm and Nursery			•	•	•			•						
Finch Blueberry Nursery			•											
G. W. Allen Nursery	•		•	•			•	•						
Hartmann's Plant Co.			•	•	•	•	•	•	•	•	•	•	•	•
Indiana Berry and Plant Co.	•		•	•	•	•	•	•	•	•	•	•	•	•
J. W. Jung Seed Co.	•		•	•	•	•		•	•	•	•	•		•
Koppes Plants	•													
Krohne Plant Farms	•													
Kube Pak Corp.		•												
Lassen Canyon Nursery	•							•						
Lewis Nursery and Farms	•	•[a]	•					•						
NorCal Nursery	•			•		•		•						
Northwoods Wholesale Nursery									•	•	•	•		•
Nourse Farms	•		•	•	•	•	•	•	•	•	•			
Schlabach's Nursery	•		•	•		•		•						
Simmons Berry Farm	•		•	•	•	•		•	•					•
Southmeadow Fruit Gardens									•	•				•
Stokes Berry Farm				•		•		•						
Strawberry Tyme Farms	•		•	•	•	•	•	•						
Tower View Nursery			•											•
V. Kraus Nurseries[b]	•		•	•					•	•				
Walker Bros.		•												
Walter K. Morss & Son	•		•	•	•									
Waters J9 Blueberry Farm														
Weeks Berry Nursery	•		•	•	•	•		•	•	•	•			•
Whitman Farms					•					•		•		•
Windermere Orchards & Nursery	•													
Zilke Bros. Nursery		•												

a. Also supplies runner tips for growers who wish to root their own plug plants.

b. Distributes through other nurseries. Call for information on local distributors.

A P P E N D I X D

Production Supplies and Services

CONTENTS

Production Supplies....263
Bird Damage Control....263
Cover Crop Seed....264
Frost Monitoring Equipment....264
High Tunnels....264
IPM—Beneficial Insects....264
IPM—Monitoring Supplies....264
Irrigation and Moisture Monitoring Supplies....265
Mammal Repellents....266
Mammal Cage or Box Traps....266
Monofilament Grape Trellis Wire....266
Packaging....266
Personal Protective Equipment....267
Petiole Sap Meters (Ion Meters)....267
pH Meters....267
Row Covers, Plastic Mulch....267
Promotional Supplies....267
Specialized Equipment....268
Organic Products....268
Services....268
Analysis of Soil and Plant Tissue....268
Fumigation....268
Plastic Recovery....268
Pollinators....268

No endorsement of the companies listed below is intended. Suppliers not listed that deal in commercial quantities are requested to contact the coordinator of this publication if they wish to be included in this listing.

PRODUCTION SUPPLIES

BIRD DAMAGE CONTROL

Bird Barrier
74 henry street
Secaucus, nj 07094
Phone: 800-503-5444
Fax: 201-348-1385
E-mail: customercare@birdbarrier.com
Web site: www.birdbarrier.com
(Balloons, netting, spike systems, other scare devices)

Bird Gard, LLC
PO Box 1690
270 E. Sun Ranch Drive
Sisters, OR 97759
Phone: 888-332-2328 or 541-549-0205
Fax: 541-549-5286
E-mail: info@birdgard.com
Web site: www.birdgard.com
(Digital recordings of bird distress calls)

Bird-X, Inc.
300 N. Oakley Blvd.
Chicago, IL 60612
Phone: 800-860-0473
Fax: 312-226-2480
E-mail: customerservice@bird-x.com
Web site: www.bird-x.com
(Scare devices, roost barriers, repellents, sound devices, plastic owls and hawks, balloons, reflective tape, netting)

Endurance Net, Inc.
PO Box 127
Roebling, NJ 08554
Phone: 800-808-6387 or 609-499-3450
Fax: 609-499-3520
E-mail: info@endurancenetinc.com
Web site: www.endurancenetinc.com
(Netting)

Fly Bye Bird Control Products
13609 NE 126th Pl #150
Kirkland, WA 98034
Phone: 800-820-1980 or 425-820-8496
Fax: 425-821-5672
E-mail: nobirds@flybye.com
Web site: www.flybye.com
(Netting and visual scare devices)

Gempler's
PO Box 44993
Madison, WI 53744-4993
Phone: 800-382-8473
Fax: 800-551-1128
E-mail: customerservice@gemplers.com
Web site: www.gemplers.com
(Visual and auditory scare devices)

Hartmann's Plant Co.
PO Box 100
Lacota, MI 49063-0100
Phone: 269-253-4281
Fax: 269-253-4457
E-mail: info@hartmannsplantcompany.com
Web site: www.hartmannsplantcompany.com
(Netting)

Indiana Berry and Plant Co.
2811 US 31
Plymouth, IN 46563
Phone: 800-295-2226
Fax: 574-784-2468
E-mail: info@indianaberry.com
Web site: indianaberry.com
(Scare-eye, netting, reflective tape)

Industrial Netting
7681 Seltzer Pkwy. N.
Minneapolis, MN 55445
Phone: 800-328-8456 or 763-496-6355
Fax: 763-496-6356
E-mail: info@industrialnetting.net
Web site: www.industrialnetting.com
(Netting)

J. A. Cissel
1995 Rutgers University Blvd.
PO Box 2035
Lakewood, NJ 08701
Phone: 800-631-2234 or 732-901-0300
Fax: 732-901-1166
E-mail: info@jacissel.net
Web site: www.jacissel.net
("Knitted" netting)

JWB Marketing, LLC
2308 Raven Trail
W. Columbia, SC 29169
Phone: 800-555-9634 or 803-939-9622
Fax: 803-796-0654
E-mail: JimB@birddamage.com
Web site: www.birddamage.com
(Distress calls, scare windmills, eagle and hawk kites)

Nixalite of America, Inc.
1025 16th Ave.
East Moline, Il 61244
Phone: 888-624-1189
Fax: 888-624-1196
E-mail: sales@nixalite.com
Web site: www.nixalite.com
(Netting, repellents, visual scare devices)

Orchard Valley Supply, Inc.
5610 Harrisburg Industrial Park Dr.
Harrisburg, NC 28075
Phone: 888-755-0098 or 704-455-4933
Fax: 704-455-4952
E-mail: info@orchardvalleysupply.com
Web site: www.orchardvalleysupply.com
(Visual and auditory scare devices)

Reed-Joseph International Co.
800 Main St.
PO Box 894
Greenville, MS 38702
Phone: 800-647-5554
Fax: 662-335-8850
E-mail: sales@reedjoseph.com
Web site: www.reedjoseph.com
(Visual and auditory scare devices, Rejex-it)

Sutton Ag Enterprises, Inc.
746 Vertin Ave.
Salinas, CA 93901
Phone: 866-280-6229 or 831-422-9693
Fax: 800-482-4240 or 831-422-4201
E-mail: info@suttonag.com
Web site: www.suttonag.com
(Netting, visual and auditory scare devices)

Wildlife Control Technology, Inc.
2501 N. Sunnyside Ave.
Fresno, CA 93727
Phone: 800-235-0262 or 559-490-2262
Fax: 559-490-2260 (sales) or 559-490-2274 (service)
E-mail: sales@wildlife-control.com
Web site: www.wildlife-control.com
(Netting, visual and auditory scare devices, owl nest boxes)

COVER CROP SEED

Albert Lea Seed House
1414 W. Main Street
Albert Lea, MN 56007-1816
Phone: 800-352-5247
E-mail: seedhouse@alseed.com
Web site: www.alseed.com

Ernst Conservation Seeds
9006 Mercer Pike
Meadville, PA 16335
Phone: 800-873-3321or 814-336-2404
Fax: 814-336-5191
E-mail: sales@ernstseed.com
Web site: www.ernstseed.com

Fedco Seeds
PO Box 520
Waterville, ME 04903
Phone: 207-873-7333 or 207-430-1106
Web site: www.fedcoseeds.com
(Untreated and certified organic seed)

Johnny's Selected Seeds
955 Benton Ave.
Winslow, ME 04901
Phone: 877-564-6697
Fax: 800-738-6314
Web site: www.johnnyseeds.com
(Untreated seed)

Seven Springs Farm
426 Jerry Lane NE
Check, VA 24072
Phone: 800-540-9181 or 540-651-3228
E-mail: 7springs@swva.net
Web site: www.7springsfarm.com
(Untreated and certified organic seed)

FROST MONITORING EQUIPMENT

Omega Engineering
PO Box 4047
Stamford, CT 06907
Phone: 800-848-4286 or 203-359-1660
Fax: 203-359-7700
E-mail: sales@omega.com
Web site: www.omega.com
(Thermocouples, thermometers)

Nolt's Produce Supplies
152 North Hershey Ave.
Leola, PA 17540
Phone: 717-656-9764
Fax: 717-556-0700
E-mail: noltsproduce@earthlink.net
(Remote frost alarm)

Spectrum Technologies, Inc.
12360 S. Industrial Drive East
Plainfield, IL 60585
Phone: 800-248-8873 or 815-436-4440
Fax: 815-436-4460
E-mail: info@specmeters.com
Web site: www.specmeters.com
(Remote frost alarms)

HIGH TUNNELS

Farmtek
1440 Field of Dreams Way
Dyersville, IA 52040
Phone: 800-327-6835
Fax: 800-457-8887
Web site: www.farmtek.com
(Single-bay tunnels)

Haygrove USA East
Ralph and Keith Cramer
694 Kraybill Church Road
Mount Joy, PA 17552
Phone: 866-haygrove
Fax: 717-492-4959
E-mail: Contact form available at www.haygrove.com/contact-us
Web site: www.haygrove.com/haygrove-usa
(Multibay and single-bay tunnels)

Greenhouse Supply, Inc.
12 Acme Rd., Suite 212
Brewer, ME 04412-1546
Phone: 800-696-8511 or 207-989-1585
Fax: 207-989-1553
E-mail: greenhse@agrotech.com
Web site: www.agrotech.com
(Single-bay tunnels)

Ledgewood Farm
132 old mountain road
Moultonborough, NH 03254
Phone: 603-476-8829
E-mail: ed@ledgewoodfarm.com
Web site: www.ledgewoodfarm.com
(Single-bay tunnels)

Rimol Greenhouse Systems, Inc.
Northpoint Industrial Park
40 Londonderry Turnpike
Hooksett, NH 03106
Phone: 877-746-6544 or 603-629-9004
Fax: 603-629-9023
Web site: www.rimolgreenhouses.com
(Single-bay tunnels, including moveable ones on tracks)

IPM—BENEFICIAL INSECTS

Biocontrol Network
5116 Williamsburg Road
Brentwood, TN 37027
Phone: 800-441-2847
Fax: 615-370-0662
E-mail: ebugs@biconet.com
Web site: www.biconet.com

IPM Laboratories, Inc.
PO Box 300
Locke, NY 13092-0300
Phone: 315-497-2063
Fax: 315-497-3129
E-mail: ipminfo@ipmlabs.com
Web site: www.ipmlabs.com

The Green Spot, Ltd.
93 Priest Rd.
Nottingham, NH 03290-6204
Phone: 603-942-8925
Fax: 603-942-8932
E-mail: Contact form is at greenmethods.com/site/contact/#gb_form
Web site: www.greenmethods.com

IPM—MONITORING SUPPLIES

Gempler's
PO Box 44993
Madison, WI 53744-4993
Phone: 800-382-8473
Fax: 800-551-1128
E-mail: customerservice@gemplers.com
Web site: www.gemplers.com
(Traps, monitoring equipment, water-sensitive paper targets)

Great Lakes IPM, Inc.
10220 E. Church Road
Vestaburg, MI 48891-946
Phone: 800-235-0285 or 989-268-5693
Fax: 989-268-5311
E-mail: glipm@greatlakesipm.com
Web site: www.greatlakesipm.com
(Baited and unbaited sticky traps, monitoring equipment)

Trece, Inc.
7569 Highway 28 West
PO Box 129
Adair, OK 74330
Phone: 866-785-1313 (for orders) or 918-785-3061
Fax: 918-785-3063
E-mail: custserv@trece.com
Web site: www.trece.com
(Traps, baits)

IRRIGATION AND MOISTURE MONITORING SUPPLIES

Aquaterr Instruments & Automation
1685 Babcock Street Unit A
Costa Mesa, CA 92627
Phone: 800-284-1201
Fax: 949-646-7493
E-mail: sales@aquaterr.net
Web sites: www.aquaterr.net
(Soil moisture, temperature, and salinity meters)

Belle Terre Irrigation
8142 Champlin Road
Sodus, NY 14551
Phone: 866-478-3747 or 315-483-6155
Fax: 315-483-4064
E-mail: dripsupply@hotmail.com
Web site: www.dripsupply.com
(Drip irrigation supplies and design)

Berry Hill Irrigation, Inc.
3744 Highway 58
Buffalo Junction, VA 24529
Phone: 800-345-3747 or 434-374-5555
Fax: 434-374-0131
E-mail: sales@berryhilldrip.com
Web site: www.berryhilldrip.com
(Drip irrigation supplies, tensiometers, injectors, soluble fertilizers, etc.)

Dosatron International
2090 Sunnydale Blvd.
Clearwater, FL 33765
Phone: 800-523-8499 or 727-443-5404
Fax: 727-447-0591
Web site: www.dosatronusa.com
(Injectors, etc.)

Dosmatic
1230 Crowley Circle
Carrollton, TX 75006
Phone: 800-344-6767 or 972-245-9765
Fax: 972-245-9000
E-mail: sales@dosmatic.com
Web site: www.dosmatic.com
(Injectors)

Forestry Suppliers, Inc.
205 West Rankin St.
PO Box 8397
Jackson, MS 39284-8397
Phone: 800-647-5368
Web site: www.forestry-suppliers.com
(Tensiometers, other soil moisture sensing equipment)

Irrometer Company, Inc.
PO Box 2424
Riverside, CA 92516-2424
Phone: 951-689-1701
Fax: 951-689-3706
E-mail: sales@irrometer.com
Web site: www.irrometer.com
(Tensiometers, other soil moisture sensing equipment)

Jain Irrigation, Inc.
740 Water St.
Watertown, NY 13601
Phone: 800-242-7467
Fax: 866-329-2427
Web site: www.jainsusa.com
(Drip irrigation supplies)

Lee Rain, Inc.
2079 E. Wheat Rd.
Vineland, NJ 08361
Phone: 877-533-7878 or 856-691-4030
Fax: 856-691-1990
E-mail: sales@leerain.com
Web site: www.leerain.com
(Drip and overhead irrigation)

Mazzei Injector Company, LLC
500 Rooster Dr.
Bakersfield, CA 93307-5555
Phone: 661-363-6500
Fax: 661-363-7500
E-mail: info@mazzei.net
Web site: www.mazzei.net
(Injectors)

Nolt's Produce Supplies
152 North Hershey Ave.
Leola, PA 17540
Phone: 717-656-9764
Fax: 717-556-0700
E-mail: noltsproduce@earthlink.net

O. A. Newton
16356 Sussex Highway
PO Box 397
Bridgeville, DE 19933
Phone: 800-726-5745 or 302-337-8211
Fax: 302-337-3739
E-mail: irrigation@oanewton.com
Web site: www.oanewtonirrigation.com
(Irrigation systems and installation)

Penn State Seed Co. (main office)
Highway 309, RR 1 Box 390
Dallas, PA 18612-9781
Phone: 800-847-7333 or 570-675-8585
Fax: 570-675-6562
E-mail: sales@pennstateseed.com
Web site: www.pennstateseed.com
(Overhead and trickle irrigation supplies)

Other Penn State Seed Locations

224 Maple Avenue
Bird-in-Hand, PA 17505-9703
Phone: 800-917-7333 or 717-295-9808
Fax: 717-295-1460
and
Hwy. 206, Box 1508
Mount Holly, NJ 08060-9694
Phone: 800-385-7333 or 609-265-8600
Fax: 609-265-9449

Rainbow Irrigation Systems
One Rainbow Drive
PO Box 70
Fitzgerald, Georgia 31750
Phone: 229-423-4341
Fax: 229-423-4645
Web site: www.rainbowirrigation.com
(Overhead irrigation)

Rain-Flo Irrigation
929 Reading Road
East Earl, PA 17519
Phone: 717-445-3000
Fax: 717-445-8304
E-mail: sales@rainfloirrigation.com
Web site: www.rainfloirrigation.com
(Trickle and overhead irrigation supplies, etc.)

Robert Marvel Plastic Mulch, LLC
2425 Horsehoe Pike
Annville, PA 17003
Phone: 800-478-2214 or 717-838-0976
Fax: 717-838-0978
E-mail: info@robertmarvel.com
Web site: www.RobertMarvel.com
(Drip irrigation)

Trickl-Eez Co.
3550 Chambersburg Rd.
Biglerville, PA 17307
Phone: 800-672-4700 or 717-337-3030
Fax: 717-337-1785
E-mail: info@trickl-eez.com
Web site: www.trickl-eez.com
(Overhead and trickle irrigation supplies, etc.)

Troyer Grower's supply
817 Rt. 97
Waterford, PA 16441
Phone: 814-796-7082
Fax: 814-796-2751
E-mail: info@troyerinc.com
Web site: www.troyerinc.com/growers_supply

Zimmerman Irrigation, Inc.
(see Trickl-Eez Co.)

MAMMAL REPELLENTS

Biocontrol Network
5116 Williamsburg Road
Brentwood, TN 37027
Phone: 800-441-2847
Fax: 615-370-0662
E-mail: ebugs@biconet.com
Web site: www.biconet.com

Deer-Out, LLC
PO Box 290
South Plainfield, NJ 07080
Phone: 908-769-4242
Fax: 908-769-3253
E-mail: info@deerout.com
Web site: www.deerout.com
(Deer-Off Deer Repellent)

Faesy and Besthoff, Inc.
143 River Road
PO Box 29
Edgewater, NJ 07020-1002
Phone: 201-945-6200
Fax: 201-945-6145
(Rabbit and Dog Chaser)

Havahart
Woodstream Corp.
69 N. Locust Street
Lititz, PA 17543
Phone: 800-800-1819
E-mail: consumercare@havahart.com
Web site: www.havahart.com

Hot Pepper Wax
305 Third St.
Greenville, PA 16125
Phone: 800-627-6840
Fax: 724-646-2302
E-mail: sales@hotpepperwax.com
Web site: www.hotpepperwax.com

Miller Chemical and Fertilizer Corp.
Box 333, 120 Radio Road
Hanover, PA 17331
Phone: 717-632-8921
(Hot Sauce Animal Repellent)

Nott Products Co., Inc.
PO Box 975
Coram, NY 11727
Phone: 631-563-4455
Fax: 631-563-3950
E-mail: nottproducts@aol.com
Web site: www.nottproducts.com
(Nibble-Not and Chew-Not)

MAMMAL CAGE OR BOX TRAPS

Havahart
Woodstream Corp.
69 N. Locust Street
Lititz, PA 17543
Phone: 800-800-1819
E-mail: consumercare@havahart.com
Web site: www.havahart.com

H. B. Sherman Traps, Inc.
3731 Peddie Drive
Tallahassee, FL 32303
Phone: 850-575-8727
Fax: 850-575-4864
Web site: www.shermantraps.com

Tomahawk Live Traps, LLC
PO Box 155
Hazelhurst, WI 54531
Phone: 800-272-8727
Fax: 715-356-4611
E-mail: trapem@livetrap.com
Web site: www.livetrap.com

MONOFILAMENT GRAPE TRELLIS WIRE

Amberg's Nursery, Inc.
3164 Whitney Rd.
Stanley, NY 14561
Phone: 585-526-5405
Fax: 585-526-6522
E-mail: info@ambergs.com
Web site: www.ambergs.com

PACKAGING

Belle Terre Irrigation
8142 Champlin Road
Sodus, NY 14551
Phone: 866-478-3747 or 315-483-6155
Fax: 315-483-4064
E-mail: dripsupply@hotmail.com
Web site:www.dripsupply.com
(Carries packaging supplies in addition to irrigation)

First State Packaging, Inc.
511 Naylor Mill Rd.
Salisbury, MD 21802
Phone: 410-546-1008
Web site: www.firststatepackaging.com

Frecon Orchard Supplies
231 Powder Mill Road
Boyertown, PA 19512
Contact: Richard Frecon, Jr.
Phone: 610-367-2933
Fax: 610-367-2934
E-mail: www.carton75@aol.com

Grower's Discount Labels, LLC
PO Box 70
632 Tunnel Road
Tunnel, NY 13848
Phone: 800-693-1572 or 607-693-1572
Fax: 607-693-4415
E-mail: info@growersdiscountlabels.com
Web site: www.growersdiscountlabels.com
(Custom labels)

Jordan Seeds, Inc.
6400 Upper Afton Road
Woodbury, MN 55125-1146
Phone: 651-738-3422 or 651-739-9578
Fax: 651-731-7690
Web site: www.jordanseeds.com

Kurt Zuhlke & Assoc., Inc.
PO Box 609
Bangor, PA 18013-0609
Phone: 800-644-8729
E-mail: sales@producepackaging.com
Web site: producepackaging.com

Monte Package Co.
3752 Riverside Rd.
Riverside, MI 49084-0126
Phone: 800-653-2807 or 269-849-1722
E-mail: sales@montepkg.com
Web site: www.montepkg.com

Pactiv Corporation
1900 West Field Court
Lake Forest, IL 60045
Phone: 888-828-2850 or 847-482-2000
Web site: www.pactiv.com
(Company headquarters; not a distributor)

Putnam Plastics, Farm Products Div.
255 S. Alex Rd.
West Carrollton, OH 45449
Phone: 800-457-3099 or 937-866-6261
Fax: 937-866-9365
E-mail: packaging@putnamfarm.com
Web site: www.putnamfarm.com

Rockford Package Supply, Inc.
10421 Northland Dr.
Rockford, MI 49341
Phone: 800-444-7225 or 616-866-0143
Fax: 616-866-4921
Web site: www.rockfordpack.com

Southern Container Corporation of Wilson, Inc.
PO Box 216
6003 Ward Blvd.
Wilson, NC 27894-0216
Phone: 800-261-2295 or 252-237-0539
Fax: 252-237-0308
E-mail: sales@socontainers.com
Web site: www.socontainers.com

Wasserman Bag Co., Inc.
70 Commerce Place
Hicksville, NY 11801
Phone: 800-634-3828 or 516-681-5900
Fax: 516-681-5905
E-mail: wassermanbag@aol.com
Web site: www.wassermanbag.com

PERSONAL PROTECTIVE EQUIPMENT

Gempler's
PO Box 44993
Madison, WI 53744-4993
Phone: 800-382-8473
Fax: 800-551-1128
E-mail: customerservice@gemplers.com
Web site: www.gemplers.com

Lab Safety Supply
PO Box 1368
Janesville, WI 53547-1368
Phone: 800-356-0783
Fax: 800-543-9910
Web site: www.labsafety.com

Northern Safety Co., Inc.
PO Box 4250
Utica, NY 13504-4250
Phone: 800-571-4646
Fax: 800-635-1591
E-mail: customerservice@northernsafety.com
Web site: www.northernsafety.com

PETIOLE SAP METERS (ION METERS)

Spectrum Technologies, Inc.
12360 S. Industrial Drive, East
Plainfield, IL 60585
Phone: 800-248-8873 or 815-436-4440
Fax: 815-436-4460
E-mail: info@specmeters.com
Web site: www.specmeters.com

Pike Agri-Lab Supplies
154 Claybrook Rd
PO Box 67
Jay, ME 04239
Phone: 207-897-9267
Fax: 207-897-9268
Web site: www.pikeagri.com

PH METERS

Ben Meadows Co. (Lab Safety Supply)
PO Box 5277
Janesville, WI 53547-5277
Phone: 800-241-6401
Fax: 800-628-2068
Web site: www.benmeadows.com

Forestry Suppliers, Inc.
205 West Rankin St.
PO Box 8397
Jackson, MS 39284-8397
Phone: 800-647-5368
Web site: www.forestry-suppliers.com

Gempler's
PO Box 44993
Madison, WI 53744-4993
Phone: 800-382-8473
Fax: 800-551-1128
E-mail: customerservice@gemplers.com
Web site: www.gemplers.com

Griffin Greenhouse & Nursery Supplies
Main office:
1619 Main St
Tewksbury, MA 01876
Phone: 800-888-0054
Fax: 978-851-0012
Web site: www.griffins.com
Local office:
200 Mountain View Rd.
PO Box 709
Morgantown, PA 19543
Phone: 800-888-0054 ext. 81439
Fax: 610-286-0012
E-mail: marbogast@griffinmail.com

Pike Agri-Lab Supplies
154 Claybrook Rd
Jay, ME 04239
Phone: 207-897-9267
Fax: 207-897-9268
Web site: www.pikeagri.com

Spectrum Technologies, Inc.
12360 S. Industrial Drive East
Plainfield, IL 60585
Phone: 800-248-8873 or 815-436-4440
Fax: 815-436-4460
E-mail: info@specmeters.com
Web site: www.specmeters.com

ROW COVERS, PLASTIC MULCH

Berry Hill Irrigation, Inc.
3744 Highway 58
Buffalo Junction, VA 24529
Phone: 800-345-3747 or 434-374-5555
Fax: 434-374-0131
E-mail: sales@berryhilldrip.com
Web site: www.berryhilldrip.com

Indiana Berry and Plant Co.
2811 US 31
Plymouth, IN 46563
Phone: 800-295-2226
Fax: 574-784-2468
E-mail: info@indianaberry.com
Web site: indianaberry.com

Ken-Bar (Garden Trends, Inc.)
355 Paul Road
PO Box 24966
Rochester, NY 14624-0966
Phone: 800-336-8882
Fax: 585-295-3608
E-mail: info@ken-bar.com
Web site: www.ken-bar.com

Nolt's Produce Supplies
152 North Hershey Ave.
Leola, PA 17540
Phone: 717-656-9764
Fax: 717-556-0700
E-mail: noltsproduce@earthlink.net

Robert Marvel Plastic Mulch, LLC
2425 Horsehoe Pike
Annville, PA 17003
Phone: 800-478-2214 or 717-838-0976
Fax: 717-838-0978
E-mail: info@robertmarvel.com
Web site: www.RobertMarvel.com

Walker Bros.
105 Porchtown Road
Pittsgrove township, NJ 08318
Phone: 856-358-2548
Fax: 856-358-6127
E-mail: Contact form is at www.walkerplants.com/info/contact.php
Web site: www.walkerplants.com

PROMOTIONAL SUPPLIES

Indiana Berry and Plant Co.
2811 US 31
Plymouth, IN 46563
Phone: 800-295-2226
Fax: 574-784-2468
E-mail: info@indianaberry.com
Web site: indianaberry.com

Monte Package Co.
3752 Riverside Rd.
Riverside, MI 49084-0126
Phone: 800-653-2807 or 269-849-1722
E-mail: sales@montepkg.com
Web site: www.montepkg.com

Rockford Package Supply, Inc.
10421 Northland Dr.
Rockford, MI 49341
Phone: 800-444-7225 or 616-866-0143
Fax: 616-866-4921
Web site: www.rockfordpack.com

SPECIALIZED EQUIPMENT

Bdi Machinery Sales Co.
430 East Main St.
Macungie, PA 18062-1713
Phone: 800-808-0454
E-mail: buydirect@bdimachinery.net
Web site: www.bdimachinery.net

Berry Hill Irrigation, Inc.
3744 Highway 58
Buffalo Junction, VA 24529
Phone: 800-345-3747 or 434-374-5555
Fax: 434-374-0131
E-mail: sales@berryhilldrip.com
Web site: www.berryhilldrip.com

Ferguson Manufacturing Co.
PO Box 1098
Suffolk, VA 23439
Phone: 757-539-3409
Fax: 757-934-3612
E-mail: fermfgsu@nettek.net
Web site: www.fergusonmfgco.com

Hillside Cultivator Co., LLC
911 Disston View Drive
Lititz, PA 17543
Phone: 717-626-6194
E-mail: sales@shenkberryfarm.com
Web site: www.hillsidecultivator.com

Kennco Manufacturing, Inc.
1105 3rd St. NE
Ruskin, FL 33570
Phone: 800-645-2591 or 813-645-2591
Fax: 813-645-7801
Web site: www.kenncomfg.com

Mechanical Transplanter Co.
1150 Central Avenue
Holland, MI 49423-5230
Phone: 800-757-5268 or 616-396-8738
Fax: 616-396-3619
E-mail: mtc@mechanicaltransplanter.com
Web site: www.mechanicaltransplanter.com

ORGANIC PRODUCTS

The Fertrell Company
601 North Second Street
Bainbridge, PA 17502
Phone: 800-347-1566 or 717-367-1566
Fax: 717-367-9319
E-mail: don@fertrell.com
Web site: www.fertrell.com

McGeary Organics
PO Box 299
Lancaster, PA 17603
Phone: 800-624-3279 or 717-394-6843
Fax: 717-394-6931
Web site: mcgearyorganics.com

SERVICES

ANALYSIS OF SOIL AND PLANT TISSUE

See Appendix B.

FUMIGATION

TriEst Ag Group
(Formerly Hendrix & Dail and Reddick Fumigants)
1101 Industrial Blvd.
Greenville, NC 27835
Phone: 800-637-9466

3002 W Main Street
Williamston, NC 27892
Phone: 800-358-8837
E-mail: vlilley@triestag.com
Web site: www.triestag.com

PLASTIC RECOVERY

Zook's Plastic Recovery
183 S. Farmersville Road
Leola, PA 17540
Phone: 717-656-4422
Fax: 717-661-7121
E-mail: daniel@zooksplastic.com
Web site: www.zooksplastic.com
(Buys certain used ag plastic; call for details)

POLLINATORS

The Web site for the Mid-Atlantic Apiculture Research and Extension Center (**agdev.anr.udel.edu/maarec**) contains links to various topics regarding pollinators in the Mid-Atlantic region.

Bjorn Apiaries at Honeycomb Farms
180 Century Lane
Dillsburg, PA 17019
Phone: 717-938-0444
Fax: 717-938-0444
E-mail: mikenida@ptd.net
Web site: www.bjornapiaries.com

Fisher Bee Farm
6395 SR 103 N
Lewistown, PA 17044
Phone: 800-736-6205 or 717-242-4373
Fax: 717-242-3978
Web site: www.fisherbeefarm.com

APPENDIX E

Additional Sources of Information

CONTENTS

Chapter 1 269
Chapter 2 269
Chapter 3 270
Chapter 5 270
Chapter 6 270
Chapter 7 270
Chapter 8 271
Appendix D 271
How to Obtain Extension Publications
Penn State 271
Rutgers University 271
University of Delaware 271
University of Maryland 271
Virginia Cooperative Extension (Virginia Tech and Virginia State University) 272
West Virginia University 272
Other Valuable Sources of Berry Production Extension Information 272
Thinking of Growing a Different Crop? 272
Postharvest Handling and Design of Postharvest Cooling Systems 272
Other States' Small Fruit Production or Pest Management Guides 272
The Strawberry Plasticulture System 272
Disease and Insect Compendia 272
General References 272
Books 272
Web Sites of Interest 272
Home Pages for Related Organizations 273

Earlier discussions referred the reader to Appendix E for additional sources of information. Topics are listed below according to the chapter in which they appeared, followed by additional reading.

CHAPTER 1

HOW TO DO A BIOASSAY FOR TRIAZINE AND OTHER HERBICIDES

"Herbicide Persistence and How to Test for Residues in Soils." Chapter 15 in Illinois Agricultural Pest Management Handbook (2007). Available online at ipm.uiuc.edu/pubs/iapmh/15chapter.pdf.

"A Quick Test for Herbicide Carry-Over in the Soil," Pub. G1891, by R. N. Klein, M. L. Bernards, and P. J. Shea, University of Nebraska-Lincoln. Available online at www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=1052.

"Step-by-Step Guide to Conducting a Bio-Assay." Available online at oregonstate.edu/dept/nursery-weeds/feature_articles/herbicide_carryover/bioassay.htm.

CHAPTER 2

THE AMOUNT OF NITROGEN ADDED TO THE SOIL BY VARIOUS COVER CROPS

Commercial Vegetable Production Recommendations (2012), Table B-9. This publication is a joint effort of Rutgers University, University of Maryland, University of Delaware, Penn State, and Virginia Tech. Available through extension publication distribution channels in each participating state (see listing below).

"Cover Crops," from *Michigan Field Crop Ecology.* Michigan State University. Available online at www.covercrops.msu.edu/pdf_files/covercrop.pdf

Northeast Cover Crop Handbook (1994) by M. Sarrantonio. Published by the Rodale Institute. To order, contact: The Rodale Institute Bookstore, 611 Siegfriedale Road, Kutztown, PA 19530. Phone: 610-683-1400. Also available through certain companies that sell cover crop seeds such as Johnny's Selected Seeds and Fedco Seeds.

Sources of Information on Growing Cover Crops and Green Manures (Table 2.2)

Building Soils for Better Crops (2002) by F. Magdoff and H. van Es, 3rd ed., 294 pages, and *Managing Cover Crops Profitably* (2007), Andy Clark Coordinator, 3rd ed., 244 pages. From SARE's Sustainable Agriculture Network. SARE Outreach Publications, PO Box 753, Waldorf, MD 20604-0753. Phone: 301-374-9696; fax: 301-843-0159; e-mail: sarepubs@sare.org. Can also be ordered or downloaded from www.sare.org/publications.

A Comprehensive Guide to Cover Crop Species Used in the Northeast United States. NRCS Plant Materials Program. Prepared by Shawnna Clark. Online at www.plant-materials.nrcs.usda.gov/pubs/nypmcpu10645.pdf

Cover Crops and Conservation Tillage for Soil Erosion Control on Cropland. Available online at pubs.cas.psu.edu/FreePubs/pdfs/uc128.pdf.

Northeast Cover Crop Handbook (1994) by M. Sarrantonio. Published by the Rodale Institute. To order, contact: The Rodale Institute Bookstore, 611 Siegfriedale Road, Kutztown, PA 19530. Phone: 610-683-1400.

Overview of Cover Crops and Green Manures. From ATTRA—National Sustainable Agriculture Information Service, PO Box 3657, Fayetteville, AR 72702. Phone 800-346-9140. Digital or print copies may be ordered at https://attra.ncat.org/attra-pub/summaries/summary.php?pub=288.

The Penn State Agronomy Guide 2011–2012, "Section 10: Cover Crops." Paper copies of *The Agronomy Guide* can be obtained through Pennsylvania county extension offices and from the Publications Distributions Center as listed below. Also available online at agguide.agronomy.psu.edu/cm/sec10/sec10toc.cfm.

Penn State's Soil Management Web site with articles and links to other sites: extension.psu.edu/soil-management.

CHAPTER 3

PESTICIDE EDUCATION WEB SITES OF EACH UNIVERSITY IN THE REGION

Penn State: extension.psu.edu /pesticide-education

Rutgers University: www .pestmanagement.rutgers.edu

University of Delaware: ag.udel.edu /extension/pesticide/index.php

University of Maryland: www.pesticide .umd.edu

Virginia Tech: www.vtpp.ext.vt.edu

West Virginia University: anr.ext.wvu .edu/pests

Sources of Information on Pesticide Toxicity to Nontarget Organisms

Material safety data sheets and labels for most products can be found through Crop Data Management Systems, Inc.'s Web site at www.cdms.net/manuf /manuf.asp.

Extension Toxicology Network Pesticide Information Profiles can be found online at pmep.cce.cornell.edu/profiles.

Some information was used from Penn State's *Tree Fruit Production Guide,* online at agsci.psu.edu/tfpg.

Pesticide reregistration information from EPA can be found at www.epa.gov/ pesticides/reregistration/status.htm

"How to Reduce Bee Poisoning from Pesticides," by H. Riedl, E. Johansen, L. Brewer, and J. Barbour, is an excellent publication, found at extension .oregonstate.edu/catalog/pdf/pnw /pnw591.pdf.

The National Pesticide Information Center

The NPIC, a cooperative effort of Oregon State University and the U.S. EPA, has a wealth of pesticide-related links for commercial producers and homeowners. Phone: 800-858-7378, 7:30 a.m. to 3:30 p.m. Pacific time (10:30 a.m. to 6:30 p.m. Eastern time), Monday–Friday; e-mail: npic@ace.orst.edu; Web site: npic.orst .edu. Active ingredient fact sheets can be found at npic.orst.edu/ingred/aifact .html.

EPA's Web Site

www.epa.gov

The Penn State Pesticide Safety Fact Sheet *EPA Worker Protection Standard for Agricultural Pesticides*

This publication can be obtained from Pennsylvania county extension offices, ordered from the Publications Distribution Center as listed below, or downloaded from pubs.cas.psu.edu /FreePubs/pdfs/uo228.pdf. Also, many other extension publications exist within the region that explain issues of pesticide use, safety, and regulations. See "How to Obtain Extension Publications" below.

CHAPTER 5

VERTEBRATE (DEER, BIRDS, ETC.) MANAGEMENT

Constructing High-Tensile Wire Fences (Pub. No. 442-132). Updated May 2009 by S. W. Gay and R. D. Heidel, Virginia Tech. Can be downloaded at pubs.ext .vt.edu/442/442-132/442-132.html.

High-Tensile Woven Wire Fences for Reducing Wildlife Damage (FS889). Rutgers University. Can be downloaded at njaes.rutgers.edu/pubs/publication .asp?pid=FS889.

Managing Deer Damage in Maryland (Bulletin 354-C). University of Maryland Cooperative Extension. Can be downloaded at extension.umd.edu /publications/PDFs/EB354-C.pdf.

Portable Electric Fencing for Preventing Wildlife Damage (FS888). Rutgers University. Can be downloaded at njaes .rutgers.edu/pubs/publication .asp?pid=FS888.

Wildlife Damage Control 14: Controlling Birds on Fruit Crops (UH121); *Wildlife Damage Control 6: Geese, Ducks, and Swans* (UH087); *Wildlife Damage Control 7: Cottontail Rabbits* (UH095); and *Wildlife Damage Control 9: Voles* (UH094). All four titles are available through most Penn State Cooperative Extension offices or from the Publications Distribution Center (as listed below) or from pubs .cas.psu.edu.

The Deer Management Assistance Program (DMAP) in PA

This program was established by the Pennsylvania Game Commission. Information is available online at www.portal. state.pa.us/portal/server.pt?open=514& objID=622401&mode=2.

CHAPTER 6

Use of Tensiometers and Other Soil Moisture Sensors

Irrigation Scheduling with Tensiometers (FS657). Rutgers University. Can be downloaded at njaes.rutgers.edu/pubs /publication.asp?pid=FS657.

The Interpretation of Strawberry Petiole Sap Nitrate and Potassium Levels

Fertilization of Strawberries in Florida. Can be viewed at edis.ifas.ufl.edu/cv003.

How to Produce Your Own Strawberry Plug Plants from Tips

Disease Management Considerations for Producing Strawberry Plug Plants by Frank Louws, North Carolina State University. Available online at www.smallfruits.org/ Strawberries/production /StrawberryPlugProductionIPM0604.pdf.

Southeast Regional Strawberry Plasticulture Production Guide. Can be viewed online at www.smallfruits.org/ SmallFruitsRegGuide/Guides /2005culturalguidepart1bs1.pdf.

CHAPTER 7

Weed Identification

Weeds of the Northeast (1997), by R. H. Uva, J. C. Neal, and D. M. DiTomaso, Cornell University Press, is an excellent reference with complete information on weeds and look-alike species. Its 416 pages contain 746 color photographs and 118 drawings. Cornell University Press Services, Box 6525, 750 Cascadilla Street, Ithaca, NY 14851-6525. Phone 607-277-2211 or visit www.cornellpress .cornell.edu.

The New Jersey Weed Gallery can be found at njaes.rutgers.edu/weeds.

The Weed Science Society of America has a photo gallery of weeds at www.wssa .net/Weeds/ID/PhotoGallery.htm.

How to Obtain PALS (formerly NRAES) Guides

Publications of specific interest to berry growers include the following:

Highbush Blueberry Production Guide (NRAES-55) (1992). Edited by M. Pritts and J. Hancock. 200 pp.

Raspberry and Blackberry Production Guide (NRAES-35) (2008). Edited by L. Bushway, M. Pritts, and D. Handley. 157 pp.

Strawberry Production Guide for the Northeast, Midwest, and Eastern Canada (NRAES-88) (1998). Edited by D. Handley and M. Pritts. 162 pp.

Other valuable NRAES publications include:

Mid-Atlantic Orchard Monitoring Guide (NRAES-75) (1995). 361 pp.

Production of Vegetables, Strawberries, and Cut Flowers Using Plasticulture (NRAES-133) (2004). 156 pp.

Sprinkler Irrigation Systems (MWPS-30) (1999). 250 pp.

Trickle Irrigation in the Eastern United States (NRAES-4) (1985). 24 pp.

Contact: Plants and Life Science Publishing, PO Box 4557, Ithaca, New York 14852-4557. Phone: 607-255-7654; fax: 607-254-8770; e-mail: PALSpublishing@cornell.edu; Web site: palspublishing.cals.cornell.edu

CHAPTER 8

The Pan Evaporation Method for Scheduling Irrigation

Basic Irrigation Scheduling in Florida, by A. G. Smajstrla, B. J. Boman, D.Z. Haman, F. T. Izuno, D. J. Pitts, and F. S. Zazueta.University of Florida Extension. Available online at edis.ifas.ufl.edu /AE111.

Managing Row Middles

Turfgrass for Orchard and Nursery Floor Management. Rutgers University, FS319. Available online at njaes.rutgers .edu/pubs/publication.asp?pid=FS319.

High Tunnel Raspberry and Blackberry Production

High Tunnel Raspberries and Blackberries. Cornell Dept. of Horticulture Publication No. 47 (2012 revision). Available online at www.fruit.cornell.edu/berry/production/pdfs/hightunnelsrasp2012.pdf.

Greenhouse Raspberry Production Web Sites

Greenhouse strawberry and raspberry production: www.fruit.cornell.edu /berry/production/pdfs/ghrasp.pdf

Greenhouse winter raspberry production: www.fruit.cornell.edu /Berries/ghrasp.pdf

The Rotating Cross-Arm Trellis

Diagrams and photos can be found at trellisgrowingsystems.com. This system was developed by F. Takeda at the USDA in Kearneysville, West Virginia.

Identification of Predatory (Beneficial) Mites and Other Beneficial Insects

Beneficial Insects (HYG-14) (Revised March 2004) by D. Caron and S. D. Walker, University of Delaware. This information covers beneficials other than mite predators. Available online at ag.udel.edu/Extension/horticulture /pdf/bi/bi-5.pdf.

Biological Control: A Guide to Natural Enemies in North America. Cornell University. Has pages on more than 100 natural enemies of pests. Available online at www.biocontrol.entomology .cornell.edu/index.php.

Mid-Atlantic Orchard Monitoring Guide. See the above section entitled "How to Obtain PALS (formerly NRAES) Guides" for information on how to order this publication.

Natural Enemies of Vegetable Insect Pests. This manual is available from The New York State Agricultural Experiments Station Online Bookstore, Barton Laboratory, 630 W. North Street, Geneva, NY 14456. Phone: 315-787-2248; fax: 315-787-2443; e-mail: gro2@cornell.edu. This publication can be ordered online from calsbookstore-lamp.cit.cornell.edu /catalog.

North Carolina State University's Biological Control Center has numerous photos of beneficial insects and look-alikes at cipm.ncsu.edu/ent/biocontrol.

Predatory Mites (Insect Identification Sheet No. 123). New York State IPM Program. This online fact sheet contains descriptions and photos of predatory mites at different growth stages. Viewable online at nysipm.cornell.edu /factsheets/treefruit/pests/pm/pm.asp.

APPENDIX D

Pollination Suppliers

The Mid-Atlantic Apiculture Research and Extension Consortium has a valuable Web site with articles on topics of interest, information on beekeeping and pollinators, and links to beekeepers' associations, along with many links to sites of interest to beekeepers and growers: agdev.anr.udel.edu/maarec

HOW TO OBTAIN EXTENSION PUBLICATIONS

A wealth of information exists in the form of extension publications from universities within the region and elsewhere. In most cases, publications containing information produced within each state can be obtained from county extension offices. In some states, paper copies are being phased out, but local extension personnel can still help with accessing Web information if necessary. Publications can also be obtained directly from each state's publications distribution centers, which are listed as follows:

Penn State

Visit the Publications Web site at pubs.cas.psu.edu to download most publications. Paper copies of the catalog and publications are also available through Penn State Cooperative Extension offices, or can be requested from the Publications Distribution Center, 112 Agricultural Administration Building, University Park, PA 16802. Call 814-865-6713, fax 814-863-5560, or e-mail AgPubsDist@psu.edu for information.

Rutgers University

Most publications can be downloaded for free from njaes.rutgers.edu/pubs. Click on "Plant Agriculture" or the category of interest.

University of Delaware

Paper copies of some publications are available through county offices. In New Castle County, phone 302-831-2506 or fax 302-831-8934. For Kent County, phone 302-730-4000 or fax 302-735-8130. For Sussex County, phone 302-856-7303 or fax 302-856-1845. Some publications can also be downloaded from ag.udel.edu /Extension/horticulture.

University of Maryland

Publications are available through Maryland county extension offices. Many can be downloaded for free from pubs.agnr.umd.edu after clicking on the topic of interest. Nonresidents of Maryland can download a form from this site to order publications.

Virginia Cooperative Extension (Virginia Tech and Virginia State University)
Visit pubs.ext.vt.edu to browse and download agriculture and natural resources numbered extension publications. Paper copies of some extension publications are available—contact your local county extension office. The Virginia Tech Extension Distribution Center may also be contacted at 540-231-1322.

West Virginia University
Visit www.wvu.edu/~exten/infores/pubs.htm and then click on the area of interest, or visit local county extension offices.

OTHER VALUABLE SOURCES OF BERRY PRODUCTION EXTENSION INFORMATION

Cornell University publications can be found at www.cals.cornell.edu/cals/hort/extension/publications.cfm; Cornell also has an excellent Web site for berry crops at www.fruit.cornell.edu/berry.index.htm.

Ohio State University's publications are available online at ohioline.osu.edu. A catalog of publications available in print can be obtained from Media Distribution, 385 Kottman Hall, 2021 Coffey Rd, Room 216, Columbus, Ohio 43210-1044. Phone: 614-292-1607; fax: 614-292-1248; e-mail: pubs@ag.osu.edu. Ohio residents should contact their local county extension offices to obtain printed copies.

University of Massachusetts publications can be found at umassextensionbookstore.com. To order, contact: UMass Extension Bookstore, University of Massachusetts Amherst, 101 University Drive, Suite A4, Amherst, MA 01002-2385. Phone: 1-413-545-2717; fax 413-545-5174.

THINKING OF GROWING A DIFFERENT CROP?

Penn State has an "Ag Alternatives" series that briefly describes the process involved in producing different high-value crops or livestock and provides budgets that give an idea of the expenses and returns that might be expected. Any publication from the complete series can be found and downloaded at extension.psu.edu/ag-alternatives or can be obtained from Penn State's College of Agricultural Sciences Publications Distribution Center as listed above. Within the berry crop area, Ag Alternatives Publications *Strawberry Production* (UA290); *Red Raspberry Production* (UA431); and *Highbush Blueberry Production* (UA265) are available.

POSTHARVEST HANDLING AND DESIGN OF POSTHARVEST COOLING SYSTEMS

North Carolina State University has a "Postharvest Commodity Series" and a "Postharvest Technology Series" that include titles such as *Postharvest Handling and Cooling of Strawberries*; *Forced-Air Cooling*; *Cool and Ship: A Low-Cost Forced-Air Portable Cooling Unit*; and many more. Available online at www.bae.ncsu.edu/programs/extension/publicat/postharv.

OTHER STATES' SMALL FRUIT PRODUCTION OR PEST MANAGEMENT GUIDES

Check to see when last updated before ordering.

Cornell 2012 Pest Management Guidelines for Berry Crops. Available online at ipmguidelines.org/BerryCrops.

Commercial Blueberry Pest Control Recommendations for New Jersey, 2012 (E265). Rutgers Cooperative Extension. Can be downloaded at njaes.rutgers.edu/pubs.

Bramble (Raspberries and Blackberries) Weed Control Recommendations for New Jersey, 2007 (E316). Rutgers Cooperative Extension. Can be downloaded at njaes.rutgers.edu/pubs.

Brambles—Production, Management, and Marketing (Bulletin 782) and *Midwest Small Fruit Pest Management Handbook* (Bulletin 861). To order a copy, contact Ohio State University Extension, Media Distribution, 385 Kottman Hall, Room 216, 2021 Coffey Rd., Columbus, Ohio 43210-1044. Phone: 614-292-1607; fax: 614-292-1248; e-mail: pubs@ag.osu.edu. Also available online at ohioline.osu.edu.

Integrated Pest Management for Strawberries in the Northeastern United States (IP-STRW). D. Cooley and S. Schloemann, eds. UMass Extension Bookstore, University of Massachusetts Amherst, 101 University Drive, Suite A4, Amherst, MA 01002-2385. Phone 1-413-545-2717; fax 413-545-5174; Web: umassextensionbookstore.com.

Pest Management Guide for Horticultural and Forest Crops (Pub. 456-017). Virginia. The small fruit section of this guide may be downloaded at pubs.ext.vt.edu/456/456-017/456-017.html.

THE STRAWBERRY PLASTICULTURE SYSTEM

Hill System Plastic Mulched Strawberry Production Guide for Colder Areas (Pub. 438-018). Virginia Tech. May be viewed online at pubs.ext.vt.edu/438/438-018/438-018.html.

DISEASE AND INSECT COMPENDIA

The following are available from the American Phytopathological Society, APS Press, 3340 Pilot Knob Road, St. Paul, Minnesota 55121-2097. Call 800-328-7560 or visit their Web site at www.apsnet.org/apsstore/shopapspress/Pages/default.aspx.

Compendium of Blueberry and Cranberry Diseases (1995). F. L. Caruso and D. C. Ramsdell, eds. 87 pp.

Compendium of Raspberry and Blackberry Diseases and Insects (1991). M. A. Ellis, R. H. Converse, R. N. Williams, and B. Williamson, eds. 122 pp.

Compendium of Strawberry Diseases (1998). 2nd ed. J. L. Maas, ed. Includes insect information. 128 pp.

GENERAL REFERENCES

Books

The Berry Grower's Companion (2000). B. L. Bowling. Timber Press, Inc. Portland, OR. www.timberpress.com

Uncommon Fruits for Every Garden (2004). Reich, L. Timber Press, Inc. Portland, OR. www.timberpress.com

Web Sites of Interest

Small Fruit Pathology Fact Sheets contain information on disease biology, including photos to help identify problems. They are found at extension.psu.edu/fruit-diseases/small-fruits.

Small Fruit IPM AdVisor contains information or links to Web sites with

information on many insects found on berries. This site is available at www.virginiafruit.ento.vt.edu/VisorSmallIPM.html.

The Berry Diagnostic Tool, a site where you can click on photos or descriptions that match your problem, can be found at www.fruit.cornell.edu/berrytool/index.htm.

Sources of small fruit cultivars can be found at www.fruit.cornell.edu/berry/nurseries/index.html.

National Sustainable Farming Information Service from ATTRA, the national sustainable farming information center, has many publications available at https://attra.ncat.org/.

The Agriculture Network Information Center has links to numerous publications at www.agnic.org.

Home Pages for Related Organizations

North American Raspberry and Blackberry Growers Association: www.raspberryblackberry.com

North American Fruit Explorers: www.nafex.org/about.php

North American Strawberry Growers Association: www.nasga.org

U.S. Highbush Blueberry Council: www.blueberry.org

extension.psu.edu

An OUTREACH program of the College of Agricultural Sciences

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

This publication is available from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802. For information telephone 814-865-6713.

Where trade names appear, no discrimination is intended, and no endorsement by Penn State Cooperative Extension is implied.

This publication is available in alternative media on request.

The Pennsylvania State University is committed to the policy that all persons shall have equal access to programs, facilities, admission, and employment without regard to personal characteristics not related to ability, performance, or qualifications as determined by University policy or by state or federal authorities. It is the policy of the University to maintain an academic and work environment free of discrimination, including harassment. The Pennsylvania State University prohibits discrimination and harassment against any person because of age, ancestry, color, disability or handicap, genetic information, national origin, race, religious creed, sex, sexual orientation, gender identity, or veteran status and retaliation due to the reporting of discrimination or harassment. Discrimination, harassment, or retaliation against faculty, staff, or students will not be tolerated at The Pennsylvania State University. Direct all inquiries regarding the nondiscrimination policy to the Affirmative Action Director, The Pennsylvania State University, 328 Boucke Building, University Park, PA 16802-5901; Tel 814-865-4700/V, 814-863-0471/TTY.

© The Pennsylvania State University 2013

Produced by Ag Communications and Marketing

Code # AGRS-097 Rev7.5CM8/12mpc3530