Colony Collapse Disorder: Links to pesticides and their alternatives

A study on pesticides that may be connected to colony collapse disorder, as well as natural alternatives that can substitute them

Tag Words: colony collapse disorder; pesticides; honeybee

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Summary

Colony Collapse disorder (CCD) is when all the workers in a honeybee hive abandon the hive. while there is no specific cause known for CCD, there are several pressures on honeybees that are believed to come together to make it occur (Watanabe). Pesticides, one of the believed causes of CCD, are a human pressures that can be removed from the equation by current technology. Pest control has evolved from sulfur in Mesopotamia over 4,500 years ago (Miller, GT), to deadly poisons, and finally to specific toxins developed in chemistry labs. Carbamate pesticides, organochlorine insecticides, pyrethroid pesticides, Malathion, Neonicontinoids, and Carbaryl are several pesticides that have been offered for pest control with varying degrees of toxicity and specificity. In the past, these effective methods of killing pests were important for human development of civilizations, however the sterile male/insect technique (SIT), physical techniques, cultural techniques, and biological control are natural methods of pest control that do not put pressures on honeybees and are beginning to be implemented. Biological methods, perhaps the most important of alternatives, is where humans use nematodes, fungi, bacteria, viruses, and genetic manipulation as a method of pest control by supporting natural enemies of the pests in order to subdue them (Gullen). Unfortunately, in the case of both genetic manipulation and pesticides, resistance is a common occurrence where the means of pest control can become obsolete. This can occur through pest individuals learning to avoid the pest control means implemented, by the pests becoming tolerant through the more resistant (more fit) individuals surviving, through physiological changes occurring in pest individual, or through the natural biochemical detoxification of pest individuals by developing enzymes to counteract the pathogens (Gullen). With honeybees pollinating roughly twenty billion dollars worth of food crops in the United States (Hickman) alone, farmers should take into account the consequences of using

pesticides that hurt the investment they are trying to protect. No progress can occur without communication between farmers and Beekeepers, as well as important research that explores natural alternatives to pesticides. (IM)

Youtube Link

http://www.youtube.com/watch?v=FY7-L84QLcc

The Issue

(CC) Humans have been utilizing various forms of pesticides to combat and protect they're crops against harmful organisms since the practice of agriculture began in ancient Mesopotamia. Indeed without the use of certain pesticides human civilization may never have developed to extent it has today as natural (and later introduced) predators to those crops vital to the growth and feeding of large villages and cities would have quickly decimated them, growing in the novel environment of the cultivated field. Biological warfare between species has been one of the major driving forces of evolution on this planet and the crop plants defenses against predators is no exception. As the plant's natural defenses against pests would not suffice the support the massive amount of crop production needed to sustain human civilization, especially after human disturbance of an ecosystem; humans had to step in and artificially protect those crop plants vital to human growth (Miller, GT). This manipulation of natural systems has drastically changed the face of the planet in some very surprising ways. It is ironic that one of the largest unforeseen victims of human's heavy use of pesticides is itself also vital to the production of food on this planet. Albert Einstein was once quoted as saying: "If the bee disappears from the surface of the earth, man would have no more than four years to live. No more bees, no more pollination … no more men!", wile he did not know it at the time, this is scenario is disturbingly close to becoming reality.

Colony Collapse Disorder Colony collapse disorder (CCD) was first described in 2006 after a large American beekeeper and bee supplier began to experience mysterious bee disappearances, a phenomenon a growing number of keepers were beginning to note. Keepers examining a hive that had recently succumbed to CCD would find almost no adult bees present within the colony and hungry larval broods with no adults to sustain them. The western honeybee (*Apis mellifera*), a species native to Europe, Asia and Africa, was introduced into North America in the 1600's, and is one of the most important tools of modern agriculture. Over one third of all food produced globally is pollinated by the honeybees, which is about $15 billion a year in crop revenues. There are over 50 commercial crops that depend on honeybees for pollination. This growing global decline in honeybee populations could drastically impact the world economies and food markets, as well as ecology of much of the old world.

While identifying a colony that has succumb to CCD is painfully easy, establishing the ultimate cause of the bee disappearance still remains a mystery that countless government, corporate and university laboratories across the world are working desperately to identify. Many apiculture associations have publicly accepted that a slew of different factors have contributed to create a 'perfect storm' for colony survival. A wide array of parasites have been found in the bodies of dead bees associated with CCD including at least two species of mites, seven species of bacteria and seven species of viruses. Although these parasites that infect the bee's bodies and others that infest their hives have been associated with CCD, similar situations are often described in healthy hives, complicating issues. Studies have identified honeybee workers with up to 25 different pesticides in their bodies and others with a minimum of at least 5. It appears that our biological war arms race against crop pests has shot us in the foot. As the chemicals used to protect our food from insect pest predation may also be killing off the insects needed for the continued pollination and production of those crops as they visit the flowers of sprayed plants and ingest a wide array of pesticides. As stated before, there is no 'smoking gun' as to the cause of CCD, and it is likely that a combination of novel bee parasites and diseases and the heavy use of pesticides by the modern agricultural community are causing the decline. With this in mind, the regulation of such pesticides that are lethal to bees must be an integral part of any measure to stop this phenomenon. Many countries in the EU have already begun to ban many types of pesticides most closely linked to CCD however the US has yet to impose any such regulations (Watanabe).

History of Pesticide Use

Because biological warfare has taken many shapes through the course of Earth's history; and so have human produced pesticides, taking the forms of organic and inorganic chemicals, other biological agents, and physical disturbances. The first recognized pesticide was powder sulfur used in Mesopotamia over 4,500 years ago (Miller, GT). In the 15th century arsenic, mercury and lead, being recognized as quite toxic to most life, were employed. The 17th century saw the development of nicotine sulfate based pesticides, a byproduct of the booming tobacco and the plant's natural defense against insect predation. Arsenic and nicotine based pesticides remained the most viable pesticide options until the 1940's with development of DDT which would become the most well known and controversial pesticide used in human history. Today pesticides based off of pyrethrin compounds have replaced DDT, and it's various successors, as the most popular pesticide route.

The development of DDT and other synthetic compounds at the end of the Second World War ushered in the "pesticide era" and the use of pesticides grew exponentially. The environmental impact of pesticide use did not become apparent until the 1960's when DDT, which had leached out of agricultural fields into the water systems across the US, was linked to large declines in predatory bird populations. Upon entering a water system low levels of the chemical were quickly absorbed into the bodies of fish. After being preyed upon by fish eating birds such the bald eagle and the osprey, the chemical climbed up the trophic latter, accumulating in larger concentrations in the birds and causing them to produce egg shells that would crack when sat upon by brooding adults, killing the developing embryo. This well publicized case caused a national outcry in the 1960's and led to, among other things, the formation of the EPA, the eventual banning of DDT based pesticides, and the dawn of the modern environmental movement (Carson).

While this story served as a wake up call to governments and the public that the use of pesticides can cause dramatic and severe impacts on the environment and it's ecology, and the use of such compounds become regulated by the EPA and other governmental bodies, the risks and environmental damage caused by the use of pesticides continues to grow.

Types and Functions of Pesticides

Pesticides may be classified and cataloged in various different ways. The type of pest they target, such as algicides (algae), fungicides (fungi) and insecticides (insects) are some examples of pesticide types grouped by the taxa they are intended to protect crops against. The origin/method of production is another way they are classified, such as biopesticides, which are natural compounds found within organisms. Lastly they may be grouped by the effect the compound has on the targeted organism: Organophosphates Pesticides – These compounds effect neurotransmittion in the nervous system and may cause paralysis. They are mostly intended for insects but can affect a wide range of organisms and are highly poisonous.

Carbamate Pesticides – acts in similar ways to organophospate pesticides with similar, but somewhat less severe results.

Organochlorine Insecticides – similar effects to the above two, but causes neuron disruption through a different pathway and is derived from different chemicals. DDT is an organochlorine insecticide.

Pyrethroid Pesticides – these are synthetic versions of pyrethrin, a naturally occurring compound produced by plants to repel or kill insect pests. It also affects the nervous system. (US Environmental Protection Agency)

	Risk Rating	Chemicals	Remarks
1	High risk to bees foraging even 10 hours after spraying	Carbaryl, chlorpyrifos, diazinon, dimethoate, omethoate, methomyl, fenthion, methamidophos, methidathion, monochrotophos.	These should never be sprayed on flowering crops especially if bees are active and the crop requires pollination.
2	Moderate risk…some losses expected 10 hours after spraying	Acephate, demeton-s-methyl	
3	Some risk with low chance of losing bees 3-5 hours after spraying	Endosulfan, dicofol, pirimicarb, petroleum oils, most pyrethroid chemicals, trichlorfon.	There is little risk of losing bees if these chemicals are sprayed in the evening when foraging has ceased.
4	No risk even if sprayed over foraging bees	*Bacillus thuringiensis, propargite,* oxythioquinox	

(Diagram1: "Lecture Slides" Mark Robson. 2011) *the risk ratings of various pesticides to honeybees*

Insecticides, those pesticides used to target insects and other arthropods, tend to have the largest impact on native insect communities as well vertebrate life. Of the many kinds of insecticides in use, here are some of the most common:

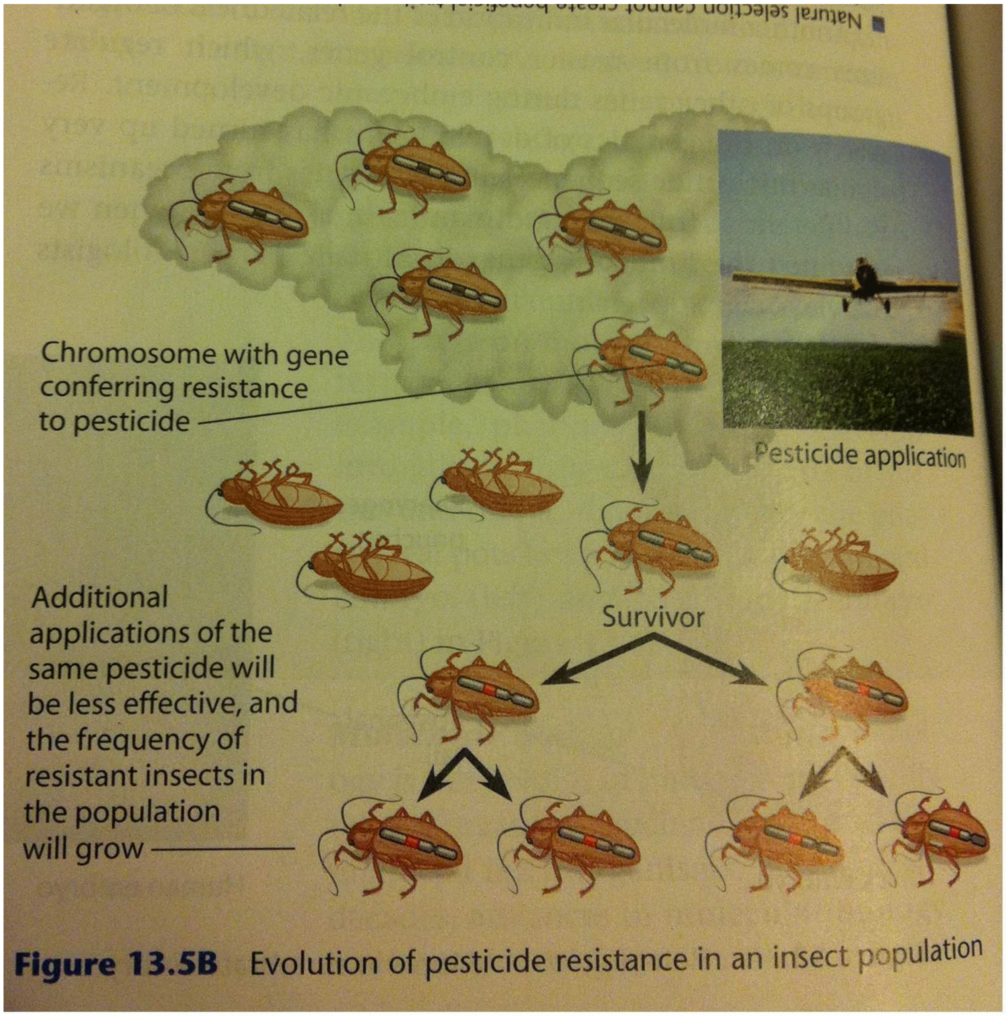
Malathion – this organophosphate pesticide has been in use since the 50's. Compared to other organophosphates, malathion is considered as only 'slightly' toxic to humans, however health issues associated with it's use have been well documented. This compound is highly toxic to most insects and is used as a general-purpose insecticide to control crop pests, disease vectors (such as mosquitoes), and household pests. Malathion has been shown to be highly toxic to many aquatic invertebrates, aquatic amphibians, and honeybees. It also ranges from being highly toxic to slightly toxic to birds and fish depending on the species. Once malathion infiltrates into the soil system it breaks down rather quickly via biological and non-biological reactions. The average half life of the compound is about six days. It has been documented to persist in most lentic and lotic water systems for about a week (Extoxnet).

Neonicontinoids – These are a class of nicotine based insecticides introduced in the 1980's. They affect the nervous system of insects, causes paralysis and death but are considered less toxic to mammals. Neonicontinoids are especially effective against aphids, beetles, and some moths and butterflies that pose a risk to food crops. In recent years many EU countries have begun to ban the use of neonicontinoid insecticides due to the possible link between them and colony collapse disorder (CCD) in honeybees. This phenomenon has effected wild and domestic honeybee populations across the globe for almost a decade. Hives that succumb to CCD experience a breakdown in worker bee's ability to navigate back to their hive, neglect of young and ultimately the death of the hive. Although this is still a very contentious issue and nicotine-based insecticides have not yet been proven to be the ultimate cause of CCD, they remain a prime suspect. If CCD continues the economic and ecological impacts could be massive due to the large role honeybees play in the pollination of crops and native plant species across the globe.

(US Environmental Protection Agency, Program Highlights) (Northern Territory Government)

Carbaryl – this is a carbamate insecticide that inhibits the expression of certain enzymes in the nervous system, causing death. Wile highly toxic to insects, it is quickly broken down in vertebrates and dose not concentrate in fat or most other compounds in food crops. Because of this it has become one of the most heavily used pesticides in the US. Because of its highly toxic nature to honeybees, many EU countries have banned the use of carbaryl as it may be connected to CCD. It is also toxic to most other non-target insects as well as crustaceans. Carbaryl will degrade in most soil and freshwater systems with in a month or less depending on temperature, microbe communities and other variables. It appears to persist in marine environments for somewhat longer (XU).

(IM) **Resistance** is a problem for many forms of countermeasures used against pests. One form of resistance is avoidance. This is where the target organism learns to avoid pathogens, as well the areas where they are applied. Another form of resistance is tolerance, where target organisms become tolerant to the applied pathogens. This is because less resistant members of the organism population are killed off, which allows more resistant individuals more exposure to resource opportunities (see Diagram2). Physiological changes are another form of resistance where the method of attacking the pest problem is no longer effective because of the physical change in the anatomy of the target. Finally, biochemical detoxification is another form of resistance. This form of resistance occurs when the target begins producing enzymes that hinder the effects of pathogens (Gullen 402).



(Diagram2 **Biology: Concepts & Connections** Campbell, Reece, Taylor, Simon. 2006. Pearson Education inc.)

Alternatives to Pesticides Alternative pest controls include the biological (or non chemical) method of physical control, cultural methods, and sterile male technique (sterile insect technique SIT?). Physical control is the most passive and is simply using traps or devices such as a fly swattes to attack pests (Gullen 420). Cultural methods use intercropping (also known as polyculture, which is the mixing of crops), protecting susceptible crops by rotating the crops, or habitat manipulation (such as marsh drainage), to combat pests (Gullen 420-421). Another method is the sterile male/insect technique, which is simply to swamp the population of the pest with infertile males. This is in-effective, however if scientists are unable to rear a large amount of the target pest, if the infertile males are not as competitive as the natural males, if differences in the genetics and physical attributes of the captive population causes them to prefer mating among themselves, if there are inadequate numbers released, if there is failure of the infertile insects to mix with wild population, or if dispersal from the release site is inadequate, then this method of pest control will be ineffective (Gullen 423).

Biological Control The most important of these alternatives to pesticides is biological control. Biological control is where, "human intervention attempts to restore some balance, by introducing or enhancing natural enemies of target organisms such as insect pests" (Gullen 408). Some enemies of pests that are manipulated to reduce pest numbers include microbial organisms called nematodes, fungi, bacteria, and viruses. Microbial control involves introducing a foreign pathogen (classical biological control), augmentation through inoculation (for season long protection) or inundation (introducing entomopathogens), and lastly through conserving the pathogens present in the environment already (Gullan 412).

Nematodes There are three types of nematode that are used in biological controls. The first is Mermithidae, which are large and infect hosts on an individual basis. This family is usually used on black flies and mosquito larvae. Next, soil dwelling families (Heterorhabditids and Steinemematids) are a cheap and easy to mass produce method that controls soil pests, plant boring beetles, and moth pests. Finally, the family Neotylenchidae has *Deladenus siricidicola* in it that causes sterilization of adult female wasps (Gullen 413). One example of nematode use benefiting honeybees was documented in 2010 when a set of nematodes named *Heterorhabditis indica* and *Steinernema riobrave* were noted by Nematodeinformation.com as effective pest management agents against small hive beetles. Hive beetles normally enter a hive as an adult, stealing food from the stomachs of guard bees until their offspring hatch and the young eat whatever food they can find in the hive (Ellis).

Fungi There are Seven hundred and fifty known types of fungi that infect arthropods. They can be used for pest control because they penetrate outer layers of insects and cause death quickly through either toxins or the disruption of metabolic activities. Unfortunately, the fungal technique is limited to the moist environments the fungi survive in (Gullen 414). Current research has recently found a situation where *Metarhizium anisopliae*, a type of fungi, is being used to control Varroa mites (Golden Harvest Organics). This form of fungus helps honeybees avoid CCD in two ways, by using this fungus in the place of pesticides that cause bee poisoning and it also avoids CCD because the target pest, Varroa mites, are believed to be another possible cause of CCD.

Bacteria are rarely used for pest control. This microbial method requires even application, active feeding of pest for lethal dose consumption, persistent strength (no denticulation by ultraviolet light), a suitable strain for target pests, and requires the, "insect population being uniformly young to be susceptible" (Gullen 414-415). *Bacillus thuringiensis* is an example of a bacterial insecticide that is currently used to kill gypsy moth caterpillars (along with other species of moths and butterfly larvae) without harming honeybees (Evans).

Viruses When it comes to viral insecticides, they should be host specific, virulent, quickly kill, stay in the area for long enough to affect the target species, and be easy to apply to large areas (Gullen 417). Only three types of viral biological control are actually able to be used, as all others lack specificity or can pass negative factors to vertebrates (Gullen 416). RNA viruses may be directly connected to CCD and scientists believe scientific research may not only help find the ability to prevent CCD, but also prove to be helpful against herbivorous insects that are agricultural pests (Miller, Bonning).

Genetic Manipulation Some plants have natural defenses from plants that include antibiosis (where the plant hurts an insect feeding on it), antixenosis (where the plant is simply a bad host), or tolerance (where the plant can survive damage done to it) (Gullen 417). Genetic engineering takes advantage of these natural factors, as well as genes from some bacteria, by placing the genetic information that code these traits in the nuclei of other plants or by putting the same genes into a bacterium that transfers its own DNA to its host upon infection called crown-gall bacterium. This method can be used on crops such as corn, cotton, tobacco, tomatoes, and potatoes (Gullen 419). This is particularly important because honeybees pollinate almost twenty billion dollars worth of food crops per year in the U.S.A. (Hickman), which includes most of our fruits, vegetables, and important field crops such as clover, cotton, and tobacco (Borror 354), of which many overlap with genetically engineered crops.

Conclusion While the use of pesticides may have helped in the development of human civilization in the past (Miller, GT), its use has become impractical today. The negative role toxic pesticides play in honeybee colony collapse disorder (CCD) outweighs any of their positive attributes. This is because humans have largely integrated honeybees into the agricultural process of pollination, so any harm to honeybees because of pesticides also harms the success of crops the toxins were meant to protect. Biological pest management systems (including bacterial, viral, fungal, and nematode systems) lack many of the consequences pesticides have, while effectively eliminating target pest populations. Perhaps, through future research, the best methods of pest control without bringing harm to honeybees will be found.

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PSA: Generate the Buzz

Our plan is inspired by the hit TV show, “Bill Nye the Science Guy.” This show was dedicated to informing children scientific facts in a fun way. At the end of each episode, the show featured a music video that parodied actual music videos while going over the basic themes of the episode it was featured in. Our goal is to use Bill Nye’s method of reaching his audience by making a music video that shows the importance of protecting honeybees by using alternatives to pesticides. Using “Flight of the Bumble Bee” (by Nikolai Rimsky-Korsakov) and a poem of our writing (Ian Mosebach) and spastic bee dancer Professor Julie Fagan, we will transfer the knowledge found in our classipedia to the watchers, in hopes that the importance of the issue becomes evident to the public, farmers, and the government.

http://www.youtube.com/watch?v=JAcWlubPyjU&feature=BFa&list=ULY4wBy1jWsV0&index=39

Generate the Buzz Poem by Ian Mosebach:

With the humans moving forward so fast,

All the bees disappeared and now I'm the last.

I've seen killing clouds kill pesky bugs on the farm,

But the pests aren't the only ones facing the harm.

While I watched all the workers abandon their posts

I knew that the farmers were being bad hosts.

Science had helped others from facing this fate,

But our farmers didn't know because they didn't communicate.

And so here I sit as the queen of an empty hive,

All the workers have left, not a drone is left alive.

Listen close to this queen of a kingdom of one,

Listen carefully to this mother who's lost everyone,

Farmers remove from your ears all of the fuzz,

So you can join us and generate the buzz:

Communicate with beekeepers to protect every crop

Because without bees, most of your crops would stop.

Support alternate methods (be it nematode or viral)

To the current pesticides that sent us in a downward spiral.

Editorial Letters

#1. To help clarify certain aspects of the issue the following letter was sent to NaturalNews.com in reaction to an article published there discussing a recent study looking at various possible causes of CCD:

To the Natural News editorial staff:

I am writing to you today in regards to an article published March 24, 2010 by David Gutierrez titled: Honeybee Colony Collapse Disorder Finally Explained: Too Many Chemicals (http://www.naturalnews.com/028429_colony_collapse_disorder_chemicals.html). In this article the author describes the findings of a study out of Washington State University that was originally reported on July 29, 2009 by the Environmental News Service. This study investigated pesticide levels in the wax of bee honeycombs as well as the impact of the microsporidian pathogen Nosema ceranae and they're possible connected with Colony Collapse Disorder (CCD). The study found high levels of pesticide residue in the honeycombs of older beehives and higher mortality rates in those hives. The study also found the pathogen N. ceranae to be wide spread in many hives and cause an immune-deficiency disorder, leaving affected individuals significantly more susceptible to other pathogens and pesticides. The article published in Natural News about this study appears to be a slightly misleading interpretation of its findings. No clear-cut definitive cause of CCD was announced in this study, contrary to the title of your article. N. ceranae has been present in the US since at least 1997, almost a decade before CCD was ever described and became wide spread. The idea that this pathogen would suddenly begin to cause CCD after ten years does not seem correct. The findings of this study were reported on in July of 2009, however Natural News did not publish this article until March of 2010, almost a year later. During that time N. ceranae has failed to be fully linked to CCD and in fact the true ultimate cause of CCD is still unknown today. What most scientists believe and indeed is stated in the original study, is that a combination of things including pathogens and pesticides is the blame, however definitive link between all of these possibilities has never been found. N. ceranae may be this link, weakening the bees' defenses against various pathogens and pesticides such as fluvalinate, coumaphos and neonicotinoids, however this has yet to be proven and appears to be rather contrary to what the Natural News article asserts which appears to be either "too many chemicals" as stated in the title, or the N. ceranae pathogen as the body of the article describes.

Thank you for time,

-Colin Clark Undergraduate senior of ecology and evolution at Rutgers University in New Brunswick, NJ

“Irish bees untroubled by colony collapse” <http://www.irishtimes.com/newspaper/ireland/2011/0512/1224296752943.html> FRANK McDONALD, Environment Editor Thursday, May 12, 2011

Sir, -As Conan McDonnel mentioned in your article, pesticides are among several factors putting pressure on honeybee colonies. While the specific cause of Colony Collapse Disorder (CCD) is still unknown, pesticides are believed to be one of the main causes. Unfortunately, many farmers do not prioritize the several biological alternatives to pesticides that are available (or are being researched).

Using biological methods in the place of chemical toxins would eliminate the possibility of pesticides contributing toward CCD. Microbial methods (such as viral, bacterial, etc) are forms of biological control that can replace pesticides and, thus, avoid pesticidal problems including the abandonment of the hive through bee poisoning, as well as the nuisance of evolutionary resistance by the target pests for which chemical pesticides are originally intended. These advantages, along with the added bonus of reducing a possible cause of CCD, happen because chemical toxins are being supplemented by natural processes that are propagated simply by utilizing natural enemies of target pests.

It's clear that agricultural pests must be controlled in order to protect crops as both an economic commodity and a food source, but this control should not be at the cost of honeybee populations (especially when harming the bees decreasing crop productivity). Using toxins when there are safer methods for the environment is irresponsible. Scientific research and experimentation of biological pest management techniques may remove the role pesticides play in causing CCD while still adequately removing pests. It is important that every effort is employed to stop man-made pressures on honeybees before they disappear forever. – Yours, etc,

IAN MOSEBACH Undergraduate senior of ecology, with minor of Entomology and Biology, at Rutgers University in New Brunswick, NJ

http://www.youtube.com/watch?v=FY7-L84QLcc