IMPACT EVALUATION OF DROUGHT TOLERANT RICE TECHNOLOGIES THROUGH PARTICIPATORY APPROACHES IN EASTERN INDIA

by

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ABSTRACT OF THE THESIS

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Rice is a staple food crop grown and consumed widely in India. A larger portion of rice acreage in India is still occupied by land race cultivars mostly cultivated by small and marginal farmers. This situation is more prevalent in upland rice farming. Upland farmers in Eastern India lacked high yielding rice variety with good quality and quantitative attributes and hence mostly cultivated poor yielding cultivars. In the late 1990s, a new approach known as Participatory Plant Breeding was adopted for breeding drought tolerant rice varieties suitable for upland cultivation in Eastern India. This was funded through Department For International Development (DFID), UK and implemented in collaboration with University of Wales at Bangor, UK in partnership with Gramin Vikas Trust (GVT), an NGO and Birsa Agricultural University (BAU). The research lead to the development of two upland rice varieties Ashoka 200F and Ashoka 228 and medium land varieties such as Sugandha 1 and Barkhe. Seed production and dissemination for these drought resistant cultivars has taken place through NGOs, farmers, and other innovative mechanisms of seed supply. However, the research and dissemination activities are carried out through donor funded projects of DFID and

Rockefeller Foundation. No private companies are interested in the multiplication of these improved cultivars due to lack of profit margins. This research is aimed at evaluating the economic benefits of drought tolerant rice research investments and its adoption in Eastern India. We use the economic surplus model to compare the cost of research and diffusion programs through participatory plant breeding in Eastern India. Further, the causal relationship between yield levels of upland varieties obtained at the farmers' fields through trials in relation to their location and varietal characteristics were determined using simple OLS regression method. We used Unnevehrs' hedonic price model to calculate the consumer and producer surplus attributing the difference in prices between Ashoka and BG102 to better quality. Lastly, we estimated efficiency of Rockefeller funding component towards the drought tolerant rice research and seed dissemination in Eastern India. Preliminary results favored higher social returns towards both drought tolerant rice research and dissemination efforts in Eastern India.

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LIST OF ACRONYMS

RF	Rockefeller Foundation
PPB	Participatory plant breeding
PVS	Participatory varietal selection
MAS	Marker Assisted Selection
ABSP II	Agricultural Biotechnology Support Project II
TNAU	Tamil Nadu Agricultural University
GVT	Gramin Vikas Trust
BAU	Birsa Agricultural University
CAZS	Center for Arid Zone Studies
DST	Drought and Salinity Tolerant
IDRC	International development research center
CIAT	International Center for tropical agriculture
KRIBHCO	Krishak Bharati Cooperative Limited
KVK	Krishi Vigyan Kendras
NGO	Non- Governmental Organization
CTS	Change in Total Surplus

A 200F	Ashoka 200F
A228	Ashoka 228
BG102	Birsa Gora 102

Breeder seed: is seed whose production is personally supervised by a qualified plant breeder and which provides the source for the initial and recurring increase of foundation seed.

Foundation seed: is the progeny of breeder seed and it can be clearly traced to breeder seed.

Certified Seed: is the progeny of foundation seed. Its production should be undertaken in a way that specific genetic identity and purity are maintained according to the standards prescribed for the crops certification.

1. INTRODUCTION AND BACKGROUND

India is considered to be one of the primary centers of origin for rice (Oryza sativa (sp) indica) in the world. Rice is a major staple food cereal here, and next to wheat, is extensively cultivated across all regions. India contributes 21.5% of the global rice production, second only to China in this regard. Rice production is carried out on 44 million hectares of land (FAOSTAT, 2007). India produced 143 million tons of rice in 2007 out of which 91 million tons were consumed (USDA, 2007). India is one of the largest exporters of rice – it exported 4 million tons of milled rice in 2007 (Oryza.com). Basmati is the major rice variety being exported from India with nearly 0.84 million tons exported in 2006-07 (Oryza.com).

Though rice is cultivated in all regions in India, it is concentrated mainly in the Eastern states of Assam, Bihar, West Bengal, Jharkhand, Chhattisgarh and Orissa. These are the major rice-growing areas, accounting for about half of the total rice production in the country (Pandey, 2007). Some of the northern central states producing rice are Madhya Pradesh, Uttar Pradesh and Punjab. In south, rice is grown in Tamil Nadu, Karnataka and Andra Pradesh. Rice-based production systems provide the main source of income and employment for more than 50 million households in the country. Rice is the staple food for 65% of the total population in India (www.fao.org).

The varieties cultivated in Eastern India are more localized, land cultivars with few improved varieties. The most common varieties of rice grown here are White Gora, Red Gora, Khandagiri, BG102, Anjali, Vandana, China Gora, Malati, Gayabali, Local Gora, Red Gara,Vandana, Ashoka 200F, Ashoka 228, and Shusk Samrat . High yielding rice varieties which developed and spread during the Green Revolution in the country are mainly grown in Andhra Pradesh, Punjab, Haryana and Uttar Pradesh. Eastern India did not gain much from the benefits of green revolution.

Rice is planted mainly in three seasons in Eastern India: June-July, mid August or late season namely September-October. Rice is grown in different types of land: [1]upland, medium land and [2]low land.

Around 253 million hectares of cropland is irrigated worldwide; 100 million of this is in India and China (Frederiksen, 1993). Rice environments in India are extremely diverse. Of the over 40 million hectares of harvested rice area, about 33 percent are rainfed lowland, 45 percent irrigated, 15 percent rainfed upland, and 7 percent flood-prone. Since the major portion (55 percent) of the area under rice in India is rainfed, production is strongly tied to the distribution of rainfall (Selvaraj, 2006).

Drought is a very common phenomenon in India - the probability of occurrence of drought here is 0.46 (Pandey, 2005). Frequency of drought for each period is estimated as the number of years in which rainfall was below 80% of the long-term average for that period (Pandey, 2005). The probability of occurrence of drought in different meteorological subdivisions of India varies from once in 15 years to once in 2.5 years. Drought occurs once in 5 years in West Bengal, Orissa, Madhya Pradesh, Konkan and Bihar. It occurs every 2.5 years in Tamil Nadu, West Rajasthan, Jammu and Kashmir and Telengana (UNDP, 2003) [refer to Appendix B for details].

Effects of moisture shortage on crop production vary depending on when it occurs. Rice is very sensitive during the grain fill period (Fisher and Fukai 2003) - a drought during

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[1] Upland rice is grown in conditions without surface water relying solely on rainfall.
[2] Lowland rice is grown in fields bunded to retain water; there is adequate water either from rainfall or irrigation.

this period leads to loss of yield. Lack of adequate rainfall in planting season could lead to poor land preparation, delayed planting and difficulties in weed control. In extreme cases of drought such as in 2002, farmers are forced to abandon crop production.

Some of the areas which are chronically affected by drought in Orissa are Bolangir, Kalahandi, Kendrapada & Phulbani. In West Bengal Bankura, Midnapore & Purulia district are very severely affected by drought. In Bihar district Aurangabad, Bhojpur, Gaya, Munger, Nawadah & Rohtas have had a very severe impact of drought. [refer to Appendix A for details]. In Eastern parts of India, with extensive acreage under upland rice cultivation, drought occurs once in 5 years. A large part of the rice growing area in Eastern India is semi arid. The local farmers still grow rice in these areas because rice is their staple food. Farmers tend to grow land races which do not have good yield or grain quality.

Drought has a very significant impact on agricultural output as well as on the lives of farmers. Dr. Pandey and his teams' report on increasing production and sustainability in rainfed rice focusing on drought prone environments takes a very in-depth look at drought in Eastern India (Pandey, 2005). It is evident from their report that the impact of drought is not limited to the farmer or the agriculture sector but affects the entire country. The economic costs of drought are very high and can become a hindrance to the development of countries like India which is on the path of rapid economic growth in its tertiary sector. During 1900 to 2004 the country lost 4.3 million human lives due to drought; 1.4 billion people were affected with cumulative damages of US$2 billion (Samra, 2004).

The world rice statistics published by the International Rice Research Institute (IRRI) estimated that 11 percent of rice area in developing countries is under marginal environments, and is mostly affected by droughts. In such environments the average yields are less than 2 tons/hectares as opposed to 5.5 tons/hectares in case of irrigated tropical and subtropical environments (IRRI, 1997).

A closer look at the consumption patterns of rice reveals that there has been a steady increase in consumption of rice in India. During 1960s, rice consumption was around 35 million tons; and steadily increased to 75 million tons in 2000 and currently stands at 91 million tons (USDA, 2007). The increase in rice consumption in the recent years is mainly attributed to the increased population growth. With the projected population growth rate of 1.38 % over the next decade, there is a lot of concern from the scientific community and policy makers regarding meeting the growing domestic demand for rice. The current population rate expects an additional 2.33 million tons of rice per annum to feed the growing demand (Selvaraj, 2006). Increased population growth is also expected to increase pressure on land utilization as other inputs such as irrigation water decrease proportionately. One way to keep up with increased demand is to be able to grow drought tolerant varieties of rice. Since a larger part of agriculture in India is still dependent on monsoons and is frequently affected by droughts, any efforts to improve the productivity of rice under drought conditions would not only enhance the overall production but would also reduce the risk of crop failure.

Drought tolerance research

In India, since early 1990s, a number of public and private institutions and universities are involved in the research of drought tolerant varieties of rice. The rice scientists in India have long viewed genetic improvement of drought prone or water deficient environments as a challenge. But in the past three decades the national and state multi location testing system (All India Coordinated Rice Improvement Program-AICRIP) has made steady progress in varietal development for marginal areas that includes drought tolerance (O'Toole, 2004) Researchers in Tamil Nadu, Karnataka and in five states of Eastern India are using new managed stress environment facilities to operate field-oriented selection practices (IRRI, 2002; Poland, 2004).

The Indian Council of Agricultural Research (ICAR) has established National Research Centre on Plant Biotechnology at the Indian Agricultural Research Institute (IARI) in New Delhi to conduct biotech research on stress tolerance for various field crops. They are working on gene isolation, resistance in transgenic plants for biotic and abiotic stress and marker assisted selection. The Department of Biotechnology, established in 1986, promotes molecular biology and biotechnology research (Pal & Byerlee, 2003), the department supports seven Centers of Plant Molecular Biology (CPMBs) in different parts of the country and aims to promote research and human resource development in plant molecular biology.

Different types of breeding techniques are being used in research. Conventional breeding using marker assisted selection is used widely in agricultural research in India and has been discussed in detail in Chapter 2. Biotech breeding is being tried with international collaboration in Tamil Nadu so far no varieties have been developed using this technique.

Participatory plant breeding research is being carried out in Eastern India. The research is being done by Birsa Agricultural University, Gramin Vikas Trust and Centre for Arid Zone Research,UK. The PPB approach led to the development of two new upland varieties Ashoka 200F and Ashoka 228. One technique that we will be evaluating in this study is the participatory plant breeding technique, also known as client-oriented breeding technology. It has also been discussed in detail in Chapter 2.

Objectives

There has been limited amount of research to breed varieties for marginal rice growing areas. Recently some novel approaches have been used to develop varieties for farmers growing rice in upland areas in order to improve their livelihood. This study tries to evaluate if the research is beneficial to farmers and society as a whole. To do this we estimate the benefits derived from Ashoka varieties that were developed by this research by measuring the increases in value of the improved quality and yield compared to the existing varieties. The main research objectives are summarized below:

1) Measure changes in yield/ productivity levels of different varieties and variability of these varieties, using data from yield trials of farmer's fields. Then calculate the value of the differences in quality of these varieties using the formulas from Unnevehrs' hedonic price model.
2) Determine the cost and benefits of research and diffusion programs on drought tolerant varieties through participatory plant breeding methods in Eastern India.
3) Evaluate the efficiency of Rockefeller financed programs for the seed production and dissemination of drought tolerant varieties.

Methods Used

Our aim is to do a cost benefit analysis to evaluate the impact of research and extension investment on drought tolerance rice research in Eastern India. We use the costs from various sources - Indian Council of Agricultural Research expenditure on agricultural universities in India, Department For International Development, UK, Gramin Vikas Trust and Rockefeller foundation investment. We also used data from past studies in this area. We expected the rates of returns to be positive because these varieties do have better yield and quality attributes. In order to capture the shift in demand due to better quality we used the hedonic price model by Unnevehr. We used the formulas from hedonic price model to calculate the change in total surplus due to difference in quality of Ashoka and BG102 based on the assumption that difference is price is due to better quality.

We use farmers' trial yield data to see the impact on grain yield of the improved varieties. We use the yields of varieties from the regression analysis in the economic surplus model to determine the rates of return of PPB. We used the data from GVT annual reports to calculate rough estimates of the annual benefits incorporating the yield increase and quality attributes brought about by dissemination of Ashoka varieties among the farming households in Eastern India.

2. PLANT BREEDING RESEARCH IN INDIA

In India rice breeding program was started by Dr. G. P. Hector, an Economic Botanist in 1911 in undivided Bengal (http://drdpat.bih.nic.in). The rice research program in India has come a long way since its inception; 720 improved rice varieties have been released so far and 62% of these varieties are for irrigated areas (Pandey, 2007).The most common types of breeding used are conventional, Biotech and participatory plant breeding. These are discussed in detail here.

a) Conventional breeding

In conventional breeding, the progeny inherits genes of both desirable and undesirable traits from both parents. The breeders conserve desirable characteristics and suppress the undesirable ones by repeatedly selecting the good progeny from each generation to be parents of the next. This leads to the development of a new variety. In conventional breeding thousands of genes get transferred in each cross - these may or may not be of use for the specific target variety. It is not easy to isolate desired traits due to incompatibility and difference in species.

b) Biotech breeding

In biotech breeding, new varieties are developed and designed by artificially inserting genes of favorable attributes from other species. A Number of scientists have been working on genetically engineered crops (including rice) for various abiotic and biotic stress tolerant conditions to improve productivity. Biologists working at the Cornell University, led by Prof. Ray Wu, successfully introduced genes for trehalose sugar synthesis into indica rice varieties. Trehalose is a simple sugar produced naturally in a wide variety of organisms like bacteria, fungi, yeasts, mushrooms and invertebrates, particularly insects. Most plants normally do not have much of trehalose, the only exception being the resurrection plants that can survive prolonged droughts in deserts. Drought stressed resurrection plants look as if they are dead, but when moisture is available they spring back to life (Selvaraj, 2006).

Five generations of transgenic rice plants with the trehalose enhancement gene sequences have been tested in the greenhouse and stress tolerance characteristics have been observed (Segelken, 2002). Transgenic rice plants are robust under a combination of environmental stresses when compared with non-engineered rice plants that do not have the trehalose enhancement gene sequences, Professor Wu's lab is working on several other genes for improving drought and salinity tolerance in rice. However, this technology needs to be transferred before the new varieties can be grown in other countries. Under the Agricultural Biotechnology Support Project II program researchers in Cornell University and TNAU are working closely on drought and salinity tolerant rice. The department of Plant Molecular Biology and Biotechnology of TNAU is conducting research on genetic engineering of rice for disease and pest resistance and creating a database on upstream sequence of drought/salt stress inducible genes in rice (http://btisnet.gov.in/uniquepage.asp).

c) Participatory plant breeding

During the early 1970's and 80's, participatory varietal selection (PVS) was carried out as a part of farming systems research or participatory research (Walker, 2006). More recently farmers are being involved in earlier stages of selection in plant breeding. One of the first applications of PPB was in Cauca Valley in Colombia where three farmer breeders worked with breeders in the CIAT bean program. The selections made by the farmer breeders helped in getting information on the demand for characteristics across several environments (Kornegay, 1996). The term PPB and the acronym PVS were coined at an IDRC workshop in 1995. The first joint use of PPB and PVS took place in Experimental Agriculture in the following year (Witcombe, 1996). Since 1995, about 30 articles relevant to PPB have been published in the plant-breeding journal Euphytica (Walker, 2006).

Participatory research can be used to increase benefits if proper choices are made about the research goals, selection of user communities and environments (Ashby & Lilja, 2004). Participatory research is based on different modes of participation. There are two groups of decision makers - the scientists (including research programs and extension agencies) and the farmers. The types of participation are conventional, consultative, collaborative, collegial and farmer experimentation.

A systematic understanding of different types of participation is needed to select suitable participatory research tools and techniques (Ashby & Lilja, 2004). The impact is also based on how early in the breeding process participation is sought. The innovation process is divided into three stages - design, testing and diffusion. The outcomes vary depending on who makes the decision and when.

A study in Nepal used participatory breeding in rice. The varieties produced were tested in mother baby trials in Bangladesh (Witcombe, 2004). The study discusses the techniques used by PPB in using germplasm that meets the demand of the farmers, identifying the farmers, matching the environments and testing the varieties in the targeted area with the farmers. These varieties were accepted by farmers in a very short span of time indicating the success of participatory plant breeding (Witcombe, 2004).

PPB Research and Extension in Eastern India

Marginal farmers of Eastern India grow rice on rainfed uplands which typically are less fertile. They desire varieties that could escape the end of season drought and also give a high yield of grain and fodder.

In 1997 a collaborative project was started in Jharkhand by GVT (E), Center for Arid Zone Studies, Bangor, Wales and Birsa Agricultural University (BAU). In 2001 it led to the release of first high yielding and early maturing varieties for rainfed uplands in Jharkhand. They looked at the available upland varieties. Amongst them Kalinga III was identified as a variety with advantages of early maturity, high grain yield, high fodder yield and good cooking quality but a limitation of poor lodging resistance . In the PPB program Kalinga III was crossed with IR64 (GVT report, 2007) and used as a parent in participatory plant breeding research to breed two varieties - Ashoka 228 and Ashoka 200F. These varieties seemed to be superior, drought tolerant and more cost effective than the land races. These varieties yield more than the control varieties including Kalinga III in both research trials and trials in farmers' fields (Virk & Witcombe, 2003).

Collaborative and Consultative breeding was used to produce the two Ashoka varieties. In case of Ashoka 200F, collaborative breeding was used – here farmers grow and select materials in their field. In case of Ashoka 228 however, consultative breeding was used – here farmers select among progenies in researchers plots.

In 1995 village surveys were conducted which showed that in the rainfed uplands farmers grew coarse-grained rice landraces that had low yields. In 1995 and 1996 appraisals were conducted by focus group discussions and individual interviews to find out the varietal traits that farmers were looking for in the new varieties. Study started in 1997 in collaboration with Birsa Agricultural University Ranchi and Center for Arid Zone Studies (CAZS) varieties were selected based on PVS trials and BAU data. Research-station trials were conducted by BAU, Ranchi at various locations. Participatory trials were done in the form of mother and baby trial methods for participatory evaluation (Joshi & Witcombe, 1996).

Mother trial was a single randomized replicate of all the test entries and controls grown in farmers fields. The trial was replicated across farmer's fields. Forty trials were conducted in the rainy season in 2000 and 2001 in GVT villages in Jharkhand, Orissa and West Bengal. Data was collected on grain yield, days to 50% flowering, height and straw yield. The farmers received the seed packets with a plot number, allocated at random by researchers, and the variety name. All plots were managed according to the farmers' practices for irrigation, fertilizer, weeding and other inputs. A farm walk was organized to find out farmers' views regarding earliness, disease, insects and pests and lodging resistance. After the harvesting, focus group discussions were held to evaluate varieties for traits like grain type, grain straw yield, grain colour, cooking quality. For all the traits considered important by farmer matrix ranking was done.

Baby trials were single replicate single test entry trials with farmers as replicates. The trials were conducted by 198 farmers in Jharkhand, West Bengal and Orissa in 2001. Out of these 65 were for Ashoka 200F and 128 for Ashoka 228. In about 50% of the baby trials of A200F and A228, Kalinga III was used as the preferred check and Birsa Gora 102 as the local check. After harvest, a household level questionnaire was completed to determine the perceptions of the household.

Qualitative data from participatory trials were highly informative, statistically analysable and cheaper to obtain than quantitative data (Virk & Witcombe, 2003). Some of the studies done by Mottram, Bourai, Ratan and Paul (GVT report, 2007) conclude that the Ashoka varieties have greater yield, early maturity, higher adoption, higher adaptability and increased food sufficiency.

Impact Assessment of PPB Varieties

Surveys were done in 2002, 2004 and 2006 to estimate the impact of these PPB varieties. A number of studies were carried out for the impact assessment. A summary of those studies is given in Table 1.

Table 1: Studies on impact of Ashoka varieties

ID	Study Details	Chief Conclusions
1	**(a) Author:** V.A. Bourai (Dec 2002) **(b) N**:159 **(c) Location:** Jharkhand, Orissa, West Bengal	• High preference (97% would grow again) for new varieties for their high yield, earlier maturity, good grain quality and higher market price. • High adoption rates (occupy 50% of household upland area in three states) of up to 100% of household upland area. • Seed spread up to 300 km and sales from 2 to 2000

		kg. • The majority of farmers indicated small to large effects of new varieties on livelihoods.
2	**(a) Author:** P.D. Paul (Nov/Dec 2004) **(b) N:** By group meetings (farmers 324) **(c) Location:** Jharkhand, Orissa, West Bengal	• Farmers get 50 to 300% yield increase over local varieties. • Identified a seed demand of about 700 tons • There is a huge seed supply gap. Private seed companies are not interested in upland rice seed production because of low profits.
3	**(a) Author:** P.D. Paul (Aug 2005) **(b) N:** By group meetings **(c) Location:** Jharkhand, Orissa, West Bengal	• Ashoka varieties have broad adaptability. Also grown in medium lands by broadcasting or transplanting due to high drought in 2005 • High rate of farm saved seed (50 and 100%) from 2004 to2005. • Predicted a demand of over 350 t seed demand for the main season of 2006.
4	**(a) Author:** CAZS-NR (March 2004)	• High preference (100% would grow again) for new varieties for their high yield, earlier maturity, good grain quality and higher market price.

	(b) N: 150 **(c) Location:** Jharkhand, Orissa, West Bengal	• High adoption rates (70% to 100% of household upland area in different states). • High rate of replacement of local varieties. • Increase in food sufficient by 2 to 3 months and trebling of grain sales from 60 to 207 kg per family • 70% farmers reported more than 20% increase in on-farm income with improved livelihoods.
5	**(a) Author:** A. Mottram (Oct 2004) **(b) N:** Whole village **(c) Location:** Jharkhand, Orissa, West Bengal	• Confirms findings of household surveys done in 2002 and 2004 • High adoption rate cultivated in (30% of upland area) • Informal seed spread is slow
6	**(a) Author:** R.P.S. Ratan (April/May 2007) **(b) N:** 106 **(c) Location:** Jharkhand, Orissa, West Bengal	• High adoption rate (66% average upland area) • New varieties occupy 93% upland area of modern varieties. • Average 20 to 80 kg seed transaction up to 500 km. • Replaced 7 landraces and 3 modern varieties. • 70% increase in seed sale and 140% increase in income from new varieties.

	• Food sufficiency increase by 3 months (36% increase). • Earlier maturity gives new options (increase in cropping intensity from 100 to 200%).

(Source: adapted from GVT annual report 2007-08)

The participatory rural appraisals showed that farmers mostly grew coarse-grained landrace ‘Brown Gora’ and a similarly coarse-grained released selection from it, ‘Birsa Gora 102’ which was used as a local check in the trials. The adoption of improved varieties, including Kalinga III, was very low. The village surveys by GVT showed that irrigation was rarely available, farm holdings were typically very small, and had shallow, infertile soils on sloping lands that gave poor yields of upland rice.

Farmers desired varieties with the following characteristics (Virk & Witcombe, 2003):

- early vigor to reduce weeds in the initial stages;
- early maturity (<100 days) to escape from end-of-season drought;
- tall plants (about 100 cm) for higher fodder yield;
- stiff straw and resistance to lodging;
- tolerance to major pests and diseases;
- higher grain yield;
- good cooking quality

In the research station trials in Jharkhand, both Ashoka 200F and Ashoka 228 yielded significantly more than both Kalinga III and Birsa Gora 102 at most locations. In the within-state, within-year analyses of mother trials, both Ashoka 200F and Ashoka 228 yielded significantly more than the check varieties, Kalinga III and BG 102. The overall mean grain yield of Ashoka 200F and Ashoka 228 over 40 trials was 51–56% more than BG 102 ($p \leq 0.001$), and 19–23% more than Kalinga III ($p \leq 0.05$) (Virk & Witcombe, 2003). In baby trials, both Ashoka 200F and Ashoka 228 yielded significantly more than BG 102 and Kalinga III.

In the mother trials of 2000, farmers observed that the Ashoka varieties had superior cooking quality to BG 102 (80% for Ashoka 200F and 95% for Ashoka 228) - Kalinga III was also superior for cooking quality to BG 102 but to a lesser extent (Virk & Witcombe, 2003).

Adoption

Another study (Virk & Witcombe, 2006) examines the case of adoption of Ashoka varieties in three states in Eastern India - Jharkhand, West Bengal and Orissa. Surveys were carried out that confirmed low adoption of modern varieties in the upland ecosystem. Farmers in marginal and diverse agricultural environments maintain landrace diversity to sustain production under adverse environmental changes or reduce the risk of poor production years (Rosenzweig and Stark 1989). Farmers do not feel the need to replace land races because the modern varieties are not an attractive option. They pay a price in terms of lost yield potential, when they grow a low-yielding variety because it has resistance to a biotic or abiotic stress. This lost yield is a measure of the farmer’s willingness to pay for genetic diversity. Thus on-farm varietal diversity is high in marginal agricultural environments. This paper determines how farmers traded-off diversity for higher yield.

Packets of Ashoka 200F and Ashoka 228 seed were distributed to farmer groups in the GVT project villages. A community based seed production program was facilitated by GVT from 2001 to 2004, with the seed produced provided to thousands of farmers. In March 2004, 150 farmers in the GVT project villages who had previously been given seed of one of the two varieties were interviewed. The survey included only those farmers who were given seed of Ashoka varieties by GVT or by other farmers. The seed was given to 6% of total households in Jharkhand, 8% in West Bengal and 2% in Orissa. Each household was asked, using semi-structured questionnaires, about their use of the new varieties from 2001 to 2003. Responses of farmers' from the 2004 survey were compared with results of an earlier survey in December 2002 on 159 farmers (76 in Jharkhand, 45 in West Bengal and 38 in Orissa) (Bourai, 2002; Virk, 2003a).

The results of the study show that farmers had adopted modern varieties to different extents in the three states but most were released many years ago, e.g. Kalinga III was released in 1983 and Heera in 1988 (both in Orissa). The adoption was not high in any of the states. Very few farmers grew a modern variety and those that did, grew it on a minority of their land. Vandana (released in 1992 in Bihar) was less popular than Kalinga III and has been identified as the most preferred variety in GVT's PVS trials since 1996. The yield of grain and straw for Vandana is more than local varieties but its grain quality is poor. Adoption of older modern varieties was highest in Jharkhand. In Orissa, adoption was the lowest where coarse-grained modern varieties such as Heera (released in 1988 in Orissa), Annapurna (released in 1968 in Madhya Pradesh) and Khandagiri (released in 1993 in Orissa) were grown by, at most, 15% of farmers on a very small proportion of their land (Virk & Witcombe, 2006).

Nearly all of the householders who had tried the varieties continued to grow them. Acceptability of A 200F was lower than that of A 228 - of the 42 households in all three states who grew both varieties, 38 (90%) preferred A 228 to A 200F. Hence, progressively fewer households grew A200F and by 2004, 37 (66%) of the 56 farmers that were originally given seed in 2001 or 2002 continued to grow it. This compares with the 90 to 100% of farmers (depending on the year and state) who continued to grow A 228. On average, 45% of farmers in all states devoted 100% of their upland fields to the new varieties (Virk & Witcombe, 2006).

Majority of farmers in the 2002 and 2004 surveys perceived that, in comparison with local varieties, the new Ashoka varieties were, higher yielding in grain and fodder, earlier to mature and had better quality of grain. They got a higher market price because of their long-slender grains. The price advantage in the 2004 survey averaged 12% for both varieties over all three states (Rs 6.28 per kg for the Ashoka varieties and Rs 5.62 per kg for the local variety) (Virk & Witcombe, 2006). After the severe drought of 2002, most farmers reported that the new varieties had better drought tolerance and weed suppression. In matrix rankings conducted during the 2004 survey the best variety was given the highest ranking. The Ashoka varieties scored high for all traits.

A large number of farmers reported that they had already replaced or intended to replace by 2004 at least a landrace or modern variety with either A200F or A228. There was a significant decline in the number of farmers growing any landrace in Jharkhand and Orissa with only West Bengal having a non significant decline. Although both Ashoka varieties were liked and adopting farmers increased the area under them A 228 was preferred over A200F. This preference for A 228 may be because of the type of land and area of the surveyed farmers that was slightly more favorable than the harsher environments where A200F performs better. A 200F is popular in areas where drought is of a more consistent occurrence, e.g., the worse drought-hit areas of Kalahandi and Bolangir districts of Orissa that were excluded from the current survey as they lay outside of the GVT project area (Virk & Witcombe, 2006). When participatory plant breeding methods were used successfully the need for trade-offs was reduced. Farmers expanded the cultivation of Ashoka varieties into the medium lands in Jharkhand; of the 57 sampled farmers, 8 in 2002 and 11 in 2003 grew them in medium land. The average area per household increased in the medium land from 0.24 ha to 0.31 ha in this period. Fallow land was brought into cultivation. In 2002 in Orissa, 19 of the 33 sampled households grew them on an average of 0.23 ha of what would have been fallow land in 2002. This increased to 20 farmers and an average area of 0.30 ha by 2003.Cultivation on rented land also increased; of the 150 sampled farmers 6 rented land to grow them on an average of 0.24 ha in 2002. In 2003, 11 farmers did so on an average of 0.29 ha (Virk & Witcombe, 2006).A200F and A 228 varieties were tolerant to abiotic stress and had no disadvantages in comparison to local landraces. In chapter 3 we talk about seed production for these drought tolerant rice varieties, seed supply and the role played by Rockefeller foundation in the research and dissemination of these varieties.

3. SEED PRODUCTION AND DISSEMINATION

Production of drought tolerant rice varieties in Eastern India

The farmers in Eastern India were provided seed of Ashoka varieties by Gramin Vikas Trust (GVT) during the first year for further multiplication through self help groups. The seed production activities were mainly concentrated in the villages around Haldikundi in Dekhanal district in Orissa during Rabi 2002-2003. The crop was monitored by plant breeders and consultants during the entire production period. At the end of the season, the seed was procured by GVT and were offered 20 % premium price than the existing seed rates of the government agency (GVT report, 2003-04). The Ashoka varieties were not notified by the Government of India till 2005, self help groups were mobilized by GVT to produce truthfully labeled seed from the year 2001 for further distribution among farmers. Since then the community based seed production has increased over the years. Various NGO's and the Catholic Relief Services (CRS) were also further involved in distribution of the multiplied Ashoka variety seeds across the eastern India states. The table below shows the amount of seed distributed through GVT efforts in Eastern India till the year 2007.

Table 2: Community based seed production since 2001-02 to 2006-07 (Kg)

Production year	Ashoka 200F	Ashoka 228	Total	Type of seeds
2001-02	110	228	338	Truthful
2002-03	2067	4785	6852	Truthful
2003-04	4318	3807	8125	Truthful
2004-05	1070	630	1700	Truthful
2005-06 rabi[3]	1,09,100	42,500	1,51,640	Certified
2005-06 rabi	4460	4500	8960	Foundation
2005-06 rabi			3218	Breeder (pipeline varieties)
2006 kharif[4]	28,038	27623	55,661	Certified
2006 kharif			4000	Breeder (pipeline varieties)

(Source: GVT, BAU & CAZS-NR, 2007)

The amount of seed produced has increased over the years from 338 kg in 2001-02 to 59661kg in kharif 2006 as shown in table 2.

Sources of Seed Supply

The Green Revolution was one of the greatest technological success stories of the Twentieth century. However, it did not reach many of the world's poorest farmers because the new varieties did not perform well in areas where water resources and soil fertility requirements could not be met. In most of these areas the farmers have been growing land races and some improved varieties e.g. Vandana and Kalinga III (Virk & Witcombe, 2006). However, these varieties do not meet the necessary production and consumption attributes required by subsistence farmers. For instance, Kalinga III, a

3 Rabi season occurs in spring. The season is from mid/late April to mid/late June.

4 *Kharif season is one of two major cropping seasons in India. It occurs during the Southwest monsoon or from July through October.*

drought tolerant, upland cultivar that was released as early as 1983 but was not adopted by the upland farmers due to poor lodging resistance. The adoption was poor not only due to the lack of attributes but also because of the lack of proper dissemination mechanisms e.g. role of private sector in Eastern India is very limited there are very few private companies and the ones present are only interested in selling hybrid seeds or transplanted varieties (http://www.future-agricultures.org).

The collaboration of Gramin Vikas Trust (GVT), Birsa Agricultural University (BAU) and Centre for Arid Zone Studies (CAZS) from 1997 onwards has lead to the development of new Ashoka varieties (A200F and A228) .These varieties were officially released in 2005 and have become popular because farmers do not have to change their farming methods to grow them. As long as they can get the seed and save some of it they can continue growing these varieties. The new Ashoka varieties will help farmers of these areas because they have higher yields and good grain quality. Some of the ways in which seed adoption and spread could take place are:

1. **Farmer to farmer spread:** since these varieties have the traits desired by the farmers growing rice in upland areas, they might share them with other farmers. This would in turn lead to adoption. However, this kind of adoption will be slow and the varieties would not be able to reach the masses. Village surveys done in Eastern India have shown that the amount of seed spread from farmer to farmer varied based on area cultivated and the amount of seed harvested. But in drought years farmers seed supply falls due to fall in total rice harvested. Also farmers consume the seed because of good grain quality. Then they have to rely on outside sources to get seed.

It is important to have a seed supply to meet the rising demand (www.future-agricultures.org).

2. **Local self help groups or Non Government Organizations:** could take up the task of providing seed to the farmers but they would require some kind of subsidy or financial support in order to support such an effort. For example, Krishak Bharati Cooperative Limited (KRIBHCO) which established Gramin Vikas Trust (GVT) to elevate poverty and enhance livelihood of rural population, could provide money to GVT to buy seed and give it to farmers at a nominal price. In addition, not all these areas have a good network of NGOs or self help groups. Almost 90% Ashoka seed has been produced by 8 Self Help Groups (4 in Dhenkanal,3 in Kheonjar and 1 in Kalajhini in Orissa) under contract of GVT and some seed was produced by BAU in Ranchi.(GVT report, 2003-04).
3. **Government Extension System:** the government has Krishi Vigyan Kendras in these areas. One of their objectives is the spread of new technologies to farmers, which can help in providing seed of Ashoka varieties. The government can give subsidies to the NGOs in the area to provide seed.
4. **Private seed companies:** this area has private seed companies selling hybrid seed and transplanted varieties over time they may decide to include the drought tolerant varieties. Currently, they are not interested in selling drought tolerant varieties because of low profit margin and the poverty of the farmers in these areas.

In this study we have attempted to quantify the impact of Ashoka varieties and its adoption based on their yield and quality (cooking and taste) attributes. This was done through simple cost-benefit analyses based on certain assumptions of GVT's efforts to multiply and disseminate seeds of Ashoka varieties in Eastern India through Rockefeller Foundation funding. In the course of this study we also do a scenario analysis where we consider two possible scenarios dissemination of Ashoka varieties with RF funding and without RF funding for the research and specifically dissemination of the Ashoka varieties.

Gramin Vikas Trust and other local agencies distributed seed of the two Ashoka varieties in all the three states and some to other states. The distribution was either done by GVT or some local agency. Till 2007 they had distributed a total of 234.41 tons of seed. Seed distribution (in tons) of upland rice varieties (Ashoka 200F and Ashoka 228) by GVT and other agencies from 2002 to 2007 is detailed in Table 3.In 2008 the distribution reached 255 tons (GVT report, 2007-08).

Table 3: Seed distribution by GVT and other agencies (2002 - 2007)

State	By whom	2002	2003	2004	2005	2006	2007
Jharkhand	GVT	12.00	9.1	9.4	2.38	3.83	9.91
	Other	4.50	7.9	9.6	0.00	88.89	171.68
Orissa	GVT	12.00	8.7	32.0	1.90	0.00	8.27
	Other	2.40	2.6	11.2	0.50	2.49	0.00
W. Bengal	GVT	12.00	9.0	14.9	0.09	2.09	0.00
	Other	2.40	0.0	5.1	0.00	0.24	0.00
Other states		0.00	0.0	0.0	12.39	58.46	44.53
Total		45.30	37.2	85.2	17.26	156.0	234.41

(Source: GVT, 2008)

The farmers as a result have not only adopted improved Ashoka varieties by replacing the existing local land races and other cultivars but they brought additional lands (fallow) under upland rice cultivation (Virk & Witcombe, 2006). Hence it could be seen that

Ashoka varieties have not only performed well under upland conditions but with proper seed production and dissemination efforts, it would be possible to maximize their level of adoption. In this context, the Department For International Development (DFID), UK financed mostly the research and to some extent the dissemination efforts of University of Wales – GVTs partnership on Ashoka varieties till the year 2005. After 2005, in order to continue the existing as well as to extend the level of adoption, there was further need for a new initiative on seed production and dissemination. From mid 2005, Rockefeller Foundation project started supporting both the research and dissemination efforts under taken by the GVT-Bangor partnerships.

Rockefeller Foundation Project

The Rockefeller Foundation project on development and dissemination of drought tolerant varieties of rice for improving the livelihoods of marginal farmers in Eastern India through participatory plant breeding and marker assisted selection is a unique partnership between the public and private sector (GVT report, 2006-07) It aims at faster delivery of seeds of the farmer preferred drought tolerant varieties thus improving the food security and livelihood of the poor farmers of Eastern India. RF felt the need to take up the production of upland rice varieties in Eastern India because private seed companies are not interested in producing seed of upland rice as it is not profitable (www.future-agricultures.org). There is less production per hectare compared to rice varieties of other regions and ecologies. Farmers in marginal areas usually grow either obsolete varieties (low yielding and disease susceptible varieties that were released often more than 20 years before) or landraces (Witcombe, 1998). The farmers of upland varieties are small farmers who own land where there is no irrigation. One of the main reasons why they grow rice is because it is their staple food. The seed dissemination is severely constrained in these areas and some NGO's and self help groups are trying to spread the seed. However, their reach is very limited.

Rockefeller foundation has been a part of this research and dissemination initiative since 2003 initially they contributed $23480 (2003 – 2005).The aim was to reduce loss in yield due to drought by genes coding for drought resistance in roots and transfer of farmer preferred traits into Kalinga III and dissemination of the new strains in target areas (GVT report, 2003-04). The year 2005-06 Rockefeller contribution to the project increased they contributed $50649 for research and dissemination of processed seed of Ashoka varieties. An assessment of seed demand was done through two surveys by independent scientists in November 2004 and August 2005. While the 2004 survey identified a seed demand of over 600t, the 2005 survey reported that Ashoka varieties were also being grown in medium land indicating a broad adaptability of these varieties. (GVT report, 2006-2007).It was clear that more processed seed had to be produced to cater to the growing demand thus three seed units were set up with RF support of $165545 in the year 2006 and 2007. These units have already started producing seed for multiplication and distribution. In 2008 there was an increase in the production of processed seed from 190 tons to 255 tons (GVT report, 2007-08), $50017 was spent on research and dissemination.

The type of seed produced is:

Breeder seed: is seed whose production is personally supervised by a qualified plant breeder and which provides the source for the initial and recurring increase of foundation seed.

Foundation seed: is the progeny of breeder seed and it can be clearly traced to breeder seed.

Certified Seed: is the progeny of foundation seed. Its production should be undertaken in a way that specific genetic identity and purity are maintained according to the standards prescribed for the crops certification. (http://agricoop.nic.in)

Under the Rockefeller grant, production of foundation seed, certified seed and research seed is being taken up in different states, in Orissa during rabi 2006, 21678 kg of seed was produced. Out of this 9250 kg was certified seed, 8958 kg was foundation seed and 3200 kg was research seed. The seed was distributed to various agencies in Jharkhand, Orissa and West Bengal.Seed was also provided to local NGO's and Krishi Vigyan Kendras run by the government.

The seed that was produced till 2005 was truthfully labeled because till 2005 the Ashoka varieties had not been released officially. A part of the seed was distributed free of cost. The beneficiaries from free seed distribution under the RF project in kharif 2006 were farmers in various villages in different states, NGO's, KVK's, NABARD and BAU. A total of 9520 kg of sees was given to 1612 beneficiaries (Source: GVT, BAU & CAZS-NR, 2007). Most of the seed was distributed to small and marginal farmers through various government and non government agencies.

The Rockefeller Foundation project funding helped to set up three seed processing units two units in Jharkhand and one in Orissa.The seed processing facility also extends its services to other seed agencies and seed growers on commercial basis at all locations in order to meet the running cost of these units. From the year 2006, the seed production of

Ashoka varieties also improved dramatically from 17 tons to 150-200 tons, increased production helped in the rapid dissemination of these varieties among the farmers, covering nearly 3000 hectares in Eastern India by the end of 2007.

In this study, we have calculated rough estimates of the annual benefits – towards the value of the yield increase and quality attributes due to Ashoka varieties dissemination among the farming households in Eastern India. This is the equivalent to estimating the consumer and producer surplus with perfectly elastic demand curves and inelastic supply curves. We estimated these returns in terms of increased value due to yield increases as well as improved price for the Ashoka varieties (which measures improved grain quality) over the existing, local upland variety namely BG 102. Ashoka being a fine variety compared to the existing BG102 also commanded higher prices in the market (12% higher) and also yielded better (15-20%).

Further we used this estimate to quantify the impacts of RF funding in the drought tolerance rice research in Eastern India, especially towards the dissemination of drought tolerant rice varieties in Eastern India. For this purpose, we compared two possible scenarios – with and without RF funding support in the introduction of these varieties. We compared the seed production and area coverage by GVT and others for the year 2005, 2006, 2007 and 2008.

Due to the RF support in establishing the seed processing units the seed can be processed and disseminated much faster leading to increased adoption and hence increase in farmer yields and income.

The research has led to the development of several new varieties for both upland and medium land. The medium land varieties are spreading in the districts where GVT, CAZS & BAU are carrying out research in Eastern India. Seed production was carried out by GVT for Barkhe and Sugandha 1, in dry season of 2004-05 and 2005-06 in Orissa (www.researchintouse.com).

Some varieties have been identified to be tested in All India Coordinated trials, state trials and on-farm trials.Promising entries are PY84, P170 (by MAS breeding for rainfed upland), Navjot, Ruby (from PPB for rainfed uplands), Sugandha 1, Barkhe, Ashoka 900F, Ashoka 165 and Judi 578 (from PPB in India and Nepal for transplanted medium land conditions).(GVT report,2007-08). Based upon the previous research papers and literature review we chose the models we would use for our study. We decided to use the cost benefit analysis to assess the impact of drought tolerant varieties and to see the impact the RF project has had on the seed production and dissemination. In the following chapter we discuss the conceptual framework for this thesis.

4. CONCEPTUAL FRAMEWORK

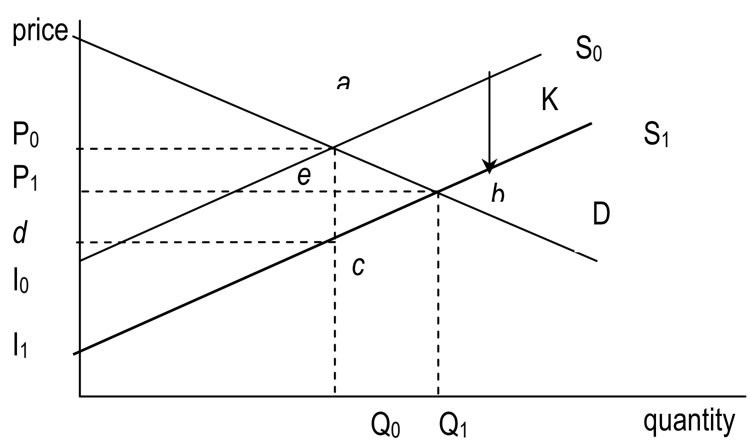
Models Used

Alston, Norton & Pardey Economic Surplus Model

In order to do an impact evaluation of drought tolerant rice technologies through participatory approaches in Eastern India this study uses the method proposed by Alston, Norton, and Pardey, 1995 in their book "Science under scarcity". This model has been

They use the concept of economic surplus to explain the changes that take place in the supply curve with an increase in supply causing a change in prices for consumers and producers. These changes are illustrated in Figure 1.

Figure 1: Economic Surplus Model



(Source: Alston, Norton & Pardey, 2005)

Here, S_0 represents the supply curve before adoption of the new Ashoka varieties and d represents the demand curve. The initial equilibrium price and quantity are P_0 and Q_0, respectively. When the new Ashoka varieties were adopted and the technology led to savings the price changed to $P_{1,}$ it would be reflected in a downward shift in the supply curve to S_1. The supply shift is assumed to be parallel. This shift leads to an increase in production and consumption of Q_1 (by $\Delta Q = Q_1 - Q_0$) and the market price falls to P_1 (by $\Delta P = P_0 - P_1$). Consumers are better off because they can consume more of the commodity at a lower price. Consumers benefit from the lower price by an amount equal to their cost saving on the original quantity (Q_0 x Δ P) plus their net benefits from the increment to consumption. Thus total consumer benefits are represented by the area P_0abP_1.

Although they may receive a lower price per unit, producers are better off too. The change in the producer surplus is given by (P_1 bI_1 – P_0 aI_0).

Total benefits are obtained as the sum of producer and consumer benefits.

The benefits are change in total economic surplus calculated for each year and the costs are the public expenditure on research and regulatory process. With the introduction of the Ashoka varieties the yield has increased leading to a downward shift in the supply curve. Based on previous literature even though this is a small project our hypothesis is that a substantial increase in benefits will occur due to the introduction of Ashoka varieties. We hope to find an impact in terms of not only the yield increase but also the better quality of these varieties. In order to determine the extent of the shift in the supply curve we need to estimate the change in yield. Change in yield has been estimated using the OLS model of regression. We use farmers' trial yield data for the regression analysis to get a precise value for mean yield.

Mathematically:

$$\Delta CS = P_0 Q_0 Z(1 + 0.5 Z\eta)$$
$$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5 Z\eta)$$
$$\Delta TS = P_0 Q_0 K(1 + 0.5 Z\eta)$$

K is vertical shift of the supply curve as a proportion of initial price

ε is elasticity of supply

η is elasticity of demand

Z = K*ε / (ε + η) reduction in price relative to its initial value due to supply shift.

OLS Regression Models

Estimating the change in yield will help us calculate the shift in the supply curve 'K'. In order to calculate the change in yield we use simple OLS regression models to help us get a precise measure as we control for unwanted influences with other independent variables and unmeasured influences in the error term. We are looking at grain yield as the dependent variable and days-to-50% flowering and varieties as the independent variables. We were trying to see the causal relationship between flowering, location and the varietal choice on the grain yield.

Description of models used

Upland 2000-2007

Grain yield = a + b 50% flowering + c Jkhand Loc + d Orissa Loc + e A200F + f A228+ g PY 84+ h Kalinga III+ i Vandana+ j year 2003 + k year 2004 + l year 2005 + m year 2006 + m year 2007 + e (1)

Medium Land 2000- 2007

Grain yield = a + b 50% flowering + c Jkhand Loc + d Orissa Loc

+ e Sugandha + f Barkhe3010+ g year 2003 + h year 2004 + I year 2005 + j year 2006 + k year 2007 + e (2)

Hedonic price model

Research in agriculture has mainly focused on increase in yield without incorporating the other desirable characteristics such as taste and quality of the variety under study. Quality of food is an important characteristic which improves consumers' utility and consumers are willing to pay more for it. Thus it needs to be measured and incorporated in the analysis if we want the true value of the research that produced these varieties. Estimates of hedonic price models can be used to evaluate returns of research to quality. Unnevehr has described such measures in her seminal studies in this area (Unnevehr 1992). We will be using formulas from her model to calculate the consumer and producer surplus for the quality traits of Ashoka varieties.

Using the original relation,

$$P^*_u = P_u\left(1 - \frac{1}{\varepsilon_s}\right) + \frac{P_u}{\varepsilon_s} + \left[\frac{\frac{G}{\varepsilon_s}}{\frac{1}{\varepsilon_s} - \frac{1}{\varepsilon_d}}\right] \tag{3}$$

P^*_u = increased price of new variety;

P_u = price of control variety;

ε_s = supply elasticity;

ε_d = demand elasticity;

G = consumer surplus gain per unit of good u consumed

Rearranging this, we have the relation for consumer surplus gain

$$\mathbf{G = (P^*_u - P_u)(1 - \varepsilon_s / \varepsilon_d)} \tag{4}$$

The new quantity demanded with improved quality is given by:

$$q^*_u = q_u + \left[\frac{G\left(\frac{q_u}{P_u}\right)}{\frac{1}{\varepsilon_s} - \frac{1}{\varepsilon_d}}\right] \tag{5}$$

q_u = original quantity demanded

Change in Consumer Surplus due to quality incorporation is given by:

$$CS = q_u G \tag{6}$$

Change in Producer Surplus due to quality incorporation is given by:

$$PS = q_u (P^*_u - P_u) + 1/2\ [(q^*_u - q_u)(P^*_u - P_u)] \tag{7}$$

Change in Total Surplus due to quality incorporation is therefore given by:

$$\mathbf{CTS_q = (CS + PS)*Adoption\ rate} \tag{8}$$

Hence, change in total surplus is given by:

$$\mathbf{CTS^* = CTS_{AP} + CTS_q\ ;} \tag{9}$$

where CTS_{AP} = Change in Total Surplus from Alston-Pardey model and CTS* sums up the benefits due to both quality and yield changes.

Research benefits would be computed as:

$$\textbf{Benefit} = \textbf{CTS}^{*} - \textbf{Cost} \qquad (10)$$

The detailed analysis is given in the following chapter. In chapter 5 we will be describing the sources of data, assumptions and limitations of the data being used. We will describe in detail the methods used for our analysis.

5. METHODOLOGY AND ANALYSIS OF YIELD CHANGE

Sources of Data

Data set to calculate yield changes: The data was collected from the mother trials that were held by GVT, BAU & CAZR from the year 2003 to 2007. We look at the mother trial data as opposed to the research station data because this data is from the farmers' fields thus similar to the actual growing experience. There is no farm level surveys done except for the GVT surveys. Data for year 2000 was collected from the varietal release proposals of the Ashoka varieties, PY84, Barkhe 3010 and Sugandha 1 varieties. Two types of data sources have been used for this study to empirically describe the objectives outlined and are segmented into the following data sets.

The farm level yield trials data on drought tolerant rice varieties was collected from trials conducted by GVT, BAU & CAZR at different location in Orissa, West Bengal and Jharkhand. The trials were conducted from the year 2003 to 2007. This was further used to determine productivity of different varieties across 3 major locations in Eastern India over multiple years. One of the major limitations is that the data is from scientists who developed these varieties. It is credible though since it has been reviewed by technical committees of other scientists. Trials were conducted on 50 drought tolerant varieties to gauge their performance in low input unfavorable environments by IRRI in 2006. Table 4 lists varieties in descending order of performance; the Ashoka varieties did very well under low input no stress environment but under short duration stress the varieties didn't do so well.

Table 4: Mean grain yield of the genotypes along with the days to flowering and plant height in unfavorable environments (arranged in descending order of performance in low-input)

No.	Entry	Grain Yield(t/ha)					Days to flowering		Plant height	
		Low input	Std error	High input	Std error	difference	Low input	High input	Low input	High input
3	Ashoka 228	.92	.16	1.03	.16	.11	69	66	80	92
2	Ashoka 200F	.82	.15	1.02	.15	.20	68	67	80	92
20	Kalinga III	.66	.20	.60	.20	-.06	66	63	81	86
50	Vandana	.59	.15	.94	.15	.34	72	70	76	87

(Source: IRRI, 2006)

Data Set Limitations

The following are the limitations associated with this data set:

- Continuous year-wise data is not available for the new Ashoka varieties.
- Impact of drought on the varieties is not obtained because of the lack of data for Jharkhand state which was earlier a part of Bihar.
- No data is available on the varietal coverage based on the area.
- The exact cost change per hectare for the new technology has not been quantified.
- There is lack of information about the extent of spread of the Ashoka varieties beyond the survey areas and their spread into other states.

Data on Research and Extension Costs: These were collected from the Rockefeller foundation proposals, annual reports of GVT, BAU & CAZR, and from ICAR websites to evaluate the returns to research investments in drought tolerant rice breeding, adoption and dissemination in Eastern India.

Data Set Limitations

The following are the limitations associated with this data set:

- Lack of research cost for the Gramin Vikas Trust NGO.
- The exact amount of seed produced and disseminated has not been quantified.
- Difficult to assess the role of KRIBCO (in expenditure terms) in GVT's research effort.

Data on Quality: The impact of quality on the benefits has been calculated using formulas from Unnevehrs' hedonic price model. We calculate the consumer and producer surplus based on the assumption that difference in price of Ashoka and BG102 is due to quality differences (detailed in chapter 4).

Farm Level Analysis

Farm level yield trial data from farmers participating in the mother baby trials of the PPB technique in Jharkhand, Orissa and West Bengal has been used. This data was collected for the multi-year multi-location testing performed by BAU, GVT and CAZR. The farmers grew the varieties on their fields under the supervision of scientists. The trials were conducted in years 2000, 2003, 2004, 2005, 2006 and 2007. We have attempted to estimate if there is a significant relationship between yield, location, years of trial and varietal traits. The variable summary (Table 5) gives a description of the number of farmers who have grown these varieties. It was observed that the maximum number of farmers grew the Ashoka varieties. By comparison, Kalinga III was grown in only two years. Total number of trial plots used was 235**.**

Table 5: Number of farmers growing different varieties in upland areas

Varieties grown	Year 2000	Year 2003	Year 2004	Year 2005	Year 2006	Year 2007	Total
A200F	17	5	6	8	6	9	51
A228	17	5	5	9	5	10	51
BG102	18	5	5	6	3	10	47
Kalinga III	18	0	5	0	0	0	23
PY84	0	4	6	8	6	10	34
Vandana	0	5	1	7	6	10	29
Total	**70**	**24**	**28**	**38**	**26**	**49**	**235**

(Source: GVT, BAU & CAZS-NR, 2008)

The continuous variables used in this study were grain yield and days to 50% flowering. We created dummy variables in our study for location, years and varieties. The minimum and maximum yields were observed to be 20 kg/ha and 3960 kg/ha, respectively. The minimum days to 50% flowering were zero because some of the famers lost their crops. The descriptive statistics around yield values for these are detailed in Table 6.

Table 6: Descriptive statistics of continuous variables used

Variable	Observations	Mean	Std. Dev	Min	Max
50% flowering	235	60.6	13.9	0	75
Grain yield	235	1713.5	801.7	20	3960

(Source: Author)

The varieties that were replaced in these areas were the local varieties like Birsa Gora 102 (BG 102) and early improved varieties like Kalinga III and Vandana. While Ashoka varieties were the first generation of improved varieties from the project, PY 84 was the second generation. The mean yield of the local varieties was observed to be less as compared to the improved varieties. While the yield of Vandana variety was high it was not preferred by farmers due to its low grain quality (Virk and Witcombe, 2006).

The summary statistics around yield values of the varieties are detailed in Table 7.

Table 7: Yield statistics of upland varieties

Variable	Observations	Mean	Std.Dev	Min	Max
BG102	47	1340.3	527.4	142	2700
Kalinga III	23	1389.6	647.7	200	2166
Vandana	29	1746.7	690.3	24	2960
Ashoka 200F	51	1768.0	678.5	182	2920
Ashoka 228	51	1808.2	695.6	80	3140
PY84	34	2196.2	1234.6	20	3960

(Source: Author)

The mother trials were conducted in all the three states of Jharkhand, Orissa and West Bengal. It was observed that the number of farmers growing rice in upland Jharkhand area was more than those in Orissa and West Bengal. This was mainly because GVT (E) is based in this state and most of the research trials are carried out in Birsa Agricultural University, Ranchi. Table 8 details a state-wise breakup of the number of farmers growing upland varieties in Eastern India.

Table 8: State wise distribution of farmers growing upland varieties

Variable name	Jharkhand	Orissa	West Bengal	Total
A200F	22	15	14	51
A228	22	15	14	51
BG102	21	15	11	47
Kalinga III	12	7	4	23
PY84	13	10	11	34
Vandana	11	8	10	29
Total	**101**	**70**	**64**	**235**

(Source: Author)

Varietal traits analysis

There are a number of differences between the new Ashoka varieties and the check variety BG 102. Based upon our review of literature it is evident that Ashoka varieties mature earlier than BG102. Table 9 summarizes these differences in traits – chief among them are Ashoka varieties being superior in terms of grain quality, color and cooking quality, and moderately resistant to diseases like blast and bacterial leaf blight.

Table 9: Differences between Ashoka varieties and Birsa Gora (102)

Varieties	Ashoka 200F	Ashoka 228	Birsa Gora 102
Year of Release	2005	2005	1993
Parentage	Kalinga III/IR64	Kalinga III/IR64	Gora rice
Duration	85-90 days	95 days	95-100 days
Cooking Quality	Good	Good	Not desirable
Grain Quality	Super fine (long slender grained)	Super fine (long slender grained)	Short bold grains
Grain color	White	White	Redish
Pest and Disease	Moderately resistant	Moderately resistant	Moderately tolerant
Price	6.28 kg^{-1}	6.28 kg^{-1}	5.62 kg^{-1}

(Source: compiled from various sources)

Upland regression

We used OLS regression to estimate the factors explaining yield variations across varieties and location over years of testing in farmers' fields. The regression analysis used data from the trials. The trials were held in 2000 and 2003 - 2007. The base year was 2000 and the base variety used was BG 102. Six different varieties suitable for upland areas were used in these yield trials. The results of the estimated model are summarized in Table 10.

Table 10: Upland regression results

Grain Yield	Coefficient	Std. Error	t-value	P > t
50% flowering	18.30	2.99	6.13	0.000
Jkhand loc	414.50	102.83	4.03	0.000
Orissa loc	470.42	109.35	4.3	0.000
A200F	**510.39**	**98.95**	**5.16**	**0.000**
A228	**482.88**	**104.48**	**4.62**	**0.000**
Kalinga III	355.48	115.05	3.09	0.002
PY 84	**711.25**	**157.26**	**4.52**	**0.000**
Vandana	**181.17**	**133.79**	**1.35**	**0.177**
Year 2003	-161.67	208.35	-0.74	.439
Year 2004	-137.13	162.70	-0.84	0.400
Year 2005	57.94	95.36	.61	0.544
Year 2006	1102.18	104.64	10.53	0.000
Year 2007	751.97	106.74	7.04	0.000
Constant	-344.69	241.08	-1.43	0.154
Number of observations	**F(13, 221)**	**R – Squared**	**Number of observations**	**F(13, 221)**
235	36.25	0.579	235	36.25

(Source: Author)

In the upland trials, 101 farmers from Jharkhand, 70 from Orissa and 64 from W.Bengal were provided seed for testing of promising upland varieties (A220F, A228, PY 84, Vandana, Kalinga III). Among the varieties compared to the check, the Ashoka varieties are positive and significant. Kalinga III, PY 84 and Vandana also have a positive impact on the yield. This proves our hypothesis that days to 50% flowering and location of the trials have a positive impact on the grain yield. We expected these results because

Ashoka varieties are early maturing, high yielding varieties that have been bred for the upland rice areas. The results show that the factors influencing yield such as flowering, location and varieties are all positive and significant. We expected the flowering to be positive because it would impact the total duration and yield of the varieties. We use the results from the OLS regression to get the supply shift because it gives us a more precise value for the mean yield as we control for unwanted influences in the error term. The value for mean yield of Ashoka variety has been calculated by taking the average difference in yield of Ashoka varieties from our regression analysis (496.64) and adding it to the mean of the base variety BG102 (1340.3) to get the mean yield of Ashoka varieties (1836.5) as opposed to (1788.1) from the data (refer table 7) the supply shift because of yield change is used to calculate the internal rate of return. To calculate the impact due to quality we use the formulas from hedonic price model to get the change in total surplus explained in detail in chapter 4. We assume the price increase is only due to better quality. We calculate consumer surplus gain per unit of good consumed (G), new quantity demanded with improved quality (q*u), using these quantities we calculate the change in consumer and producer surplus. The change in total surplus because of quality comes out to be $52666. This is used to calculate CTS* [for details please refer Appendix table G].

Medium Land Varieties

The principal varieties grown in medium land conditions are IR 64, Barkhe 3010 and Sugandha. IR 64 is an old variety developed at the International Rice Research Institute in the Philippines and released many years ago. It is grown in some of the low and medium land fields in this area and has been used as the control in the research trials.

Barkhe 3010 and Sugandha are new varieties that have come out of participatory plant breeding program. Data on number of farmers using these medium land varieties is detailed in Table 11.

Table 11: Number of famers growing medium land varieties

Year	Barkhe 3010	IR 64	Sugandha 1	Total
2000	5	5	4	14
2003	14	14	14	42
2004	9	9	10	28
2005	17	17	17	51
2006	9	9	9	27
2007	15	15	15	45
Total	**69**	**69**	**69**	**207**

(Source: Author)

The trials for these varieties were held in clusters of villages in the Eastern India states of Jharkhand, Orissa and West Bengal. Total number of plots used was 207; the varieties were grown by 69 farmers. The minimum number of plots used was 14 in the year 2000 and the maximum was 51 in the year 2005.

Table 12 details the number of farmers growing the medium land varieties across different states the maximum number of trial plots were in Jharkhand chiefly because it has the maximum upland area and GVT is based in that state.

Table 12: Number of farmers growing medium land varieties in different states

State	Barkhe 3010	IR 64	Sugandha 1	Total
Jharkhand	33	33	33	99
Orissa	17	17	17	51
West Bengal	19	19	19	57
Total	**69**	**69**	**69**	**207**

(Source: Author)

The two new varieties Barkhe and Sugandha 1 were proposed for released in 2005, where as IR64 is an old variety that was released in 1991. The qualitative traits of these medium land varieties are summarized in Table 13.

Table 13: Traits of medium land varieties

Qualitative traits	Barkhe 3010	Sugandha 1	IR64
Year of Release	2005	2005	1991
Parentage	Kalinga III/IR64	Pusa Basmati-1.	IR-5857-33-2-1 x IR-2061-465-1-5-5
Duration	120 days	120 days	115-120days
Pest and Disease	Moderately tolerant	Moderately tolerant	Resistant

(Source: release proposals)

All these medium land varieties take 120 days to mature on average and are moderately resistant to pest and diseases. The participatory plant breeding program has been successful in producing both upland and medium land varieties.

Medium land regression

A total of 69 farmers from each of the three states were given promising medium land varieties for testing, namely IR 64, Sugandha 1 and Barkhe 3010. Tests were conducted for multiple periods between 2000 and 2006. In our analysis the base year was 2000 and the check variety was IR64. The number of farmers who were given seed samples across these years ranged from 14 to 57.

A simple OLS regression was fit to determine the factors affecting the yields across different varieties in the 3 major rice growing states in Eastern India.

We used the following model to determine grain yield. The medium land regression results are detailed in Table 14.

Table 14: Medium land regression results

Grain Yield	Coefficient	Std. Error	t-value	P>t
50% flowering	7.0	6.4	1.09	.276
Jkhand Loc	941.5	133.6	7.05	0.000
Orissa Loc	-413.8	152.2	-2.72	.0007
Sugandha 1	518.0	127.7	4.06	0.000
Barke3010	656.8	143.8	4.57	0.000
Year 2003	836.6	236.9	3.53	0.001
Year 2004	1793.3	301.0	5.96	0.000
Year 2005	1739.1	240.4	7.23	0.000
Year 2006	1769.3	222.0	7.97	0.000
Year 2007	2262.1	221.5	10.21	0.000
Constant	348.8	547.2	.64	.525

(Source: Author)

From the regressions, it could be seen that the number of days to 50% flowering of a variety did not have any significant influence on the yield (in spite of a positive coefficient). The 50% days to flowering is an important parameter, as it decides the maturity of the grain and filling of the grains (grain weight).This variable might do better or come out significant when we could test with other continuous variables or other qualitative and quantitative variables.

The state of Orissa did not have a significant impact on the yield of medium land varieties, compared to Jharkhand or West Bengal. The medium land varieties performed well and are highly significant in the state of Jharkhand because they were first proposed for release for the medium lands of Jharkhand. But because of their adaptability they have also been grown in West Bengal and Orissa.

Among the varieties, compared to the check variety IR 64, both Sugandha 1 and Barkhe 3010 were positive and highly significant in determining the yield. Birsa Vikas Sugandha1 is observed to be preferred by poor farmers because of its aromatic, medium slender grains. The variety responds well to medium fertilizer management, has higher yield and matures early. The plants are taller with more straw yield, have good cooking quality, resistance to lodging and higher drought tolerance (release proposal, 2005). IR64 is the most widely grown rice variety in the tropics (www.iris.irri.org). It was released in 1991 (www.drdpat.bih.nic.in) as semi-dwarf variety, resistant to blast disease and has white grains. It has been used as a parent in breeding new varieties. Birsa Vikas Dhan 203 or Barkhe 3010 has medium maturity; it is a semi-tall plant with medium slender grain. It has drought escaping characteristics, is responsive to fertilizer use and can be sown directly or transplanted. These varieties have spread in the areas where GVT, CAZS & BAU are doing research in Eastern India. In the following chapter we describe the cost and benefit analysis for Eastern India PPB rice research and dissemination.

6. COSTS AND BENEFITS OF BREEDING AND SEED PRODUCTION OF DROUGHT TOLERANT RICE

This chapter combines the yield increases and changes in grain quality measured in the previous chapter with the spread of these varieties to calculate the benefits from breeding and disseminating these drought tolerant varieties.   These benefits are compared with the costs of the breeding and dissemination programs to calculate internal rates of return to these programs.

Costs and Benefits of Eastern India Rice research program

This section calculates the costs and benefits of the DT breeding program carried out in Jharkhand, Orissa and West Bengal. In order to calculate the net present value and internal rate of return we used the annual cost of research being carried out in Eastern India. Initially only Gramin Vikas Trust (GVT) and CAZS were involved in the research. We take 1997 as the starting year since participatory research with regard to drought tolerant varieties began in that year. While the research cost of GVT and CAZS was funded by DFID the cost of CAZS was taken from an earlier study (DIFD, annual report 2002) we do not have the exact amount spent by GVT, we have assumed GVT's research cost to closely match DFID's. Rockefeller foundation invested in the research and dissemination of Ashoka varieties from the year 2003 onwards. The yearly costs of Rockefeller foundation were taken from GVT's annual project reports [Appendix Table D].

The two key elements of the benefit calculations are the yield per ha and grain quality improvements. We have several measurements of yield improvements. Ideally we would like the change in yields in the fields of adopting farmers. However, that will be measured in a future study. At present, we have data on yields from farmers who grew these varieties under the supervision of GVT/Wales scientists. The differences in the mean yields between the local variety (Birsa Gora102) and the Ashoka varieties in AICRIP trials & GVT BAU (99-01) was 560 kg/ha the trials were held in Jharkhand.

We have opted for the increase of Ashoka varieties over local varieties from the regression analysis the difference in yield of Ashoka varieties and BG102 was 497 kg/ha.

The yield advantage of the second generation of GVT/Wales variety PY84 is 712 kg/ha. The area over which the Ashoka varieties spread is calculated as follows. In Eastern India the total area of rice is 11,884,000 ha and the area of upland rice is 6,352,000 ha. Based on our literature review (DFID Annual report, 2002) we assumed a maximum adoption rate of 40% of the upland area in Eastern India with adoption starting in the year the trials of Ashoka varieties began.

We used the Economic Surplus Model for closed economy because the Ashoka varieties are being produced for poor farmers of upland areas who do not produce enough to participate in the market, most of the production is for self consumption. The supply is inelastic for the upland areas and most of the varieties grown there did not have high yields. The introduction of the higher yielding and better quality Ashoka varieties will enable the farmers to take some of their produce to the market. A similar study performed by Selvaraj (Selvaraj, 2007) on impact of drought and salinity tolerant rice in Tamil Nadu was utilized for the elasticity data. We use the Alston Norton and Pardey model assumption for proportionate input cost change per hectare for our analysis because change in cost has not been quantified. We performed scenario analysis for participatory plant breeding method - the assumptions for the analysis are detailed in Table 15.

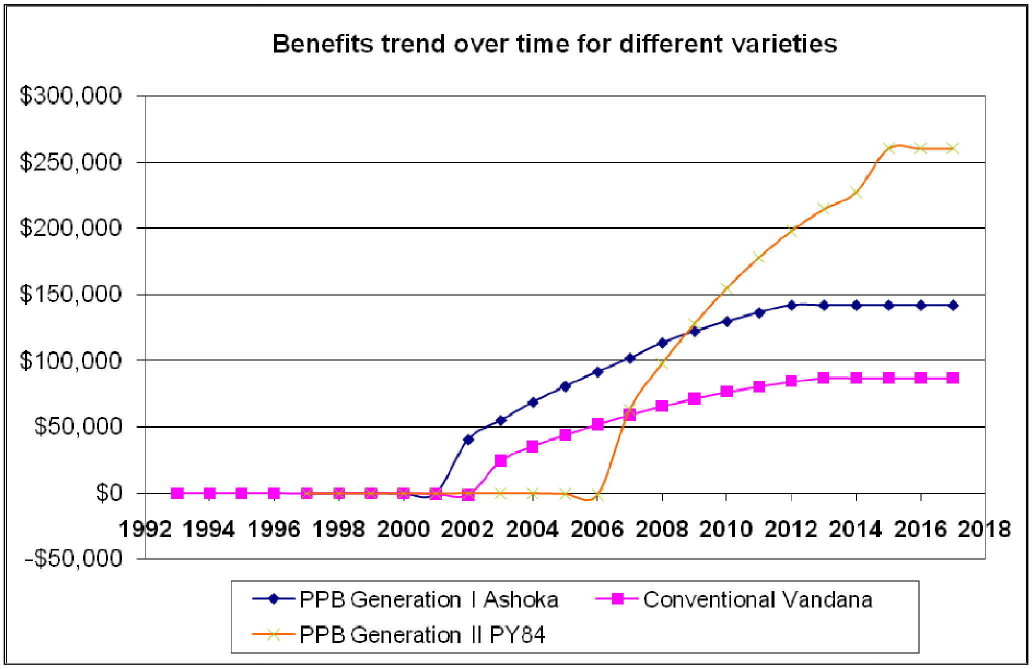
Table 15: Assumption for scenario analysis

Assumption	Participatory Plant Breeding
Supply Elasticity	.35
Demand Elasticity	.40
Maximum adoption rate	40%
Minimum adoption rate	8%
Discount Rate	5%
Prop. input cost change/ha	.10
CAZS expenditure	$71,684
GVT annual expenditure	$70,000

(Source: Compiled from various sources)

Based upon these assumptions we used the spread sheet approach by Alston, Norton & Pardey for calculating the net present value and internal rate of return for the research and dissemination of Ashoka varieties in Eastern. The benefits over time for the varieties are shown in figure 2.

Figure 2: Benefits over time for different varieties



(Source: Author)

We can see that PY84 a second generation upland PPB variety has very high benefits. The Ashoka varieties lead to more benefits than Vandana.

NPV ($ 888,268) for the research that developed the Ashoka varieties has been calculated using the formula:

$$\sum_{j=1997}^{2017} \frac{\{\Delta \text{TS} - \text{Research Cost}\}_j}{(i+r)^j}$$

and IRR (1.67) is calculated when the NPV function is zero or IRR is given by ‘rate’ in

$$\sum_{j=1997}^{2017} \frac{\{\Delta \text{TS} - \text{ Research Cost}\}_j}{(i+r)^j} = 0$$

j: year

r: the discount rate which in our study is 5% based on previous studies.

In case of participatory plant breeding the time to adoption is less because of the collaboration of scientists and farmers from the beginning [APPENDIX G]. Based on our analysis the Net present value of the research being carried out in Eastern India (PPB 1) is ($888,268). The NPV is positive indicating that the project is profitable. The research being done in Eastern India is beneficial. The NPV for the PPB generation II (PY 84) variety is also high ($894,018) indicating that research efforts in Eastern India continues to successfully develop better varieties for upland areas. Our results indicate that the IRR 167% from 1997-2017 for the research being carried out in Eastern India. The project is successful and the investments made by RF in the research effort in Eastern India have a positive impact on drought prone areas of Eastern India.

We change the maximum adoption rate to 10% then to 40% to see the impact it would have on the NPV and IRR of the research and dissemination project in Eastern India we can see from table 17 that adoption rate has a major impact on NPV and IRR.

Table 16 indicates that adoption rate does have a significant impact on the benefits derived from research. The benefits from Vandana are too low to yield a rate of return. When we compare our results to other studies done on economic impact evaluation we can see that our study fits in the IRR of research and extension projects range (min -100

% to max 430 %) [see appendix table L]. In case of Rice, IRR ranges from (min 11.4% to max 466%) [see appendix table M].

Table 16: Impact of Change in Adoption rates

Adoption Rate	NPV	IRR
ASHOKA*		
10%	$92,324	96.48%
40%	$888,268	166.70%
PY84**		
10%	$370,639	69.72%
40%	$894,018	76.41%
VANDANA***		
10%	$55,498	0
40%	$125,605	0

(Source Author)

*Ashoka - research started in the year 1997, year of release is 2005. Adoption began in the year 2002 and maximum adoption will be reached in the year 2011.

**PY84 – research started in 1997, year of release is 2009. Adoption began in the year 2007 and maximum adoption will be reached in the year 2014.

***Vandana – research started in 1993, year of release is 2002. Adoption began in the year 2003 and maximum adoption will be reached in 2013.

Costs and Benefits of Rockefeller Foundation's seed production project

In the following section, we calculated the benefits in terms of the value of the yield increase and grain quality due to the Rockefeller funded program to disseminate Ashoka varieties among the farming households in eastern India. RF started funding GVT seed distribution in 2003 as the DFID funding for seed distribution was declining and then picked up the entire program in 2005 when DFID stopped funding this program. RF invested a total of $289,691 in this program.

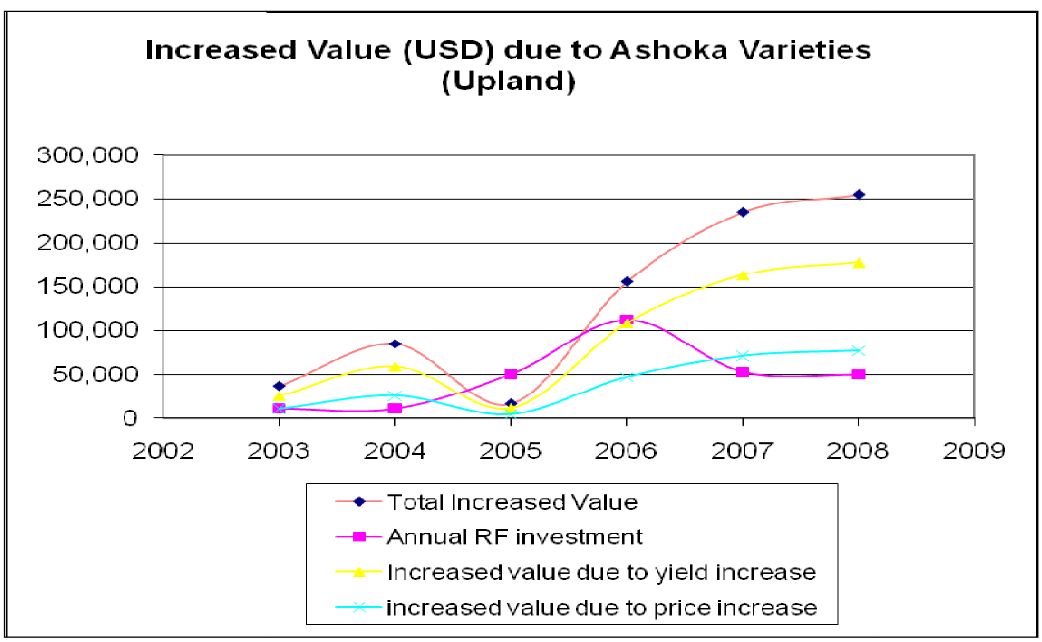
The benefits of this program are based on the same yield gains and grain quality improvements of the Ashoka varieties over the existing, local upland variety namely BG 102. Ashoka being a fine grain quality variety compared to the existing BG102 commanded higher prices in the market (12% higher) and also yielded (15-20%) more.

In this case unlike the previous section we actually have some data on the spread of the varieties – the amounts of seed the GVT, NGOs, and government agencies distributed each year. These amounts are found in Table 3. They grew from a low of 17.26 in 2005 the transition year – to a high of 255t in 2008.

However, in addition to the seed sold by GVT and its collaborators, farmers saved some seed and replanted some of it as well as giving or selling some to their neighbors. This means that the seed had a multiplier effect - in the second year the beneficiaries were not only the farmers who planted and saved the new varieties but also the farmers who got seed from other farmers. Unfortunately, we do not have very good evidence on how much of the seed was saved and replanted.

We calculate the rates of return to the seed production and dissemination program with perfectly elastic demand curves and inelastic supply curves. This is the equivalent to using the Alston-Pardey models estimating the consumer and producer surplus. We estimated these returns in terms of increased value due to yield increases as well as improved quality for the Ashoka varieties. For this purpose, we compared two possible scenarios – with and without RF funding support in the introduction of these varieties. We compared the seed production and area coverage by GVT and others for the year 2005, 2006, 2007 and 08[Appendix table K]. In 2005 the funding from DFID came to an end and the seed production was also minimal. But once the RF initiated its funding towards the end of 2005, the multiplication activities were enhanced subsequently in 2006, 2007 and 2008 as is evident from figure 3 which shows a dip in the total increased value due to Ashoka varieties for the year 2005.

Figure 3: Increased value and investment on Ashoka varieties



(Source: Author)

The amount of seed produced without any specific funding for seed production and dissemination during 2005 was around 17.2 tons of seed, covering only 216 hectares in all the three states. By the year 2008 the seed processing units were set up with the funding of RF project and resulted in higher seed production (255 tons) and area coverage (3188 Ha) in 2008. It should be also noted that without any external agency to aid the production and the dissemination of seeds, the most common way is farmer to farmer exchanges and other means of informal transfers in the farming community. However, in the case of the Ashoka varieties in Eastern India there are important limitations of farmer seed exchange, especially if the farmers are given only small, trial quantities, thus resulting in small surplus for any further exchanges outside their farms (L. Sperling and M. Loevinsohn, 1993). Also if the farm size is small, subsistence growers also would restrict exchanges outside their farm (Tripp 2001).

We used the total RF investment for seed production and dissemination and increase in value due to Ashoka to calculate the benefits and compute the internal rate of return for the project. The rate of return is very high as can be seen from the table 17.

Table 17: Internal Rate of Return for seed production and dissemination

IRR for seed production and dissemination	243%

(Source: Author)

This clearly shows that there are very high social returns to R&D investment in seed distribution activities, with minimal effort from the existing extension services.

We do a sensitivity analysis with the seed production assuming one third of the farmers who bought Ashoka were replacing it, there is 1/3 fall in increased value due to Ashoka. The internal rate of return falls to 95.32%.

7. CONCLUSIONS

In this study an attempt has been made to assess the economic impact of the drought tolerant rice varieties using cost benefit analysis. The quality impact has been measured using formulas from hedonic price model. We evaluated the Ashoka varieties with regard to their contribution towards increased yield and improved quality aspects and thus on the farmer welfare in upland rice growing regions of Eastern India. This study clearly shows that the research is beneficial. A spill over benefit has been the successful development of new pipeline varieties - some of these have been released or are in the process of being released (GVT report, 2008).

Major findings of the research include:

1. The internal rate of return of drought tolerant rice research efforts in Eastern India is 167%. This is very high indicating that the research being done in Eastern India is very efficient and the project is worth investing.

2. Based on our literature review we can say that among breeding methods, PPB seems to be much more efficient than conventional and biotech breeding. In our scenario analysis, the Net Present Value of investments in PPB research in Eastern India is $888,268. A high net present value indicates that the project is successful. Investments made in the project will result in benefits of $888,268. With Biotech breeding the benefits could be higher but the initial cost of investment (mostly infrastructure) is much higher when compared to both conventional and PPB methods (Selvaraj, 2006). In addition, the regulatory costs involved in the approval of biotech varieties are higher and the overall time

involved longer. As an example, Bt rice remains in trials for eight years in India before they are ready for release (http://www.business-standard.com).

3. The internal rate of return using cost benefit analysis for the seed production and dissemination program of Rockefeller foundation is 243%. The high rate of return indicates that the RF project is making a big difference in the spread of the Ashoka varieties in Eastern India. The program has been successful in increasing the area under Ashoka varieties enabling more marginal farmers to have access to better varieties of rice.

Implications

One of the major hurdles in improving the livelihood of poor farmers growing upland rice in Eastern India had been the lack of varieties with good quality and yield characteristics. Before the PPB approach had been used in Eastern India the farmers had limited choice and were mostly growing landraces (Virk & Witcombe, 2006). PPB is a good approach for breeding and adoption for varieties grown by semi-subsistence households because it incorporates the desired traits very early in the breeding process. The development and adoption of varieties takes place much faster than conventional methods.

The success of PPB has resulted in the development of improved upland cultivar like Ashoka with farmer desired qualities. The success of research will only be beneficial if the farmers are able to access the drought tolerant varieties. To make Ashoka varieties reach maximum level of adoption it has to be backed by a good seed supply mechanism e.g KVK's and state seed corporations.

The internal rate of return for the seed dissemination effort is very high in Eastern India. Adoption can be even more widespread if public investment is made for increasing seed multiplication and large scale adoption. Government agencies need to play an active role in the production and dissemination efforts being undertaken in Eastern India. Efforts need to be made to encourage private sector companies to have a greater role in the marketing and sale of drought tolerant rice seed. PPB has proven to be a very good example of public and private partnership.

Future Work

Based on our study there will be losses experienced due to drought. However, this study takes a very concentrated focus of the drought situation since we do not have the data to calculate the actual loss due to drought in these areas.

It would be very interesting to be able to assess the extent of spread of the Ashoka varieties in Eastern India and in other states where these varieties are being grown. There is very little information on the spread of the Ashoka varieties in areas outside the GVT, BAU & CAZR trial areas. We expect to obtain more information when a more detailed survey will be done to overcome this limitation.

One of the major aspects in the success of the Ashoka varieties is the production and dissemination of seed. It is evident that the seed companies are not interested in selling these varieties because selling them is not profitable. The Indian government can provide subsidies to the firms to interest them in selling the seed of these varieties or companies like KRIBKO can provide financial backing to GVT to further the spread of these varieties to improve the livelihood of poor farmers of Eastern India.

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APPENDIX

TABLE A: Administrative districts chronically affected by drought conditions in Eastern India

STATES	DISTRICTS
Bihar	Munger, Nawadah, Rohtas, Bhojpur, Aurangabad, Gaya
Orissa	Phulbani, Kalahandi, Bolangir, Kendrapada
West Bengal	Bankura, Midnapore, Purulia
Jharkhand	Palamau

(Adapted from Pandey, 2005)

TABLE B: Probability of occurrence of drought in different meteorological sub-divisions, India

Meteorological sub-division	Frequency of deficient rainfall (75% of normal or less)
Assam	Very rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar, and Orissa	Once in 5 years
South Interior Karnataka, Eastern Uttar Pradesh, and Vidarbha	Once in 4 years
Gujarat, East Rajasthan, western Uttar Pradesh	Once in 3 years Tamil Nadu,
Tamil Nadu, Jammu and Kashmir, and Telengana	Once in 2.5 years
West Rajasthan	Once in 2.5 years

Adapted from Pandey, 2005

TABLE C: RF cost incurred in production of Ashoka varieties (2003 – 08)

Year	Cost Incurred (USD)
2003	11,740
2004	11,740
2005	50,649
2006	112,234
2007	53,311
2008	50,017

Adapted from Gramin Vikas Trust Reports 2003-04, 2004-05, 2006-07

Assumptions:

1. Total research cost from 2003-05 is $23,480. Hence annual cost over this period is assumed to be an average value of $23,480/2 = $11,740

TABLE D: Research cost of Birsa Agricultural University

Year	Research Expenditure BAU($)
1997	248,886.85
1998	174,835.73
1999	138,004.36
2000	214,385.76
2001	315299.83
2005	536,158.59
2006	1,324,634.72
2007	1,693,207.34

(Compiled from various sources)

TABLE E: **Mean grain yield of the genotypes along with the days to flowering and plant height in favorable environments (arranged in descending order of performance in high input)**

No.	Entry	Grain Yield(t/ha)					Days to flowering		Plant height	
		Low input	Std error	High input	Std error	difference	Low input	High input	Low input	High input
3	Ashoka 228	.93	.23	2.19	.23	1.26	68	67	84	94
2	Ashoka 200F	1.08	.21	1.85	.21	.76	69	68	84	96
20	Kalinga III	1.17	.32	1.66	.32	.50	68	67	81	91
50	Vandana	1.22	.21	1.86	.21	.64	69	68	85	92

(IRRI 2006)

APPENDIX F: Explanation of table columns and terms used

Year: Annual benefits are projected till the year 2017 twelve years after the variety was released.

Supply elasticity of rice (ε): taken from earlier studies (*Selvaraj, 2007*)

Demand elasticity of rice (η): taken from earlier studies (*Selvaraj, 2007*)

Proportionate yield change, E(Y): the expected proportionate yield change per hectare, presuming research is successful and fully adopted. The regression analysis for the upland varieties was used to determine proportionate yield change. E(Y) = yield of (Ashoka – BG102)/ yield of BG102. E(Y) = (1836.5 – 1340)/ 1340 = .37

Gross proportionate cost change per hectare: (Proportionate yield change / Supply elasticity of rice) converts the proportionate yield change to a proportionate gross reduction in marginal cost per ton of output. (*Alston, Norton & Pardey, 2005*).

Proportionate change in input cost per hectare, E(C): was used from the Alston closed economy model.

Proportionate input cost change per ton of output: equals {E(C)/ (1+ E(Y))} and converts the proportionate input cost change per hectare to a proportionate input cost change per ton of output.

Net proportionate change in cost per ton of output: equals {(Gross proportionate cost change per hectare - Proportionate input cost change per ton of output)}, and nets out the effect of the variable input cost changes associated with yield change to give the maximum potential net change in marginal cost per ton of output.

Probability of research success: probability that research will reach the yield change E(Y)

Adoption rate: reflects the rate of adoption, A_t, defined in relation to years t, from commencement of research. In this study we use step-wise adoption with no adoption for the first five years as explained in Alston, 2005. It is assumed that research takes five years before the technologies are available. Following that, adoption occurs till it reaches a maximum of 40% of upland area in Eastern India (*PSB report, 2002*)

Depreciation factor: 1 – adoption rate of technologies.

Proportional supply shift in year t (K_t): equals {Net proportionate change in cost per ton of output x Probability of research success x Adoption rate x Depreciation factor}, giving the cumulative proportionate shift downwards, in the supply curve.

Proportionate decrease in price in the year t (Z_t): equals $K_t * \varepsilon / (\varepsilon + \eta)$.

Price: in our study we use the price/kg of the Ashoka varieties = Rs 6.28 (*Virk, 2006*) to calculate the total price in tons. USD/INR exchange rate at 15-Mar-09 has been used.

Quantity: the pre research quantity is constant. In our study we assumed a research lag of 5 years.

Change in total surplus in year t (ΔTS_t): equals K_t * Price * Quantity * $[1+ 0.5 * (K_t * \varepsilon)]$. Total surplus is represented in (000's) dollars/year.

Research Cost: Annual research cost of the commodity corresponding to expected yield increase. In our study we have used the research cost of DFID, BAU and RF. The costs have been taken from annual reports, ICAR websites and from PBS report 2002.

Benefits: equals {ΔTS_t – Research Cost}

NPV: Net Present Value of the research project is calculated using the formula embedded in the spreadsheet program employing the total benefits and a discount rate of.

NPV

$$\sum_{j=1997}^{2017} \frac{\{\Delta \mathrm{TS} - \text{ Research Cost}\}_j}{(i+r)^j}$$

Where j is number of years starting from 1997 upto 2017 .

rate is discount rate which is 5% based on previous studies

IRR

$$\sum_{j=1997}^{2017} \frac{\{\Delta \mathrm{TS} - \text{ Research Cost}\}_j}{(i+r)^j} = 0$$

the rate at which the NPV function is zero

APPENDIX G: Data & Assumptions used

Average Yield (BG102): 1340.3 kg/ha from the sample.

Average Yield (A200F): 1850 kg/ha from the sample.

Average Yield (A228): 1823 kg/ha from the sample.

Average Mean Yield: 1836.5 kg/ha from the regression.

Total Upland area in Eastern India: 6352000.0 ha (*Annual report, 2003*)

Research cost:

- from 2011 to 2017 is extrapolated to be minimum over the research project.
- from 2003 to 2005 averaged to a total $23,480.
- from 1997-2001 is taken from *www.iasri.res.in*
- from 2005-2007 is taken from *http://www.iasri.res.in/agridata/HOME.HTML*
- CAZS expenditure assumed to be: $71,694.30 based on *PSB annual report 2002*
- GVT annual expenditure assumed to be: $70,000

Quantity produced: from 2010 onwards is extrapolated to be the maximum value over the research period.

Adoption rate: upto 40% has been assumed and adoption starts after five years.

USD/GBP exchange rate: as at 18-Mar-09.

Proportionate input cost change per hectare: .10 using Alston Pardey closed economy model.

Discount rate of: 5% based on previous studies.

USD/INR exchange rate: as at 15-Mar-09.

Price of Ashoka varieties: Rs 6.28 /kg (Virk & Witcomeb, 2006)

Price of BG102 variety: Rs 5.62 /kg (Virk & Witcomeb, 2006)

Quantity produced from 2010 onwards equated to maximum value until that year.

Research cost in ‘000s of dollars as per Alston Pardey Model

Fraction of total research expenditure allocated to rice assumed to be .33

Simulations based on the Alston Pardey Model

Sample Calculations for the year 2002

Supply elasticity of rice (ε) = .40

Demand elasticity of rice (η) = .35

Proportionate yield change, E(Y) = E(Y) = (yield of Ashoka – yield of BG102)/ (yield of BG102). E(Y) = (1836.5 – 1340)/ 1340 = .37

Gross proportionate cost change per hectare = E(Y)/ (ε) = .37/.40 = .93

Proportionate change in input cost per hectare, E(C) = .10 assumed

Proportionate input cost change per ton of output = {E(C)/ (1+ E(Y))} = .10/(1+.37) = .07

Net proportionate change in cost per ton of output = [(E(Y)/ (ε)) **-** {E(C)/ (1+ E(Y))}] = .85

Probability of research success = 1

Adoption rate = maximum 40%

Depreciation factor: 1 – adoption rate of technologies.

Proportional supply shift in year t (K_t) = {**[(**E(Y)/ (ε)) **-** {E(C)/ (1+ E(Y))}]* Probability of research success* Adoption rate * Depreciation factor. e.g. year 2002 [.85*1*.08*.92] = .06

Proportionate decrease in price in the year t (Z_t) = K_t * ε / (ε + η) e.g. year 2002 = [.06*.40/ (.40+.35)] = .03

Price = 6.28 Rs/kg, price of Ashoka in dollars per ton (6.28*1000* .019419) = $121.95

Quantity = (6352000 * 1836.5*.40)/1000 = 4666.18 t

Change in total surplus in year t (ΔTS_t) = K_t * Price * Quantity * [1+ 0.5 * (K_t * ε)] = e.g. for year 2002 **(ΔTS_t) =** [.03*121.95*4666.18(1+.5(.03*.40)] = $36,159.84

CTS* = \$40,373.08 change in total surplus due to increased yield and better grain quality

Research Cost = cost of DFID, BAU &RF e.g. in the year 2002 its \$ 141.69

Benefits = $\{\Delta TS_t$ – Research Cost$\}$ e.g. in the year 2002 they are (\$40,373.08 - \$141.69) = \$40231.38

Net Present Value

$$\sum_{j=1997}^{2017} \frac{\{\Delta \mathrm{TS} - \text{ Research Cost}\}_j}{(i+r)^j}$$

j= 1 to 20

values: benefits from year 1997 to 2017

discount rate is 5% based on previous studies.

Net Present Value of the research project is calculated using the formula embedded in the spreadsheet program = \$888,268.

Internal Rate of Return

$$\sum_{j=1997}^{2017} \frac{\{\Delta \mathrm{TS} - \text{ Research Cost}\}_j}{(i+r)^j} = 0$$

is calculated at the rate at which the NPV function is zero in our study it is 166.70%

Table H: Cost-benefit analysis on research in Eastern India (PPB 1)

(using 2002 as an example for showing the calculations)

Year	Supply Elasticity (e) C1	Demand Elasticity (n) C2	Prop. Yield change C3	Gross Prop. Cost change C4	Prop. cost change per ha C5	Prop. cost change per ton C6	Net change C7	Prob. of success C8	Adoption Rate C9	Dep Rate C10	Supply Shift (K) C11	Price dec C12	Price (USD/tones) C13	Quantity (000 tons) C14	CTS C15	CTS* Quality C16	Cost USD (000s) C17	Benefit C18
	(e)	(n)	(Ashoka - BG102)/ BG102	C3 / C1	assumed	C5 /(1+C 3)	C4 - C6	Research in use	Step wise max 40%	1- C9	C7*C8*C9* C10	(C1*C11)/(C1+C2)	6.28*1000*.019419	4,666,179.2/1000	(C11*C13*C14)(1+.5*C11*C1)	C15+ 52665.5*C9		C18-C17
1997	.40	.35	.37	.93	.10	.07	.85	1	0	1	0	0	0	0	0	0	390.58	-390.58
1998	.40	.35	.37	.93	.10	.07	.85	1	0	1	0	0	0	0	0	0	316.53	-316.53
1999	.40	.35	.37	.93	.10	.07	.85	1	0	1	0	0	0	0	0	0	279.70	-279.70
2000	.40	.35	.37	.93	.10	.07	.85	1	0	1	0	0	0	0	0	0	356.08	-356.08
2001	.40	.35	.37	.93	.10	.07	.85	1	0	1	0	0	0	0	0	0	456.99	-456.99
2002	.40	.35	(1836.5-1340.3/ 1340.3 = .37	.37/.40 = .93	.10	.10/(1+.37) = .07	.93 - .07 = .85	1	.08	1-.08 = .92	.85*1* .08*.92= .06	(.40*.06)/ (.40+.35) =.03	6.28*1000*.019419= 121.95	4,666,179.2/1000 4666.18	(.06*121.95*4666.18)(1+.5*.06*.40)= 36159.84	36159.84+ 52665.5*.08 = 40373.08	141.69	40373.08-141.69 = 40231.39
2003	.40	.35	.37	.93	.10	.07	.85	1	.11	.89	.08	.05	121.95	4666.18	49075.73	54974.26	141.69	48136.55
2004	.40	.35	.37	.93	.10	.07	.85	1	.14	.86	.09	.06	121.95	4666.18	61066.42	68650.25	153.43	54974.26
2005	.40	.35	.37	.93	.10	.07	.85	1	.18	.82	.11	.07	121.95	4666.18	72107.70	81376.82	617.90	68650.25
2006	.40	.35	.37	.93	.10	.07	.85	1	.21	.79	.13	.07	121.95	4666.18	82177.45	93131.86	1445.28	81376.82
2007	.40	.35	.37	.93	.10	.07	.85	1	.24	.76	.14	.08	121.95	4666.18	91255.61	103895.32	1875.44	93131.86
2008	.40	.35	.37	.93	.10	.07	.85	1	.27	.73	.15	.09	121.95	4666.18	99324.44	113649.25	123.31	103895.32
2009	.40	.35	.37	.93	.10	.07	.85	1	.30	.70	.16	.10	121.95	4666.18	112371.45	122377.75	120.02	113649.25
2010	.40	.35	.37	.93	.10	.07	.85	1	.34	.66	.17	.10	121.95	4666.18	117324.53	130067.05	120.02	122377.75
2011	.40	.35	.37	.93	.10	.07	.85	1	.37	.63	.18	.11	121.95	4666.18	212217.05	136705.42	120.02	136705.42
2012	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22
2013	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22
2014	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22

2015	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22
2016	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22
2017	.40	.35	.37	.93	.10	.07	.85	1	.40	.60	.18	.11	121.95	4666.18	121217.05	142283.23	120.02	142163.22

Table: I Cost-benefit Conventional Breeding Vandana

Year	Supply Elasticity (e)	Demand Elasticity (n)	Prop. Yield change	Gross Prop. Cost change	Prop. cost change per ha	Prop. cost change per ton	Net change	Prob. of success	Adopti on Rate	Dep Rat e	Supply Shift (K)	Price dec	Price (USD/t ones)	Quantity (000 tons)	CTS	Cost USD (000s)	Benefit
1993	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	120.02	-120.02
1994	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	120.02	-120.02
1995	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	120.02	-120.02
1996	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	120.02	-120.02
1997	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	456.99	-456.89
1998	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	141.69	-141.69
1999	.40	.35	.30	.76	.10	.08	.68	1	0	1	0.00	0.00	0.00	0.00	0.00	141.69	-141.69
2000	.40	.35	.30	.76	.10	.08	.68	1	.08	.92	0.00	0.00	0.00	0.00	0.00	153.43	-153.43
2001	.40	.35	.30	.76	.10	.08	.68	1	.10	.90	0.00	0.00	0.00	0.00	0.00	617.90	-617.90
2002	.40	.35	.30	.76	.10	.08	.68	1	.13	.87	0.00	0.00	0.00	0.00	0.00	1445.28	-1445.28
2003	.40	.35	.30	.76	.10	.08	.68	1	.15	.85	0.05	0.03	116.51	4438.02	26193.45	1875.44	24318.01
2004	.40	.35	.30	.76	.10	.08	.68	1	.18	.89	0.07	0.04	116.51	4438.02	35518.81	123.31	35395.50
2005	.40	.35	.30	.76	.10	.08	.68	1	.20	.86	0.08	0.04	116.51	4438.02	44162.31	120.02	44042.29
2006	.40	.35	.33	.76	.10	.08	.68	1	.23	.82	0.10	0.05	116.51	4438.02	52109.90	120.02	51989.89
2007	.40	.35	.30	.76	.10	.08	.68	1	.25	.79	0.11	0.06	116.51	4438.02	59348.73	120.02	59228.71
2008	.40	.35	.30	.76	.10	.08	.68	1	.28	.76	0.12	0.07	116.51	4438.02	65867.18	120.02	65747.16
2009	.40	.35	.30	.76	.10	.08	.68	1	.30	.73	0.13	0.07	116.51	4438.02	71654.82	120.02	71543.81
2010	.40	.35	.30	.76	.10	.08	.68	1	.33	.70	0.14	0.08	116.51	4438.02	76702.45	120.02	76582.43
2011	.40	.35	.30	.76	.10	.08	.68	1	.35	.66	0.15	0.08	116.51	4438.02	81002.04	120.02	80822.03

2012	.40	.35	.30	.76	.10	.08	.68	1	.38	.63	0.16	0.08	116.51	4438.02	84546.81	120.02	84426.80
2013	.40	.35	.30	.76	.10	.08	.68	1	.40	.60	0.16	0.09	116.51	4438.02	87331.17	120.02	87211.15
2014	.40	.35	.30	.76	.10	.08	.68	1	.40	.60	0.16	0.09	116.51	4438.02	87331.17	120.02	87211.15
2015	.40	.35	.33	.76	.10	.08	.68	1	.40	.60	0.16	0.09	116.51	4438.02	87331.17	120.02	87211.15
2016	.40	.35	.30	.76	.10	.08	.68	1	.40	.60	0.16	0.09	116.51	4438.02	87331.17	120.02	87211.15
2017	.40	.35	.30	.76	.10	.08	.68	1	.40	.60	0.16	0.09	116.51	4438.02	87331.17	120.02	87211.15

Table: J Cost-Benefit PY 84 (PPB 11)

Year	Supply Elasticity (e)	Demand Elasticity (n)	Prop. Yield change	Gross Prop. Cost change	Prop. cost change per ha	Prop. cost change per ton	Net change	Prob. of success	Adoption Rate	Dep Rate	Supply Shift (K)	Price dec	Price (USD/tones)	Quantity (000 tons)	CTS	CTS*	Cost USD (000s)	Benefit
1997	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	390.58	-390.58
1998	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	316.53	-316.53
1999	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	279.70	-279.70
2000	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	356.08	-356.08
2001	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	456.99	-456.99
2002	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	141.69	-141.69
2003	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	141.69	-141.69
2004	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	153.43	-153.43
2005	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	617.90	-617.90
2006	.40	.35	.53	1.33	.10	.07	1.26	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00	1445.28	-1445.28
2007	.40	.35	.53	1.33	.10	.07	1.26	1	.08	.92	0.09	0.05	121.95	5212.58	60114.78	64821.38	1875.44	62945.94
2008	.40	.35	.53	1.33	.10	.07	1.26	1	.13	.87	0.14	0.07	121.95	5212.58	90579.50	97975.59	123.31	97852.27
2009	.40	.35	.25	1.33	.10	.07	1.26	1	.17	.83	0.18	0.10	121.95	5212.58	117982.39	128067.95	120.02	127947.94
2010	.40	.35	.53	1.33	.10	.07	1.26	1	.22	.78	0.21	0.11	121.95	5212.58	142160.42	154935.47	120.02	154815.45
2011	.40	.35	.53	1.33	.10	.07	1.26	1	.26	.74	0.24	0.13	121.95	5212.58	162971.78	178436.32	120.02	178316.30
2012	.40	.35	.53	1.33	.10	.07	1.26	1	.31	.69	0.27	0.14	121.95	5212.58	180295.88	198449.90	120.02	198329.88
2013	.40	.35	.53	1.33	.10	.07	1.26	1	.35	.65	0.29	0.15	121.95	5212.58	194033.32	214876.82	120.02	214756.80

2014	.40	.35	.53	1.33	.10	.07	1.26	1	.40	.60	0.30	0.16	121.95	5212.58	204105.90	227638.88	120.02	227518.87
2015	.40	.35	.53	1.33	.10	.07	1.26	1	.40	.69	0.35	0.19	121.95	5212.58	237254.04	260787.02	120.02	260667
2016	.40	.35	.53	1.33	.10	.07	1.26	1	.40	.69	0.35	0.19	121.95	5212.58	237254.04	260787.02	120.02	260667
2017	.40	.35	.53	1.33	.10	.07	1.26	1	.40	.69	0.35	0.19	121.95	5212.58	237254.04	260787.02	120.02	260667

TABLE K: SCENARIO ANALYSIS (UPLAND) – ASHOKA VARIETIES

Ashoka varieties	2003		2004		2005		2006		2007		2008	
Particulars (@exchrate Rs.50/US$)	**In Rs.**	**US$**	**In Rs.**	**US$**	**In Rs.**	**US$**	**In Rs.**	**US$**	**In Rs.**	**US$**	**In Rs.**	**US$**
Annual RF investment	**587,000**	**11,740**	**587,000**	**11,740**	**2,532,450**	**50,649**	**5,611,700**	**112,234**	**2,665,550**	**53,311**	**2,500,850**	**50,017**
Total seed produced (kg)	37,200		85,200		17,260		156,000		234,410		255,000	
Total area covered (Ha)	465		1,065		216		1,950		2,930		3,188	
BG 102 yield 1340 kg/ha	1,340		1,340		1,340		1,340		1,340		1,340	
Avg yield of DT variety (Ashoka) per ha.	1,837		1,837		1,837		1,837		1,837		1,837	
Difference in yields	497		497		497		497		497		497	
Total output (grains) Kg	854,205		1,956,405		396,333		3,582,150		5,420,500		5,855,438	
Increase in output due to Ashoka	231,105		529,305		107,228		969,150		1,456,210		1,584,188	
Average price of Ashoka varieties (Rs/Kg)	6.28		6.28		6.28		6.28		6.28		6.28	
Average price of BG 102	5.62		5.62		5.62		5.62		5.62		5.62	
Increased price due to improved quality	0.66		0.66		0.66		0.66		0.66		0.66	
Total value realized (as grain and seed)												
Increased value due to yield increase	1,298,810	25,976	2,974,694	59,494	602,620	12,052	5,446,623	108,932	8,183,900	163,678	8,903,134	178,063
increased value due to price increase	563,775	11,276	1,291,227	25,825	261,580	5,232	2,364,219	47,284	3,577,530	71,551	3,864,589	77,292
Total increased value due to Ashoka varieties	**1,862,585**	**37,252**	**4,265,921**	**85,318**	**864,200**	**17,284**	**7,810,842**	**156,217**	**11,761,430**	**235,229**	**12,767,723**	**255,354**
Total value of the output	**5,364,407**	**107,288**	**12,286,223**	**245,724**	**2,488,970**	**49,779**	**22,495,902**	**449,918**	**34,040,740**	**680,815**	**36,772,148**	**735,443**

TABLE L: RANGES OF RATES OF RETURN

Sample	Number of observations	Rate of return				
		Mean	Mode	Median	Minimum	Maximum
	(count)			*(percent)*		
Full sample[a]						
Research only	1,144	99.6	46.0	48.0	-7.4	5,645
Extension only	80	84.6	47.0	62.9	0	636
Research and extension	628	47.6	28.0	37.0	-100.0	430
All observations	1,852	81.3	40.0	44.3	-100.0	5,645
Regression sample[b]						
Research only	598	79.6	26.0	49.0	-7.4	910
Extension only	18	80.1	91.0	58.4	1.3	350
Research and extension	512	46.6	28.0	36.0	-100.0	430
All observations	1,128	64.6	28.0	42.0	-100.0	910

[a]The original full sample included 292 publications reporting 1,886 observations. Of these, 9 publications were dropped because, rather than specific rates of return, they reported results such as >100% or <0. As a result of these exclusions, 32 observations were lost. Of the remaining 1,854, two observations were dropped as extreme (and influential) outliers. These two estimates were 724,323% and 455,290% per year.

[b]Excludes outliers and observations that could not be used in the regression owing to incomplete information on explanatory variables.

Source: Alston et al., 2000a.

TABLE M: RATES OF RETURN BY COMMODITY ORIENTATION

Commodity orientation	Number of observations	Rate of return				
		Mean	Mode	Median	Minimum	Maximum
	(count)	(percentage)				
Multicommodity[a]	436	80.3 (110.7)	58.0	47.1	-1.0	1,219.0
All agriculture	342	75.7 (110.9)	58.0	44.0	-1.0	1,219.0
Crops and livestock	80	106.3 (115.5)	45.0	59.0	17.0	562.0
Unspecified[b]	14	42.1 (19.8)	16.4	35.9	16.4	69.2
Field crops[c]	916	74.3 (139.4)	40.0	43.6	-100.0	1,720.0
Maize	170	134.5 (271.2)	29.0	47.3	-100.0	1,720.0
Wheat	155	50.4 (39.4)	23.0	40.0	-47.5	290.0
Rice	81	75.0 (75.8)	37.0	51.3	11.4	466.0
Livestock[d]	233	120.7 (481.1)	14.0	53.0	2.5	5,645.0
Tree crops[e]	108	87.6 (216.4)	20.0	33.3	1.4	1,736.0
Resources[f]	78	37.6 (65.0)	7.0	16.5	0.0	457.0
Forestry	60	42.1 (73.0)	7.0	13.6	0.0	457.0
All studies	1,772	81.2 (216.1)	46.0	44.0	-100.0	5,645.0

Notes: Standard deviations are given in parentheses. Sample excludes two extreme outliers and includes only returns to research only and combined research and extension, so that the maximum sample size is 1,772. In some instances further observations were lost owing to incomplete information on the specific characteristics of interests.

[a] includes research identified as all agriculture or crops and livestock, as well as unspecified.

[b]Includes estimates that did not explicitly identify the commodity focus of the research

[c]Includes all crops, barley, beans, cassava, sugar cane, groundnuts, maize, millet, other crops, pigeon pea or chickpea,potato, rice sesame, sorghum and wheat.

[d]Includes beef, swine, poultry, sheep or goats, all livestock, dairy, other livestock, pasture, dairy and beef.

[e]Includes other tree and fruit and nuts.

[f]Includes fishery and forestry.

Source: Alston et al., 2000a.