Technical Bulletin
2010 No. 14

Hybrid rice adoption in India: farm level impacts and challenges

Aldas Janaiah and Fangming Xie

IRRI
International Rice Research Institute

Technical Bulletin
2010 No. 14

Hybrid rice adoption in India: farm-level impacts and challenges

Aldas Janaiah and Fangming Xie

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today, IRRI is one of the 15 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR – www.cgiar.org).

IRRI receives support from several CGIAR members, including the World Bank, European Union, Asian Development Bank, International Fund for Agricultural Development, Rockefeller Foundation, Food and Agriculture Organization of the United Nations, and agencies of the following countries: Australia, Brazil, Canada, Denmark, France, Germany, India, Iran, Japan, Malaysia, Norway, People's Republic of China, Republic of Korea, Republic of the Philippines, Sweden, Switzerland, Thailand, United Kingdom, United States, and Vietnam.

The responsibility for this publication rests with the International Rice Research Institute.

Mailing address: DAPO Box 7777, Metro Manila, Philippines
Phone: +63 (2) 580-5600
Fax: +63 (2) 580-5699
Email: irri@cgiar.org
Web: www.irri.org.
Rice Knowledge Bank: www.knowledgebank.irri.org
Courier address: Suite 1009, Security Bank Center
6776 Ayala Avenue, Makati City, Philippines
Tel. +63 (2) 891-1236, 891-1174, 891-1258, 891-1303

Suggested Citation:

Janaiah A, Xie F. 2010. Hybrid rice adoption in India: farm-level impacts and challenges. IRRI Technical Bulletin No. 14. Los Baños (Philippines): International Rice Research Institute. 20 p.

ISSN 0074-7807

Hybrid rice adoption in India: farm-level impacts and challenges

Aldas Janaiah and Fangming Xie

This study focuses on assessing the farm-level impacts and key challenges of hybrid rice adoption in selected states of India, and the economic aspects of F_1 seed production. It covers two major rice-producing states of eastern India, Chattisgarh and eastern Uttar Pradesh, for an assessment of farm-level impacts of recently released rice hybrids, and Haryana in northern India for studying the impacts of recently released Basmati rice hybrids (aroma type). Farm-level data from 185 sample households covering 26 villages in three districts were generated through surveys conducted during April-May 2009. Those farmers who grew both hybrid and inbred rice during the same season (2008-09 wet season) on the same land side by side were included only in the sample frame. Two comparable "comparison groups," one for hybrid rice (treatment group) and another for inbred rice (control group), were formed to trace the net impact of replacing hybrid rice with inbred rice under similar agro-climatic, biophysical, and socioeconomic conditions.

To study the economics of hybrid rice seed production, survey data from 60 sample seed producers in eight villages of Karimnagar District in Andhra Pradesh State were collected.

An analysis of survey data reveals that rice area planted by sample farmers to rice hybrids as a share of total rice area was 68%, 73%, and 23% in Chattisgarh, Uttar Pradesh, and Haryana, respectively, during the 2008 wet season (WS). The findings show that hybrid rice varieties are indeed superior to inbred rice varieties in yield and profitability in Chattisgarh and eastern Uttar Pradesh. Hybrid rice outyielded existing inbred varieties under farmers' field conditions by about 36% in Chattisgarh and by 24% in Uttar Pradesh. However, for Haryana, the yield of both Basmati hybrid rice and popular inbred rice varieties (non-Basmati) is almost the same. On average, the yield gain of hybrid rice over existing popular inbred rice varieties in eastern India is about 30% in farmers' fields, which is a phenomenal increase under rainfed uplands. Hybrid rice cultivation generated an additional net profit of about 13% in Chattisgarh and about 34% in Uttar Pradesh. In Haryana, net profit is almost the same for both hybrid and inbred rice cultivation as the yield and price were almost the same for both varieties. Farmers' perceptions show that grain quality is not as serious an issue for the latest generation of rice hybrids as it was until 2001, although it remains a key challenge for future hybrid rice R&D, particularly in the irrigated rice system.

Average seed yield of about 2.5 t/ha was obtained on sample seed farms during the 2009 Dry Season (DS). Among cost components, labor alone accounted for about one-third of the total input cost because of the additional labor requirement in seed production. However, the labor requirement has come down significantly as seed growers gain experience and skills. If hybrid rice cultivation expands on a large scale, it has potential to generate substantial employment in seed production.

On the whole, the latest generation of rice hybrids has considerably outperformed existing inbred rice varieties in yield gain and profitability in eastern India. Although there has been a considerable improvement in grain quality and consumer acceptance over the period, the large-scale adoption of hybrid rice in the future largely depends on further improvement of grain quality comparable with that of popular inbred varieties. Hybrid rice seed production would not be a constraint to the large-scale adoption of acceptable hybrid rice as F_1 seed production is highly profitable for seed producers. The key challenges for hybrid rice R&D, however, are the development of new rice hybrids with a competitive and comparable grain quality, with wider adaptability, suitable for irrigated areas; a further increase in yield potential; a reduction in retail seed price, etc.

Introduction

Rice is the lifeline for Asians because it is not only a dominant food crop but also an important crop in their national economy. It accounts for a major share of cereal consumption, ranging from 40% in India to 97% in Myanmar. Rice contributes 30–76% to total daily calorie intake (Hossain and Pingali 1998). Therefore, boosting rice production and making rice available to consumers at affordable prices is always at the top of the political agenda for national governments for economic growth, social security, and political stability on the continent. Recent food inflation further alerted Asian countries to keep rice development strategy and policy as a top priority in order to sustain food security.

Recent changes in the rice sector

Asia has done remarkably well in meeting the food needs of its growing population since the start of the Green Revolution in the mid-1960s. Rice production increased at about 2.6% per year during 1968-90 in Asia, keeping pace with population growth and income growth-induced change in per capita

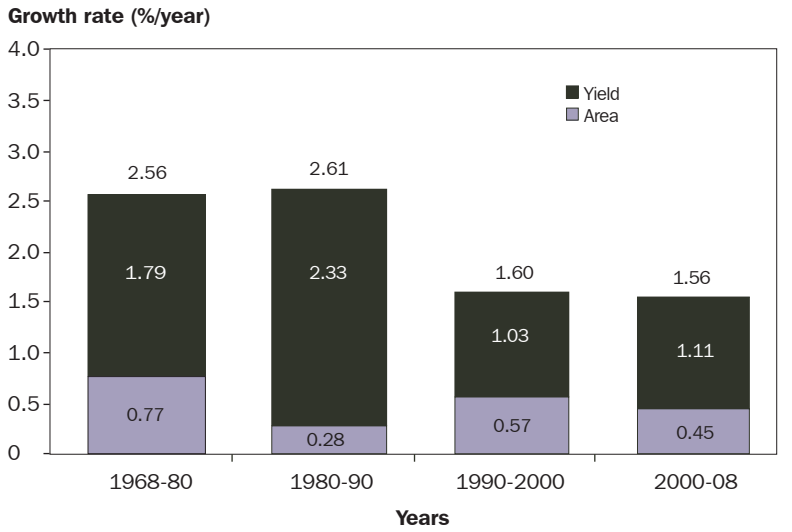


Fig. 1. Annual growth rate in area, production, and yield: early and late Green Revolution periods, Asia, 1968-2008. Growth rate estimated by fitting semi-logarithmic trend line on time-series data. Source of raw data: USDA (2009).

Table 1. Changes in annual growth rate of rice yield in major Asian countries, 1968-2000 and 2001-08.[a]

Country	Growth in rice yield (%/year)		% Rice irrigated area, 2008	% Rice area under modern varieties, 2008	Paddy yield (t/ha), 2008
	2001-08	1968-2000			
Japan	0.53	0.07	100	100	6.78
Korea (Rep. of)	1.14	0.11	100	100	6.99
China	2.51	0.67	100	100	6.61
Bangladesh	2.12	2.11	48	75	4.01
Indonesia	2.40	1.16	60	81	4.88
Nepal	1.01	0.23	21	75	2.76
Philippines	2.42	2.89	68	94	3.82
Sri Lanka	2.31	1.67	75	99	4.29
Thailand	1.05	0.80	25	30	2.75
Vietnam	2.62	2.29	85	94	4.88
India	2.21	1.95	56	77	3.37
Myanmar	2.04	–2.35	30	76	2.61
Asia	1.97	1.11	60	75	4.30

[a]Computed using the available data by country for Asia.
Source of raw data: World Rice Statistics (2009).

food consumption. More than four-fifths of the increases in production came from increases in yield during this period (Fig. 1), made possible through the gradual replacement of traditional varieties by modern varieties (MVs), supported by public investment for the expansion of irrigation infrastructure (David and Otsuka 1994, Pingali et al 1997). As a result, the downward trend in the real price of rice (adjusted for inflation) observed in many Asian countries since the late 1970s helped reduce poverty by empowering the rural landless and the urban laboring class to acquire more food from the market (Hossain and Pingali 1998). However, growth in rice production decelerated considerably to about 1.6% per year during 1990-2008, and the contribution of yield increases to rice production growth also declined substantially. The yield growth of rice declined substantially after 2000 in high-productivity nations such as Japan, South Korea, and China, where rice is grown on 100% irrigated areas with complete adoption of modern varieties (Table 1).

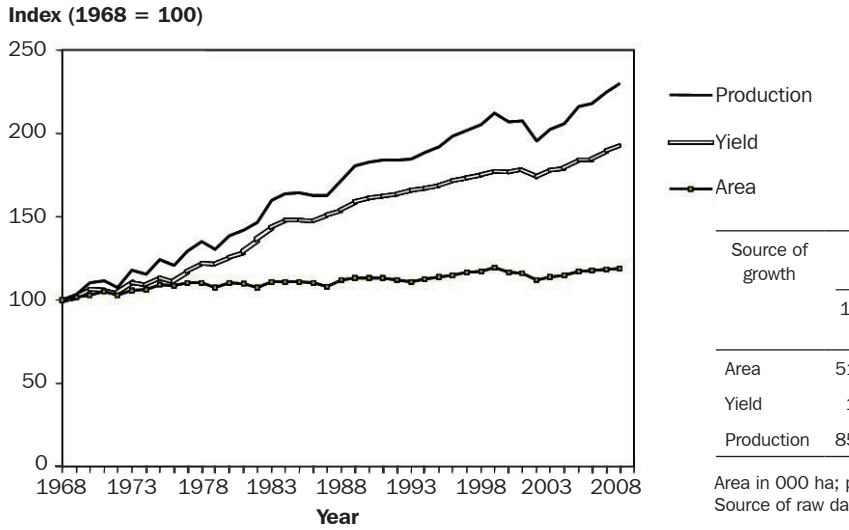


Fig. 2. Trends in rice area, production, and yield, South Asia, 1968-2008.

Source of growth	3-year average				Growth rate (%/year)	
	1968-70	1988-90	1998-2000	2006-08	1968-2000	2000-08
Area	51,006	56,961	59,996	60,418	0.51	0.41
Yield	1.68	2.56	2.98	3.40	2.10	1.92
Production	85,932	145,756	178,756	205,503	2.61	2.33

Area in 000 ha; production in 000 tons-paddy; yield in tons/ha-paddy.
Source of raw data: USDA (2009).

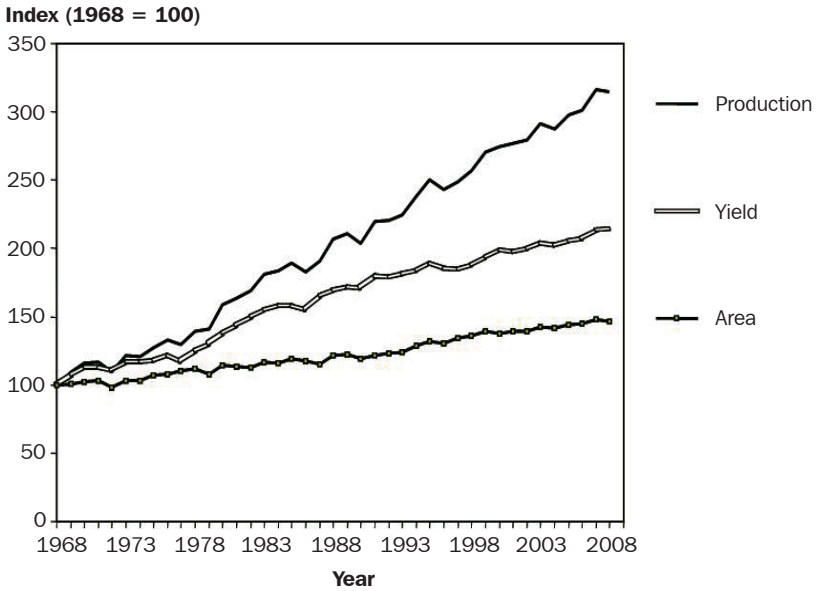


Fig. 3. Trends in rice area, production, and yield, Southeast Asia, 1968-2008.

Source of growth	3-year average				Growth rate (%/year)	
	1968-70	1988-90	1998-2000	2006-08	1968-2000	2000-08
Area	31,029	37,201	42,352	44,991	1.01	0.87
Yield	1.88	3.00	3.40	3.72	2.13	1.00
Production	58,417	111,522	143,952	167,357	3.14	1.87

Area in 000 ha; production in 000 tons-paddy; yield in tons/ha-paddy.
Source of raw data: USDA (2009).

The issue is whether Asia will be able to sustain favorable food balances and further improve food security for low-income households in low-income countries in the 21st century. The impressive growth in rice production over the last four decades has generated a sense of complacency regarding Asia's ability to meet the growing demand for staple food. However, the post-1990 era has witnessed a significant deceleration in the growth of rice yield to nearly 1% per year in Asia, a rate that grew at 2.3% per year during the Green Revolution period of 1968-90 (Fig. 1). The growth in rice production in South and Southeast Asia slackened considerably in the 1990s, mostly because of stagnant growth of yield (Table 1 and Figs. 2-3). In

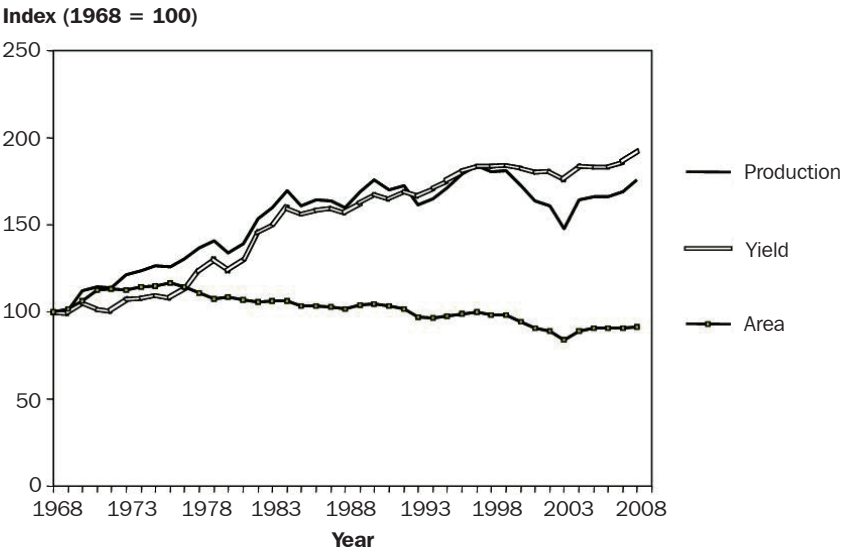


Fig. 4. Trends in rice area, production, and yield, East Asia, 1968-2008.

Source of growth	3-year average				Growth rate (%/year)	
	1968-70	1988-90	1998-2000	2006-08	1968-2000	2000-08
Area	36,647	36,994	34,597	34,479	−0.44	−0.05
Yield	3.48	5.56	6.29	6.41	2.21	0.62
Production	127,542	205,687	217,612	208,235	1.77	0.57

Area in 000 ha; production in 000 tons-paddy; yield in tons/ha-paddy.
Source of raw data: USDA (2009).

Table 2. Changes in annual growth rate of paddy production in major Asian countries, 1968-2000 and 2001-08.

Country	Growth in paddy production (%/year)		Paddy production (000 tons)
	1968-2000	2000-08	2008
Japan	–1.04	–0.55	11,029
Korea (Rep. of)	0.78	–1.84	6,545
China	2.19	0.74	193,000
Bangladesh	2.29	2.89	46,505
Indonesia	3.77	1.53	57,829
Nepal	1.86	0.29	4,279
Philippines	2.77	3.90	16,814
Sri Lanka	2.49	2.17	3,275
Thailand	2.10	1.56	29,394
Vietnam	4.17	1.97	35,898
India	2.76	2.12	148,365
Myanmar	2.60	–0.36	17,500
Asia	2.36	1.56	600,541

Source of raw data: World Rice Statistics (2009).

East Asia, rice area declined significantly after 1990 without affecting production levels (Fig. 4). In many countries across Asia, growth in rice production was considerably slower after 2000 than before 2000 except in the Philippines and Bangladesh (Table 2). Thus, rice production growth after 2000 was lower than population growth in many Asian countries, reversing the upward trend in the per capita availability of rice from domestic production. The real prices of rice, which were declining until the mid-1990s across Asia, started reversing their trend in the mid-1990s. The recent rice crisis that crippled Asia during late 2007 and early 2008 gave a wake-up call to think about a new strategy for boosting domestic supplies and for developing a strong market strategy (Mohanty 2008).

India's rice sector: an overview

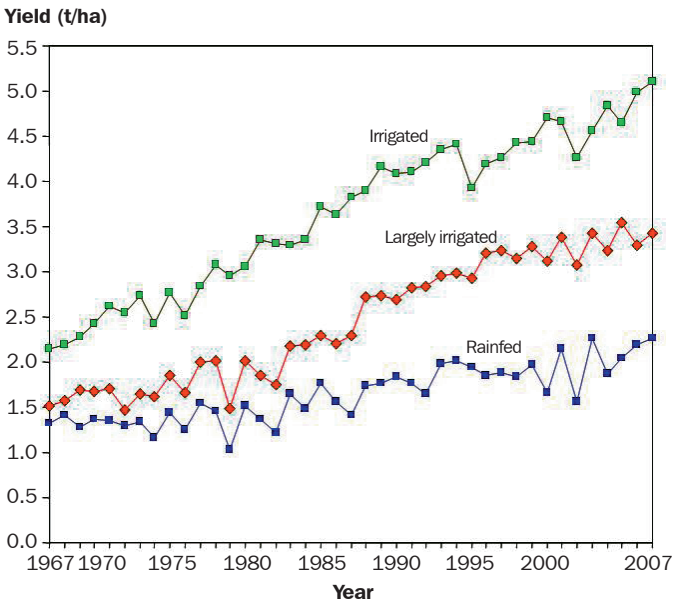
India's rice sector has experienced remarkable progress over the past four decades, largely driven by technological breakthroughs. The rice research programs in India, mainly in the public domain, over the past 50 years largely centered on shifting the yield frontier, which contributed substantially to achieving food security through increased rice supplies (CRRI 1996). Several studies indicated high payoffs to rice research in India (Evenson and Mckinsey 1991, Evenson 1993, Kumar

and Rosegrant 1994, Pingali et al 1997, Janaiah and Hossain 2004, Janaiah et al 2006). Rice output growth was 2.8% per annum during 1968-2000, with the highest rate of growth (4% per year) achieved during the 1980s. Yield improvements in rice were the major sources of a strong output growth, largely because of the widespread adoption of modern rice varieties in favorable irrigated environments (Barker and Herdt 1985, David and Otsuka 1994, Hossain 1997, Pingali et al 1997). However, the sense of complacency in the demand-supply balance began disappearing in the early 1990s when it was observed that yield advances in rice slowed down dramatically for the irrigated rice system in India (Janaiah et al 2006). The intensive rice-growing states of Andhra Pradesh, Tamil Nadu, Punjab, and Haryana, which made significant yield improvements until the 1980s, witnessed either a plateau or deceleration in yield growth after 1990 (Table 3 and Fig. 5). The economically exploitable yield of existing high-yielding varieties (HYVs) of rice has almost reached the technical optimum in irrigated rice systems with the universal adoption of HYVs (Janaiah et al 2005). On the other hand, increased demand for rice will make it difficult to meet the food requirements of the growing population and increasing income-induced consumption levels. Demand for rice is also projected to increase in many developing countries in the face of increasing prices of other food items such as fruits, vegetables, and livestock products (Mohanty 2008).

Table 3. Yield growth of rice in Indian states, 1971-2007 (% per annum).

State	1971-80 (TE)[a]	1981-95 (TE)	1996-2007 (TE)
Andhra Pradesh	2.6***[b]	1.9***	2.0***
Karnataka	1.6**	1.8***	2.0***
Tamil Nadu	0.4	3.5***	–1.7
Orissa	0.7	3.1***	2.6***
Bihar	–0.2	2.5***	–1.1
West Bengal	1.3**	4.1***	1.9***
Assam	0.2	2.2***	0.4
Maharashtra	5.1**	1.1**	0.1
Madhya Pradesh	–1.2	2.7***	2.4*
Uttar Pradesh	2.0**	4.1***	–0.7***
Punjab	4.4***	0.8***	1.9***
Haryana	4.9***	0.6***	2.2***
All India	1.6***	2.8***	1.1***

[a]TE = triennium ending (detrended by three years' moving average).
[b]*** = 1% level of significance, ** = 5% level of significance, * = 10% level of significance.



Ecosytem	Average yield (t/ha)			Growth rate (%/year)	
	1967-69	1989-91	2005-07	1967-90	1990-2007
Irrigated	2.21	4.12	4.91	2.8	1.1
Largely irrigated	1.59	2.75	3.42	2.4	1.3
Rainfed	1.33	1.79	2.17	1.2	0.9

Source of raw data: Directorate of Economics and Statistics, Ministry of Agriculture, India.

Fig. 5. Trends in rice yield for irrigated and rainfed ecosystems, India, 1967-2007.

Focus of the study

Among various options, policymakers and research managers in India during the late 1980s considered hybrid rice as a readily available technology to reverse the declining trend of productivity growth under irrigated environments. China's miraculous success in the popularization of hybrid rice technology in the late 1970s and the 1980s motivated countries in tropical Asia to invest more resources for hybrid rice R&D in the 1990s. The private seed sector also participated in a big way in the early 1990s in these countries in research, seed production and marketing, and seed imports, expecting a huge and guaranteed seed business with rice being a widely cultivated crop in the region.

India was the first country to initiate hybrid rice research at the Central Rice Research Institute, Cuttack, in the early 1950s (Sampath and Mohanty 1954). Subsequently inspired by Chinese success, research efforts on hybrid rice started in the early 1980s in collaboration with the International Rice Research Institute (IRRI), Philippines. The Indian Council of Agricultural Research began a focused hybrid rice R&D program in India in 1989 with an objective of developing and releasing indigenous rice hybrids to farmers (DRR 1997). The rigorous efforts of hybrid rice R&D in India over the past two decades resulted in the development and release of 35 rice hybrids, by both the public and private sector. Since the first-generation rice hybrids released to farmers in the early 1990s, hybrid rice R&D has encountered major challenges in India such as acceptable grain quality, pest and disease resistance, seed costs, etc. However, it is important to note that the hybrid rice R&D strategy being adopted is dynamic, and it continues the refinement process by taking farmers' feedback/constraints into consideration in research priority setting to meet emerging challenges. Thus, there is considerable improvement in the recently released hybrids as compared with the first- and second-generation hybrids of the 1990s in grain quality, yield gain, pest and disease resistance, seed yield, etc. (DRR various reports, 2000-08). Several farm-level impact studies carried out during the 1990s and early 2000 (Janaiah 2002, Janaiah et al 2002) provided useful feedback on and insights into the hybrid rice R&D program for re-orienting its strategy toward farmers' preferences that resulted in the development of many farmer-acceptable hybrids after 2003.

Keeping in view the relevance of assessing the farm-level impacts of recently released hybrid rice, a joint collaborative study titled "Impact assessment of hybrid rice in India: socio-economic, policy, and institutional considerations" was begun by Acharya N.G. Ranga Agricultural University (Hyderabad, India) and the International Rice Research Institute (IRRI) during March 2009, with the following specific objectives:

(i) To estimate and analyze the productivity gains and financial profitability of commercial cultivation of hybrid rice;

(ii) To assess the factors affecting farmers' decisions to adopt hybrid rice;

(iii) To analyze farmers' perceptions of constraints to the large-scale adoption of hybrid rice; and

(iv) To study the economics of F_1 seed production of hybrid rice.

Note that this study primarily focuses on assessing farm-level impacts and key challenges of hybrid rice adoption in the selected states, and the economic aspects of F_1 seed production based on surveys conducted during April-May 2009.

This report is organized as follows: The next section provides an overview on the nature and extent of hybrid rice adoption in India. The third section discusses sampling details and describes the sample profile and approach being adopted to trace farm-level impacts. The results from the survey data on farm-level impacts of hybrid rice cultivation are documented and discussed in the fourth section, while the economics of hybrid rice seed production are discussed in the fifth section. The major findings and their implications for policy relevance are summarized in the last section.

Study sites and methodology

Study sites

As most of the recently released rice hybrids are spreading in eastern India, the study covered two important rice-producing states of the region, Chattisgarh and eastern Uttar Pradesh, to assess the farm-level impacts of hybrid rice cultivation. A recently released Basmati rice hybrid (aroma type) was reported to be widely adopted in Punjab and Haryana (northern Indian high-productivity rice states); thus, Haryana was selected for studying the impact of this unique rice hybrid. Similarly, Andhra Pradesh, widely known as the Seed Capital of India, where about 800 seed companies are concentrated, was selected to study the economics of hybrid rice seed production. Table 4 provides a basic profile of the study sites and sample farm households.

From each state, eight to nine villages in one district were selected based on the quantity of hybrid rice seed marketed by various public and private seed agencies during the 2008-09 wet seasons (WS). The sample size of farm households that grew hybrid rice during the 2008-09 WS in each selected state was fairly large, ranging from 60 to 64. The selected sample households are from the areas where the adoption of hybrid rice is the highest and performance is better. However, in view of the scattered adoption of hybrid rice and because it has yet to spread in large areas, a random sampling technique could not be strictly followed. A purposive sampling technique was followed in the selection of sample farm households in consultation with local stakeholders from both the public and private sector. Only those households that adopted hybrid rice on a considerable land area along with regular existing inbred varieties were included in the sample frame for assessing the farm-level impacts of hybrid rice cultivation. Thus, two

Table 4. Basic profile of the study sites and sampling in different states of India, 2008-09 WS.

Item	Chattisgarh	Uttar Pradesh	Haryana
Characteristics of study sites			
Number of districts	1	1	1
Number of villages	8	9	9
Method of sampling	Purposive	Purposive	Purposive
Sample size	61	64	60
Crop year	2008-09 WS	2008-09 WS	2008-09 WS
% of sample that grew hybrid rice during preceding year	85	88	68
Profile of sample farmers			
Age (years)	42	48	42
Educational status (schooling years)	11	10	11
Average landholding (ha)	6.6	2.0	10
Average rice area (ha)	5.7	1.8	9.3
% of irrigated rice area	66	94	100
% of rice area planted to hybrid rice by sample farmers	68	73	23

Source: Survey data (2009).

comparable "comparison groups," a treatment group (hybrid rice) and control group (inbred rice), were formed to trace the farm-level net impacts of hybrid rice cultivation.

For the economics of seed production, random sampling is followed in the selection of 60 sample seed producers in Andhra Pradesh, as most of the farmers in the study area are seed growers.

Implementation of surveys and collection of data

Data on area planted to F_1 seed production, seed yield, and seed sales by various public and private seed agencies from 1996 to 2008 were obtained from the Directorate of Rice Research, Hyderabad, India (DRR various reports, 2000-08, Ramesha et al 2009). These data were used to estimate the adoption rate of hybrid rice, and its share in the rice economy in India, assuming that all seed produced was marketed, and the same is being used by farmers.

Field surveys using a structured and pretested questionnaire were conducted at all study sites during April-May 2009 to collect the required data from the sample farmers. Farm-level data on socioeconomic characteristics of the sample households, allocation of land to cultivation of hybrid and existing inbred varieties, details of crop management practices, and costs and returns were generated through surveys. In addition, farmers' perceptions on the experience of hybrid rice cultivation and the grain quality of hybrid rice were also obtained during the surveys. The survey data are related to the 2008-09 crop year (2008 WS). The method of collection of survey data from sample farmers is personal interviews by administering the pretested and focused questionnaire by well-trained enumerators under the direct supervision of researchers.

Approach to trace and estimate farm-level impacts

Technological interventions such as hybrid rice R&D make an impact at different levels: national/regional (economy-wide impact), program, household, and farm. Various approaches are available to trace the impacts of technological interventions at each level. This study primarily focuses on assessing farm-level impacts of hybrid rice. For this, the formation of two comparable "comparison groups," one for hybrid rice and another for inbred rice, is essential to trace the net impact of replacing hybrid rice with inbred rice under similar agro-climatic, biophysical, and socioeconomic conditions. Such an approach allows for controlling counterfactual effects and measuring the net impact of hybrid rice on intended outcome indicators. Thus, to implement this approach, the sample farmers were selected in such a way that they grew both hybrid rice and inbred rice varieties side by side on the same land area (some area for hybrid varieties and some for inbred varieties) during the same crop season under similar agro-climatic, biophysical, and socioeconomic conditions. However, there may be a marginal variation in crop management between hybrid and inbred rice, which is largely due to farmers' usual tendency to take extra care of any new technology in the initial period. Therefore, any change in the outcome indicators (for instance, yield) between two comparison groups can be attributed largely to a change in variety, that is, hybrid rice in place of inbred rice under similar agro-climatic, biophysical, and socioeconomic conditions.

After forming two comparable comparison groups, hybrids and inbreds, the survey data were analyzed by applying various measures of central tendencies such as mean, ratio, percentage, etc., to measure intended outcome indicators. The difference in the intended outcome indicators is tested for statistical significance by estimating paired-t values. The paired-t test is applied in this case because hybrid and inbred rice form two comparable groups (a pair) as both were grown by the same sample farmers during the same crop years under similar conditions.

Study hypotheses

The following key hypotheses were empirically tested using both survey data and published data from various hybrid rice project reports:

- Hybrid rice has considerably contributed to the growth of the national rice sector.
- The economic superiority of the latest generation of rice hybrids (from both the public and private sector) in the form of having a higher profit than the best existing inbred varieties is a key motivating factor for expanding hybrid rice in different states of India.

Table 5. Current status of hybrid rice development and its adoption rate in selected Asian countries.

Country	Year when R&D began[a]	Year of first hybrid release	Number of hybrids released, 2008[d]			Area planted to hybrid rice, 2008	
			Public sector	Private sector	Total	000 ha	% of total rice area
India	1989	1994 DS	9	26	35	1,400	3.2
Bangladesh	1997	1999 DS	2	51	53	735	7.6
Vietnam	1992	1992 WS[b]	15	10	25	645	9.0
Philippines	1993	1993 WS[c]	15	10	25	346	10.2

[a]Year when mission-mode R&D began.
[b]First rice hybrid released was imported from China.
[c]First rice hybrid released in the Philippines was developed at IRRI, where hybrid rice research began in 1979.
[d]Includes imported hybrids from China and India in Bangladesh and Vietnam. DS = dry season (Nov./Dec.-March/April); WS = wet season (June/July-October/November).

- Pest and disease resistance, grain quality, and consumer acceptance of some rice hybrids are still issues in some parts of India, which is causing a slow spread of the technology.
- The improvement of F_1 seed yields over the years has helped to bring down the retail seed price to make seed affordable to farmers.

Impact indicators

The following outcome indicators were considered and measured, keeping in view the focus and objectives of the study:

- Profitability gain;
- Unit cost of production (commercial cultivation);
- Product value as measured by grain price in the open market;
- Motivating factors for hybrid rice adoption;
- Constraints to large-scale adoption, if any;
- Cost of F_1 seed production; and
- Relationship of farm-level hybrid rice seed yield and retail seed price.

Hybrid rice adoption

The efforts of the hybrid rice R&D program over the past 15 to 20 years across tropical Asia resulted in the development and release of a considerable number of rice hybrids for farmers. Table 5 summarizes the progress made in the hybrid rice R&D program in selected Asian countries. India is the second country after China to develop and release the first rice hybrid during the 1994 DS, while, in other countries, such as Vietnam and Bangladesh, the first released rice hybrids were imported from China (Janaiah and Hossain 2003). It was reported based on early experiences that many farmers who grew hybrid rice initially for one or two seasons started dropping out from hybrid rice cultivation in India (Janaiah 1995, 2000, 2002, Janaiah et al 1993, 2002) and Bangladesh (Hussain et al 2001). Therefore, the rate of hybrid rice adoption by farmers was too limited and scattered in these countries until 2004. Subsequently, Bangladesh imported more than 50 rice hybrids largely from China and India, which were notified and released by the National Seed Board of Bangladesh. By the 2008-09 crop year, about 8% of the rice area was planted to different rice hybrids in Bangladesh (Table 5). The active participation of the private sector and NGOs in the hybrid rice seed sector and the government's liberal policy on seed imports from other countries were a key factor in the increased diffusion of hybrid rice in Bangladesh. In Vietnam, the rate of hybrid rice adoption (mostly hybrids imported from China) reached about 8% of rice area by 2003. Since then, it stagnated at this level as Vietnam's government removed the price subsidy on seed cost during 2004. Hybrid rice adoption in the Philippines is modest at about 12%.

Nature and extent of hybrid rice adoption in India

In India, the hybrid rice R&D strategy was basically targeted at reversing the decelerating yield trend under the intensive rice-rice systems of southern India and the rice-wheat systems of northern India. Later on, favorable environments in eastern India, especially the boro rice lands, were targeted for expansion of hybrid rice cultivation during 1995, when it was realized that the first-generation hybrids were not suited to the irrigated rice lands of southern and northern India (DRR 1997, Rao et al 1998).

Expectations arose and ambitious targets were fixed at the macro level for the expansion of hybrid rice cultivation. It was projected that hybrid rice would cover nearly 5%, 25%, and 60% of total rice area by 2000, 2010, and 2020, respectively (Barwale 1993). Based on these projections, an ex ante evaluation study estimated that hybrid rice would contribute 35–40% to meet the additional rice demand by 2020 (Janaiah et al 1993). Further, it was projected that this technology would generate huge employment opportunities for female workers through hybrid seed production in rural India. An ex ante assessment

of hybrid rice potential in India based on on-farm trial data (1992-93 and 1993-94) reported 12% yield gains of hybrids over inbred varieties (Janaiah 1995). Farmers' perceptions during on-farm testing, however, indicated that the poor grain quality of the tested rice hybrids would constrain large-scale acceptance of this technology by both farmers and consumers in India (Janaiah et al 1993, Janaiah 2002). Many of the first-generation rice hybrids released during the 1990s in India were those tested during on-farm trials in 1992-93 and 1993-94, ignoring farmers' perceptions during the prerelease testing period. Many commercial farmers in the irrigated environment began dropping out from hybrid rice cultivation after one or two crop seasons. In spite of the efforts of seed companies to move hybrid rice from one state to another to obtain a market, area expansion remained much below the projected level until early 2000. Thus, the adoption rate of hybrid rice in India was meager, less than 1% of total rice area until 2003 (Table 6), although the first rice hybrid was released in 1994.

In 2004, the hybrid rice R&D strategy in India was re-oriented, especially with respect to expanding the multilocation testing approach to on-farm evaluation of a wide range of rice hybrids under diverse production environments across the country. The strategy was also re-focused toward favorable rainfed areas where rice is grown under groundwater, mainly in the eastern parts of the country. The current base yield of different inbred varieties of paddy under rainfed uplands is low, 3.0 to 3.5 t/ha, with yield of hybrid rice under on-farm testing reported at 4 to 4.5 t/ha, a yield gain of about 30–35%. Further, a large number of private seed companies started engaging in R&D and seed production after 2004, expecting a huge business as rice was a widely cultivated crop (Ramesha et al 2009). Some state governments have initiated an incentive policy in the form of a subsidy on hybrid rice seed during the initial years for the promotion of hybrid rice. Another significant development in hybrid rice R&D during recent years is the development and release of the first Basmati rice hybrid from a public-sector institution (Indian Agricultural Research Institute, IARI) for the states of Punjab and Haryana. As many as 20 private seed companies have entered into an agreement with IARI to access seeds of base material of this hybrid from IARI, and they have produced a large quantity of F_1 seeds and marketed them in Haryana and Punjab recently.

Current share of hybrid rice in India's rice sector

All the developments in hybrid rice R&D strategy and policy after 2004 led to a real kickoff for the technology in farmers' fields, especially in eastern India. Based on total seed production by both the public and private sector, the area planted to hybrid rice during 1996 to 2008 was estimated. As to the exact quantity of seeds marketed by various companies, it is assumed that whatever quantity of seed is produced is marketed and actually used by farmers. Thus, the current share of hybrid rice based on seed production may be higher. Accordingly, adoption rates and the contribution of hybrid rice to India's rice sector were estimated.

Table 6. Area planted to hybrid rice cultivation in India, 1996 to 2008.

Year	Gross rice area (million ha)	Area planted to hybrid rice[a]	
		000 ha	% of gross rice area
1996	42.84	50	0.12
1997	43.43	90	0.21
1998	43.45	100	0.23
1999	44.80	150	0.33
2000	45.16	175	0.39
2001	44.71	180	0.40
2002	44.90	200	0.45
2003	41.18	275	0.67
2004	42.59	570	1.34
2005	41.91	750	1.79
2006	43.66	1,000	2.29
2007	43.81	1,100	2.51
2008	43.77	1,400	3.20

[a]Source: Estimated based on seed production during preceeding year considering seed rate at 15 kg per ha. Source for seed data: Ramesha et al (2009).

The adoption rate of hybrid rice, which was less than 1% during the first decade after the release of the first hybrid, increased substantially to 3.2% by 2008 (Table 6). The area planted to hybrid rice during 2008 was estimated at about 1.40 million ha of the total rice area, largely concentrated in Chattisgarh, Bihar, and eastern Uttar Pradesh. The average yield of hybrid rice recorded on sample farms in Chattisgarh and Uttar Pradesh is used to estimate the share of hybrid rice in India's rice production. Accordingly, the contribution of hybrid rice to total rice production in India as a whole is computed at 5.6%, although its share of total rice area is only 3.2%. Hybrid rice thus covered about 7% of the rice area in eastern India, accounting for nearly 13% of the rice output in the region. This shows that there is a potential opportunity for India to increase rice production in the future, especially in the low-income areas of eastern India, without additional rice area, or even by releasing some of the existing rice area to other crops by the large-scale adoption of hybrid rice, as has been done in China. As rice is a key source of livelihood in eastern India, where poverty and malnutrition persist widely, a considerable increase in yield through hybrid rice will have a major impact on household food security, income, and nutrition besides an economy-wide impact in the region. The large-scale adoption of hybrid rice, however, depends on the sustainability of the technology in farmers' fields.

Table 7. Share of popular rice hybrids in total hybrid rice area planted by sample farmers, 2008-09 WS.

State/popular hybrids	% of hybrid rice area covered	Market price (Rs/t)	Yield (t/ha)
Chhattisgarh (total area under all hybrids = 235 ha)			
1 US 312	28	11,600	4.7
2 Dhanya 775	23	11,400	4.4
3 Dhanya 448	18	11,500	4.6
4 Kaveri 9090	17	11,200	4.3
5 Pioneer P 25	14	11,600	4.5
Uttar Pradesh (total area under all hybrids = 84 ha)			
1 64-44	40	7,800	6.3
2 Dhanuka Irbid	10	7,600	6.4
3 Euro-9	20	7,700	6.2
4 Euro-36	20	7,550	6.1
5 Euro-27	10	7,400	6.0
Haryana (total area under all hybrids = 128 ha)			
1 PR-71	16	10,600	7.6
2 Pioneer P-77	17	10,000	7.8
3 PR 257	12	10,200	7.4
4 Devgan PR-664	12	10,000	7.3
5 JK seeds RH-10	11	10,000	7.4
6 JK seeds RH-401	12	10,100	7.5
7 PR-6129	11	10,000	7.2
8 Bayer PR-64-44	9	10,700	7.3

Source: Estimated from household survey data (2009).

Table 8. Share of popular inbred rice varieties in total inbred rice planted by sample farmers, 2008-09 WS.

State/ popular inbreds	% of inbred rice area covered	Market price (Rs/t)	Yield (t/ha)
Chhattisgarh (total area under all inbreds = 110 ha)			
1 IR36	63	11,620	3.6
2 MTU 1010	18	11,500	3.4
3 IR64	14	11,580	3.1
Uttar Pradesh (total area under all inbreds = 31 ha)			
1 Mansuri	52	8,310	5.0
2 Saryu52	22	7,670	4.9
3 NDR	18	7,070	4.2
4 Samba	6	8,400	7.9
5 Dhanuka	2	7,000	6.9
Haryana (total area under all inbreds = 340 ha)			
1 PR114	27	9,630	7.4
2 CSR30	22	24,640	3.5
3 Pusa44	17	9,760	8.4
4 PR147	10	9,540	7.7
5 PR127	5	9,810	7.6

Source: Estimated from survey data (2009).

Farm-level impacts of hybrid rice cultivation

Basic profile of sample households

The sample farmers are in the middle age group, ranging from 42 to 48 years old, with educational status of an average of 10th to 11th grade (Table 4). Average farm landholdings owned by sample farmers are 5.7 ha, 2.0 ha, and 10 ha in Chattisgarh, Uttar Pradesh, and Haryana, respectively. The average farm size of sample households is higher than the Indian average of about 1.2 ha because of the purposive sampling adopted for the study in view of the scattered and thin adoption of hybrid rice. Out of total land area, 80–90% was planted to rice during the 2008-09 WS, largely under irrigated conditions, expect in Chattisgarh, where one-third of the rice area was under rainfed conditions. The sample farm households are primarily representative of rice-producing farmers in the respective states. A majority of the sample farmers are repeat adopters of hybrids, who have grown hybrids during previous years. The average rate of adoption of hybrid rice on sample farms during the 2008-09 WS (year of survey) was 68%, 73%, and 23% in Chattisgarh, Uttar Pradesh, and Haryana, respectively (Table 4).

Popular varieties of hybrid and inbred rice

The total rice area planted by sample farmers during the 2008-09 WS was 345, 115, and 558 ha in Chattisgarh, Uttar Pradesh, and Haryana, respectively, of which 68%, 73%, and 23% was planted to various rice hybrids in the respective states. More than 20 private seed companies are actively engaged in both the production and marketing of hybrid rice seed with different brand names in eastern India. The popular rice hybrids grown by the sample farmers during the 2008-09 WS in the study areas are listed in Table 7 along with adoption rates, yield, and market price for final output. Similar details for the popular inbred rice varieties grown by the sample farmers are summarized in Table 8. The yield of various hybrids is considerably higher than that of the popular inbred rice varieties

in Chattisgarh and eastern Uttar Pradesh. However, the market price of the final output is marginally lower for many hybrids than for popular inbred varieties.

The first Basmati rice hybrid (Pusa Basmati RH-10) was developed and released by the Indian Agricultural Research Institute (New Delhi) during 2006 for the Basmati rice-growing areas of Punjab, Haryana, and western Uttar Pradesh. This hybrid is primarily meant for higher yields of Basmati rice than existing Basmati inbred varieties such as Pusa Basmati-1, whose yields are relatively low, but it fetches a two- to threefold higher price for produce in the market. Therefore, the newly released Basmati rice hybrid is expected to yield as high as non-Basmati inbred rice varieties, but with better grain quality and aroma for fetching a higher price in the market than for Basmati inbred varieties. A large number of private seed companies came forward to produce and market F_1 seeds of this hybrid, expecting a large market for this hybrid in northern India, especially in Haryana and Punjab. Several seed companies entered into an agreement with IARI for accessing parental seeds of the Basmati hybrid during 2006 and 2007 for large-scale production of F_1 seeds. About 10 seed companies are now producing and marketing F_1 seeds of the Basmati hybrid with different company brand names. However, most of the seed companies have started marketing F_1 seeds of the Basmati rice hybrid in nontraditional Basmati areas (nontargeted areas), where high-yielding inbred varieties are extensively grown.

The popular Basmati rice hybrids grown by the sample farmers in Haryana are shown in Table 7. The adoption rate of all Basmati rice hybrids on sample farms is only 23%. The yields of various Basmati rice hybrids being marketed by several seed companies with different brands (Table 7) and the popular inbred rice varieties (non-Basmati inbred varieties) (Table 8) are by and large the same, 7.3–7.5 t/ha. Further, the market price for Basmati hybrid grain and inbred non-Basmati rice grain is also similar. Thus, the adoption rate of Basmati rice hybrids is low, and it declined after the first two years of farmers' experiences.

Yield and profitability gains

As with any other technology, the adoption of hybrid rice in a market economy is basically an economic decision of farmers. The profitability of the technology compared to any other existing activity that competes for the same resources is the ultimate factor that would determine farmers' decisions in reallocating rice land from existing varieties to hybrids. The extent of profitability gains is a more important consideration than merely yield gains for farmers as most rice farmers in India sell a large portion of rice output to the market.

Any new technology in crop production can generate an additional profit margin over the existing technology through three basic means: (1) a change in yield, (2) a change in the price of the product, and (3) a change in the cost of production. Here, we decompose the change in profitability on account of these three factors. The estimates of yield gains, costs of various inputs, and cost-return profile for both hybrid rice and inbred rice cultivation in the study areas are documented in Tables 9 to 11.

Table 9. Average yield (t/ha) of hybrid and inbred rice varieties on sample farms in selected states of India (2008-09 WS).

State	Hybrid	Inbred	Yield gain	% yield gain	Paired t-value
Chhattisgarh	4.5	3.3	1.2	36.4	17.0***
Uttar Pradesh	6.2	5.0	1.2	24	11.4***
Basmati hybrid, Haryana	7.5	7.3	0.2	3	1.27

Source: Estimated from survey data (2009).

The findings show that hybrid rice varieties are indeed superior to inbred rice varieties for yield and profitability in Chattisgarh and eastern Uttar Pradesh. Hybrid rice outyielded the existing inbred varieties by about 36% in Chattisgarh and 24% in Uttar Pradesh (Table 9) under farmers' field conditions. However, for Haryana, the yield of both Basmati rice hybrids and popular inbred rice varieties (non-Basmati) is almost the same for the reasons explained above. On average, the yield gain of hybrid rice over the existing popular inbred rice varieties in eastern India is about 30% in farmers' fields, which is a phenomenal increase under rainfed uplands.

Among the sample farmers in eastern India, variation is considerable between Chattisgarh and Uttar Pradesh in the use of various inputs for the cultivation of hybrid and inbred rice (Table 10). The seed cost for hybrid rice in all states is significantly higher than the seed cost of inbred rice, as much as sixfold in Haryana. The retail price of F_1 seed that most of the seed companies offered during the 2008-09 WS was about $3.50–$4.00 per kg. Total input costs incurred by sample farmers in Chattisgarh are significantly higher by 29% for hybrid rice than for inbred rice (Table 10). Farmers in Chattisgarh have invested more in organic manures, chemical fertilizers, plant protection, machinery, etc., for hybrid rice cultivation, expecting large yield gains and profit as base-level paddy yields in Chattisgarh are low. In the other two states, input costs are by and large the same for both hybrid and inbred rice, with some variation in the cost of some inputs.

The other most important factor that determines the net profitability of hybrid rice cultivation is the market price of the final produce, which is an indicator of grain quality. Hybrid rice grain fetched almost the same price as inbred rice grain in Uttar Pradesh and Haryana, whereas it was about 11% lower for hybrid rice than for inbred rice in Chattisgarh (Table 11). In Chattisgarh, most of the popular inbred varieties (as shown in Table 8) have high grain quality, but yields are quite low. It is important to note that the market price of Basmati rice hybrids in Haryana is also the same as that of non-Basmati

Table 10. Costs (US$/ha) of various inputs for the cultivation of hybrid and inbred rice varieties on sample farms in selected Indian states (2008-09 WS).

Inputs	Hybrid rice	Inbred rice	% Difference	Paired t-value
Chattisgarh				
Seed rate (kg/ha)	14.8	74.1	−400	–
Seed	57.71	27.56	109	22.6***
Organic manure	157.13	113.36	39	5.7***
Chemical fertilizers	70.74	54.39	30	1.3
Labor	199.66	184.73	8	0.6
Rental charges of machinery use	59.47	46.73	27	9.4***
Plant protection	15.17	6.86	121	9.6***
Irrigation	12.36	12.11	2	1.3
Miscellaneous	33.60	24.57	37	9.7***
Total input cost	605.83	470.32	29	4.3***
Uttar Pradesh				
Seed rate (kg/ha)	13	38	−192	–
Seed	54.48	12.20	346	29.4***
Organic manure	100.81	112.37	−10	1.1
Chemical fertilizers	68.84	67.91	1	1.0
Labor	91.83	107.60	−15	−1.7*
Rental charges of machinery use	53.74	46.79	15	1.1
Plant protection	21.65	22.74	−5	1.0
Irrigation	23.57	30.00	−21	−4.9***
Miscellaneous	26.46	26.12	1	1.0
Total input cost	441.36	425.75	4	3.9***
Haryana				
Seed rate (kg/ha)	13	30	−131	–
Seed	53.60	7.62	603	43.7***
Organic manure	87.47	71.55	22	1.3
Chemical fertilizers	62.48	72.32	−14	−1.0
Labor	210.04	236.35	−11	−6.4***
Rental charges of machinery use	71.09	54.74	30	9.1***
Plant protection	131.39	138.49	−5	−3.0***
Irrigation	130.75	140.99	−7	−3.7***
Miscellaneous	39.59	40.88	−3	0.8
Total input cost	786.42	762.95	3	3.6**

Source: Estimated from survey data (2009).

Table 11. Comparative cost-return profile (in US$ per ha) for the cultivation of hybrid and inbred rice varieties on sample farms in selected states of India.[a]

Cost/returns	Chattisgarh			Uttar Pradesh			Haryana		
	HR	IR	%Diff.	HR	IR	%Diff.	HR	IR	%Diff.
Grain yield (t/ha)	4.5	3.3	36.4	6.2	5.0	24.0	7.5	7.3	2.7
Market price (US$/t)	245	275	−10.9	163	169	−3.6	216	214	0.9
Straw value	44	40	10.0	25	27	−7.4	9	28	−67.9
Gross returns	1,147	948	21.0	1,036	872	18.8	1,629	1,590	2.4
Total costs	606	470	28.9	441	426	3.5	786	763	3.0
Net returns	541	478	13.2	595	446	33.3	843	827	1.9
Cost of production (US$/t)	135	142	−5.4	71	85	−16.5	105	105	0.3

[a]HR = hybrid rice; IR = inbred rice varieties (conventional modern varieties), gross returns also include straw value (by-product value).
Source: Estimated from survey data (2009).

inbred rice, as both private grain traders and government agencies are reluctant to offer a higher price for Basmati hybrid rice grain. It was reported during the survey that traders are not considering Basmati hybrid rice grain as high-quality grain to compete with traditional or inbred Basmati varieties. Further, the government has not yet recommended hybrid Basmati rice grain as Basmati type as grain quality parameters of the released Basmati rice hybrids are yet to be accepted by traders and government agencies.

The net farm profit from the cultivation of hybrid rice and inbred rice varieties is computed based on three parameters: yield, total input costs, and market price of grain. Hybrid rice cultivation generated an additional net profit of about 13% in Chattisgarh and about 33% in Uttar Pradesh (Table 11). Although farmers in Chattisgarh received 13% additional net profit from hybrid rice cultivation, this is lower than in Uttar Pradesh because of higher input costs and a relatively lower output price for hybrid rice. Results imply that additional profitability is a key motivating factor for the adoption of hybrid rice in these states. In Haryana, net profit is almost the same for both hybrid and inbred rice cultivation for the reasons already explained earlier.

Table 12. Comparative cost-return profile (in US$ per ha) for the cultivation of hybrid and inbred rice varieties from 1993 to 2001 in India.[a]

Cost/returns	1993-95[b]			1997-98[c]			2000-01[d]		
	HR	IR	%Diff.	HR	IR	%Diff.	HR	IR	%Diff.
Grain yield (tons/ha)	6.31	5.63	12.1	6.91	5.91	16	6.8	6.0	13.3
Market price (US$/ton)	98	107	−8.5	105	117	−11	119	128	−7.0
Gross returns[d]	676	665	1.7	758	739	2.6	845	869	−2.8
Total costs	295	263	12.1	283	239	19	377	320	17.8
Net profit	381	402	**−5.2**	475	500	**−5.0**	468	549	**−14.8**

[a]HR = hybrid rice; IR = inbred rice varieties (conventional modern varieties)
Sources: [b]Janaiah (2000); [c]Janaiah and Hossain (2000); [d]Janaiah and Hossain (2003).

Table 13. Comparative cost-return profile (in US$ per ha) for the cultivation of hybrid and inbred rice varieties in Bangladesh, the Philippines, and Vietnam.[a]

Cost/returns	Bangladesh, 1999 boro			Philippines, 2000-01			Vietnam, 2000-01		
	HR	IR	%Diff.	HR	IR	%Diff.	HR	IR	%Diff.
				Dry season					
Grain yield (tons/ha)	6.44	5.63	14.4	5.9	5.1	17	6.33	5.25	21
Market price (US$/ton)	126	122	3.0	162.8	162.8	–	124.4	128.4	−3.0
Gross returns[a]	853	735	16.2	969	829	17	788.9	676.4	17
Total costs	469	382	22.6	445	370	20	522.6	482.4	8
Net profit	384	353	**9.0**	524	459	**14.0**	266.3	194.0	**37.0**
				Wet season					
Grain yield (tons)				5.2	4.9	6.0	6.07	4.99	22
Market price (US$/ton)				144.4	144.4	–	118.0	123.7	−5.0
Gross returns[a]				754	712	6.0	720.3	621.7	16.0
Total costs				411	332	24.0	478.8	443.4	8.0
Net profit				343	380	**−10.0**	214.5	151.3	**42.0**

[a]HR = hybrid rice; IR = inbred rice varieties (conventional modern varieties).
Source: Janaiah and Hossain (2003).

Is there progress in yield gain and profitability over the period?

A critical review of the hybrid rice R&D program in India reveals that three generations of rice hybrids were released to farmers by both the public and private sector over the past 15 years. They are first-generation hybrids (1994-98), second-generation hybrids (1999-2003), and third-generation hybrids (2004 until now). Sample farmers of this study grew third-generation rice hybrids (listed in Table 7). Various farm-level impact studies carried out based on surveys of sample farmers in different states of India during 1993, 1998, and 2001 showed that hybrid rice was higher yielding by 12–16% than inbred rice, but did not generate additional net profit as yield gains could not compensate for the lower market price and higher input costs for hybrid rice (Janaiah 1995, 2000, 2002, Janaiah and Hossain 2003). Similar results were reported in other countries, too. The farm-level profitability gains in hybrid rice cultivation during 1999 (year of introduction) in Bangladesh and in Vietnam and the Philippines during 2001 were robust. Only in Vietnam was hybrid rice cultivation substantially more profitable than the cultivation of inbred rice (Janaiah and Hossain 2003). The key findings of earlier studies are summarized in Tables 12 and 13.

Net profit from the cultivation of hybrids in India was about 5% lower in 1994 and 1998 and 15% lower in 2001 than growing inbreds (Table 12). The farm-level performance

of the latest generation of hybrids in 2008-09, however, was significantly superior to that of the existing popular inbred rice varieties in yield and profitability gains (Table 11).

Noteworthy to mention here is that the level of yield gains and difference in output price and production cost for hybrid rice cultivation in India over the period, as discussed above, are comparable with results reported from Chinese experiences in farmers' fields during the initial years. Hybrid rice had about a 15% yield advantage over the best inbred varieties in China, but suffered from lower output price because of poor grain quality. Thus, hybrid rice production was not more profitable than that of popular inbred varieties (He et al 1987). It was also reported that rice hybrids were more susceptible to insect pests and diseases. However, it was reported that government intervention was the major factor besides higher yields that contributed to the rapid adoption of hybrid rice in China, especially during the initial-stage prereform period. As the supply of hybrid seed and procurement of the final produce were in the hands of the state, poor grain quality and higher hybrid seed cost did not constrain the large-scale adoption of this technology in China.

From this discussion, we can conclude that the farm-level performance of the latest generation of hybrids in 2008 is considerably superior to that of the existing popular inbred rice varieties in yield and profitability gains. Both yield gains and additional net profitability of recently released rice hybrids were substantially higher in farmers' fields compared with first- and second-generation rice hybrids. This explains why the adoption of hybrid rice was very slow, and lingering until 2003, and why it picked up during subsequent years in India. The difference in market price between hybrid and inbred rice decreased over the period, which is a clear reflection of an improvement in grain quality in successive generations of rice hybrids over the same period. In general, farmers' perceptions show that grain quality is not as serious an issue for the latest generation of rice hybrids as it was until 2001, although grain quality is a key challenge for future hybrid rice R&D, particularly in the irrigated rice system.

Farmers' perceptions

Consumer acceptance of grain quality is one of the key challenges that constrain the large-scale adoption of hybrid rice in India. Earlier farm-level impact studies, starting with an ex ante study in 1993 (Janaiah 1995), reported that the quality of hybrid rice grain was inferior to the grain quality of the existing popular inbred rice varieties. Thus, hybrid rice grain fetched a lower market price, leading to a lower net return to hybrid rice than to inbred rice despite a yield gain of 12–16%. Therefore, most of the farmers who grew hybrid rice until 2001 discontinued hybrid rice (Janaiah 2002, Janaiah and Hossain 2003). To verify whether "grain quality" is still a challenge for the latest generation of rice hybrids, a subjective assessment of farmer-consumer perceptions was carried out during the surveys. It revealed that, among the sample farmers, about 43% in Chattisgarh and Haryana and 97% in Uttar Pradesh consumed hybrid rice grain during 2008. Most of those farmers that consumed hybrid rice grain in Chattisgarh and Uttar Pradesh reported that hybrid rice grain has inferior quality in one form or another, such as no taste, stickiness, and flavorless smell of cooked rice (Table 14). This may be a reason why hybrid rice grain of hybrids had a lower price in the market. Thus, some farmers reported that traders have not readily accepted hybrid rice grain in Uttar Pradesh and Haryana, and have offered a lower price on account of lower grain quality (Table 15). In Chattisgarh, farmers reported that they did not face problems from traders. The public sector regulated farmers' cooperative marketing system purchases of paddy grain from farmers directly in Chattisgarh irrespective of grain quality, but offered a relatively lower price for hybrid rice.

Out of the total of sample farmers, almost all reported that they will continue cultivating hybrid rice in the future in Chattisgarh and Uttar Pradesh (Table 16). Regarding the reasons and motivating factors for continuing, most of the farmers at all study sites reported that hybrid rice had a higher yield potential, and thereby higher profitability, and they were hoping for much better new rice hybrids. A majority of the sample farmers in Chattisgarh and Uttar Pradesh reported that

Table 14. Farmer-consumer perceptions of hybrid rice grain for domestic consumption in selected Indian states (2008-09 WS).

Perception	% Farmers reporting		
	Chattisgarh (N = 26)[a]	Uttar Pradesh (N = 61)	Haryana (N = 26)
Poor grain quality	8	20	0
No taste	23	41	12
Poor cooking and keeping quality	19	42	–
Flavorless smell of cooked rice	46	59	4
Stickiness of cooked rice	58	33	8

[a]N = number of sample farmers who consumed hybrid rice grain.
Source: Survey (2009).

Table 15. Farmers' perceptions on reasons for lack of ready acceptance of hybrid rice grain by traders in the market (2008-09 WS).

Reason	% of farmers reporting this		
	Chattisgarh	Uttar Pradesh	Haryana
Not immediately accepted by traders	–	0	25
Offered lower price on account of poor quality	–	67	50
Mixed seeds	–	–	21

Table 16. Farmers' perceptions on reasons for continuing hybrid rice cultivation in India (2008-09 WS).

Reason	% of farmers reporting this		
	Chattisgarh (N = 61)[a]	Uttar Pradesh (N = 59)	Haryana (N = 42)
Hoping for better yield in the next season	100	100	100
Hoping for better new hybrids	97	100	98
Higher yield	98	100	83
Higher price	36	97	93
Higher profitability	98	97	98
Suitable for family consumption	25	81	5
Suitable for popped rice	13	39	17
Better adaptability	67	78	5
Suitable for parboiling	5	83	31
Better resistance	54	76	7

[a]N = number of sample farmers willing to continue hybrid rice in the future.
Source: Survey data (2009).

Table 17. Farmers' perceptions on reason for dropping out of hybrid rice cultivation in India (2008-09 WS).

Reason	% of farmers reporting this		
	Chattisgarh (N = 0)	Uttar Pradesh (N = 3)	Haryana (N = 17)
Lower yield	–	100	100
Lower price	–	100	47
Lower profit	–	100	82
Highly susceptible to winds/lodgiing	–	33	18
Heavy grain shedding due to lodging	–	33	59
Lack of consumer demand in local market	–	100	53
Poor grain quality	–	33	0
Lower head-rice recovery (milling %)	–	33	9
High risks from pests and diseases	–	67	59
Unfit for domestic consumption	–	100	82
Higher seed cost	–	100	100
Requires high crop care	–	100	82
Difficult to get good-quality hybrid seed	–	67	100
More chaffiness	–	33	6

[a]N = number of sample farmers not willing to continue hybrid rice in the future.
Source: Survey data (2009).

rice hybrids have better adaptability with more resistance to pests and diseases.

When we asked those who reported that they would discontinue hybrid rice cultivation in the future, especially in Haryana, most of them indicated that hybrid rice had lower yield and profits than inbred rice (Table 17). The lack of consumer acceptance of hybrid rice grain because of poor cooking, eating, and keeping qualities, leading to a lower market price, and higher costs, especially for hybrid rice seed, etc., were reported as other serious constraints that led to the discontinuance of hybrid rice cultivation in Haryana and Uttar Pradesh.

Economics of F_1 seed production

The availability of quality hybrid seed at a reasonable price is crucial to the success of any hybrid technology in any crop. The history of success in hybrids in crops such as maize, pearl millet, jowar, sunflower, and others has clearly shown the need for an economical and efficient production and distribution of hybrid seed for the large-scale adoption of hybrid crop technology in any country like India (Janaiah 2003).

The trend in large-scale seed production

India has a strong infrastructure for the seed sector in both the public and private sector. As in other crops in which hybrids are widely cultivated, the private sector has taken the lead in the production and marketing of hybrid rice seed from the start of the hybrid rice program. More than 20 private seed companies have taken up large-scale seed production and about 10 of them possess their own R&D setup (Ramesha et al 2009). Large-scale seed production is carried out extensively in Karimnagar, Warangal, Nizamabad, and Kurnool districts of Andhra Pradesh. Noteworthy to mention is that 80% of the total hybrid rice seed in India is produced in the northern Telangana region (Karimnagar, Warangal, and Nizamabad) of Andhra Pradesh. The maximum area planted to hybrid rice seed production is in Karimnagar and Warangal districts of Andhra Pradesh, where all the leading seed companies do large-scale seed production. Seed yields are higher in the dry season than in the wet season. Hence, large-scale seed production is generally done in the dry season only because it offers appropriate conditions for successful production.

It is estimated that, during the 2008 DS, hybrid seed production was carried out on nearly 18,000 hectares and approximately 22,000 tons of hybrid seed were produced in the country, largely in the northern Telangana region of Andhra Pradesh. During the 2009 DS, the area under hybrid rice seed production was estimated to surpass 25,000 ha (Ramesha et al 2009). Among the public-sector seed agencies, the State Seed Corporations of Maharashtra, Karnataka, and Uttar Pradesh

Table 18. Area and production of hybrid rice seed (F_1) in India, 1996 DS to 2008 DS.[a]

Year	Area (ha)	Seed production (tons)	Average seed yield (kg/ha)
1996	195	200	1,026
1997	1,075	1,200	1,116
1998	1,485	1,800	1,212
1999	1,630	2,200	1,350
2000	1,660	2,500	1,506
2001	1,630	2,700	1,656
2002	1,625	2,900	1,785
2003	1,635	3,100	1,896
2004	2,865	4,000	1,396
2005	4,350	8,600	1,838
2006	6,800	12,500	1,838
2007	15,000	20,000	1,333
2008	18,000	22,000	1,222

[a]1995-96 to 2007-08 DS is shown as 1996 to 2008 DS.
Source: Ramesha et al (2009).

and the National Seed Corporation are undertaking hybrid rice seed production on a small scale.

Hybrid rice seed production in the country started with less than 200 tons of total production in 1995 but surpassed 20,000 tons from 18,000 hectares in the 2008 DS. Initially, the seed yields obtained were very low (0.3–0.5 t/ha), but, with experience over the years, 1.5 t/ha average seed yields are now obtained (Table 18).

Hybrid rice seed production is considered a highly knowledge-intensive process. The risks of obtaining a low yield from poor synchronization of parental lines, weather changes, etc., are high in hybrid seed production. Farmers would not engage in it unless it were more profitable than the alternative activity (inbred rice cultivation) and unless the additional profit compensated for the risks and skills involved in it. Therefore, it is essential to understand the economics of F_1 seed production in farmers' fields with respect to the costs involved, contractual arrangements between seed growers and companies, profitability, and farm-level constraints.

The economics of hybrid rice F_1 seed production was studied based on a survey of 60 sample seed producers in Andhra Pradesh that produced F_1 seed for various seed companies during the 2009 DS. This state alone produces nearly 80% of the total hybrid seeds of all crops in India, and supplies them to other parts of the country. Nearly 20 fairly large seed companies are now engaged in hybrid rice seed production in the state.

Basic profile of the sample seed growers

Sixty samples of seed producers were selected from eight villages in Karimnagar District of Andhra Pradesh. Karimnagar District is widely known as a seed district and it is home to all the major seed companies for the production of hybrid seeds of all crops, including rice. Most of the farmers at the study sites (selected villages) are seed producers of rice and other crops for leading companies. Thus, a random sampling technique is followed in the selection of sample seed producers. The survey covered the crop season of 2008-09 DS (November 2008 to March 2009). Among the sample seed growers, 30% had taken up hybrid rice seed during the preceeding year (2008 DS).

Table 19. Basic features of sample seed producers in Andhra Pradesh, India, 2008-09 DS.

Particulars	Values
Study areas	
• Number of districts covered	1
• Number of villages covered	8
• Sampling method	Random
• Sample size	60
• Year of study	2008-09 DS
Features of samples	
• Age	41.5
• Educational status (schooling years)	8.2
• Number of samples having previous experience with hybrid rice seed production	18 (30%)
• Average farm size (ha)	1.22
• % area irrigated	97
• Average area under hybrid rice seed production (ha)	1.16

Source: Survey data (2009).

It is interesting to note that the average farm size of sample producers is only 1.22 ha, 97% of it under irrigation, that is, small farmers are in seed production (Table 19). The private seed companies purposively opt to engage small farmers who have an assured irrigation facility for seed production because these small farmers usually do seed production in almost all crop areas (seed companies also insist on the same), and engage fully in seed production without shifting to other farm activities. Thus, almost the entire cropped area of sample seed producers is devoted to seed production (Table 19).

All sample seed producers had a contract agreement with seed companies. The contractual arrangement between seed growers and seed companies includes the seed price to be paid by the seed companies to the seed growers, the supply of parental line seeds and gibberellic acid (GA_3), and payment of a risk allowance in case of crop failure (Table 20).

Cost-return profile

An average seed yield of about 2.5 t/ha was obtained on sample seed farms during the 2009 DS, almost the same as in

Table 20. Details on contractual arrangements of sample seed producers with companies, 2008-09.

Particulars	Value
1. Number of sample seed producers that had a contract agreement with seed companies	60 (100%)
2. Number of sample seed producers that had agreement on...	
• *Seed price to be offered by company*	*60 (100%)*[a]
• *Supply of parental line seed by company*	*60 (100%)*
• *Supply of GA_3 by company*	*56 (93%)*
• *Payment of risk allowance by company in case of crop failure*	*60 (100%)*
3. Number of sample seed producers reporting that seed companies did not abide by contract	0
4. Number of sample seed producers reporting that they would continue seed production in the coming years	60 (100%)

[a]Agreed seed price for F_1 to be paid by companies, Rs 50 per kg.
Source: Survey data (2009).

Table 21. Area planted to hybrid rice seed production and yields on sample seed farms, 2007-08 and 2008-09 DS.

Year	Average area (ha)	Seed yield (t/ha)	Average seed price paid by company (Rs/kg)
2008-09 DS (N = 60)	1.16	2.47	46.6
2007-08 DS (N = 18)[a]	1.22	2.43	45.8

[a]Number of sample seed producers that had taken up seed production during 2007-08 DS. N = number of sample seed producers.
Source: Survey data (2009).

the 2008 DS for the repeat seed growers (Table 21). Sample seed producers' yields are higher than the national average because the sample areas surveyed are widely considered as seed production hot spots for the seed industry. The cost and return profile for hybrid rice seed production is summarized in Tables 22 and 23. Among all cost components, labor alone accounted for about one-third of the total input cost because of the additional labor requirement. However, labor alone accounted for 48% of total input costs during 2001 (Janaiah and Hossain 2003), implying that the labor requirement has declined significantly as seed growers gain experience and skills. This shows the potential of generating substantial employment in a seed production system if hybrid rice cultivation expands on a large scale. The seed companies provided seeds of parental lines (A and R seed) and GA_3 (additional inputs for hybrid seed production) to the seed growers free of cost. The average cost of hybrid seed production on sample seed

Table 22. Costs (per ha) of various inputs for hybrid rice seed production on sample seed farms in Andhra Pradesh, India, 2008-09 DS.

Particulars	Quantity	Values (US$)
A-line seed (kg)[a]	12.7	–
R-seed (kg)[a]	7.5	–
Organic manure (t)	17.2	102
Chemical fertilizers[b] (kg)	658.7	87
Plant protection chemicals (kg)	0.69	145
Irrigation	–	5
GA_3[a]	NA	–
Rental charges of machinery use	–	160
Labor for normal farm operations (land preparation, transplantation, weeding, harvesting, threshing, etc.)	93 person-days/ha	150
Labor for additional farm operations (row planting, roguing, supplementary pollination, leaf clipping, etc.)	74 person-days/ha	139
Other costs, if any	–	11
Total input costs	–	799

[a]Seed companies supplied seeds of parental lines and GA_3 to seed growers free of costs.
[b]Includes urea, DAPm, and other complex fertilizers.
Source: Estimated from survey data (2009).

Table 23. Profitability (US$ per ha) of hybrid rice seed production on sample seed farms in Andhra Pradesh, India, 2008-09 DS.

Particulars	Values
1. F_1 seed yield	2,470 kg/ha
2. Price of F_1 seed received by seed producers ($/kg)	0.99
3. Return from F_1 seed ($)	2,449
4. R seed yield	2,000 kg
5. Price of R seed ($/kg)	0.17
6. Returns form R seed ($)	340
7. Straw value ($)	17
8. Gross returns ($)	2,806
9. Total input cost ($)	799
10. Net returns ($)	2,007
11. Cost of F_1 seed production ($/kg)	0.32

Source: Estimated from survey data (2009).

farms during the 2008 DS was $0.32 per kg (Table 23), which is about 20% lower than in 2001. The private sector procured hybrid seed from contract seed growers at about $1.00 per kg. At this price, hybrid rice seed production is significantly more profitable than the alternative economic activity (inbred rice cultivation). On average, hybrid rice seed production generated a net profit of $2,007 per ha, which is about 4 times more profitable than inbred rice cultivation. Therefore, hybrid seed production is not a limiting factor once demand for hybrid seed is created among farmers, as has been experienced in eastern India over the past three years.

The private sector, however, obtains seed from seed growers at $1.00 per kg and sells the seed to farmers at Rs 150–180 per kg ($3.50 to $4.00). The selling price of hybrid rice seed was $2.00 to $2.50 per kg during 2001, when seed yield was only 1.2 t/ha, and the procurement price was only $0.60 per kg (Table 24).

Perceptions of seed growers

A subjective assessment of seed producers' perceptions revealed that 100% of them are willing to take up seed production in the future because of its high profitability and assured profits (Table 25). However, most sample seed growers mentioned that synchronization, labor scarcity, inefficiency of available labor due to a lack of skills, and abnormal rains during pollination are serious constraints to higher seed yields (Table 26).

Table 24. Production cost and market price of hybrid rice seed (1998-99) in various countries (US$/kg).

Country	Production cost	Market price (retail)
India	0.60	2.00–2.50
Bangladesh	–	4.00
Philippines	0.60–0.80	2.50
Vietnam	–	1.40
China	0.50	1.10

Source: Janaiah and Hossain (2003).

Table 25. Perceptions of sample seed producers on reasons for continuation of hybrid rice seed production in Andhra Pradesh, India, 2008-09 DS.

Reason	Sample seed producers reported (N = 60)[a]	
	Number	Percent
Higher profitability	60	100
Less risk	0	–
Assured procurement by seed agency	60	100

[a]N = number of sample seed producers willing to continue hybrid rice seed production in the coming years.
Source: Survey data (2009).

Table 26. Problems faced by hybrid seed producers in Andhra Pradesh, India, 2008-09 DS.

Problem	Sample seed producers reporting (N = 58)	
	Number	Percent
Bad weather	6	10
Low rainfall	1	2
Labor-intensive work	30	51
Synchronization	59	100
Inefficient labor	49	82
Rain during pollination	30	51
High wages	1	2

Source: Survey data (2009).

Conclusions

A macro-level assessment shows that the adoption rate of hybrid rice, which was less than 1% during the first decade after the release of the first hybrid, increased substantially to 3.2% by 2008, and contributed about 5.6% of the total rice output in the country. As rice is a key source of livelihood in eastern India, where poverty and malnutrition persist widely, a considerable increase in yield through hybrid rice will have a major impact on household food security, income, and nutrition, besides an economy-wide impact in the region.

An analysis of survey data reveals that the farm-level performance of the latest generation of hybrids in 2008 is significantly superior to that of existing popular inbred rice varieties in yield and profitability gains. Both yield gains and additional net profitability of hybrids over inbreds have increased substantially in farmers' fields over the past 15 years. This explains why the adoption of hybrid rice was very slow, and lingering until 2003, and why it picked up during subsequent years in India. The difference in market price between hybrid and inbred rice has decreased over the period, which is a clear reflection of the improvement in grain quality in successive generations of rice hybrids over the same period. Farmers' perceptions show that grain quality is not as serious an issue for the latest generation of rice hybrids as it was until 2001, although grain quality is a key challenge for future hybrid rice R&D, particularly in the irrigated rice system.

On the whole, the latest generation of rice hybrids has considerably outperformed existing inbred rice varieties in yield gain and profitability in eastern India. Although there has been a considerable improvement in grain quality and consumer acceptance over the period, the large-scale adop-

tion of hybrid rice in the future largely depends on the further improvement of grain quality, to make it comparable with that of popular inbred varieties. Hybrid rice seed production would not be a constraint to the large-scale adoption of acceptable hybrid rice as F_1 seed production is highly profitable for seed producers. The key challenges, however, for hybrid rice R&D are the development of new rice hybrids with competitive and comparable grain quality with wider adaptability, suitable for irrigated areas; a further increase in yield potential; and a reduction in retail seed price.

References

Barker R, Herdt RW. 1985. The rice economy of Asia. Washington, D.C. (USA): Resources for the Future.

Barwale BR. 1993. Hybrid rice food security in India. Madras (India): Macmillan India Limited.

CRRI (Central Rice Research Institute). 1996. Miracle rice varieties. Cuttack (India): CRRI.

David CC, Otsuka K. 1994. Modern rice technology and income distribution in Asia. Boulder, Col. (USA): Lynne Reiner Publishers, Inc.

DRR (Directorate of Rice Research). 1997. Development and use of hybrid rice technology in India: project report. Hyderabad (India): DRR.

DRR (Directorate of Rice Research). 2000-08. Progress Reports of Hybrid Rice Project and AICRIP (various issues). Hyderabad (India): DRR.

Evenson RE, Mckinsey JW. 1991. Research, extension infrastructure and productivity change in Indian agriculture. In: Evenson RE, Pray CE, editors. Research and productivity in Asian agriculture. Ithaca, N.Y. (USA): Cornell Univ. Press.

Evenson RE. 1993. Technological distance and rice productivity in India. Paper presented at the National Workshop on Agricultural Research Evaluation: Methods and Applications, National Academy of Agricultural Management (NAARM), Hyderabad.

He Guiting, Zhu X, Flinn JC. 1987. A comparative study of economic efficiency of hybrid and conventional rice production in Jiangsu Province. Oryza 24:285-296.

Hossain M. 1997. Rice supply and demand in Asia: a socioeconomic and biophysical analysis. In: Teng PS, Kropff M, editors. Application of systems approaches at the farm and regional levels. London (UK): Kluwer Academic Publishers. p 263-279.

Hossain M, Pingali PL. 1998. Rice research, technological progress and impact on productivity and poverty: an overview. In: Pingali PL, Hossain M, editors. Impact of rice research. Los Baños (Philippines): International Rice Research Institute and Bangkok (Thailand): Thailand Development Research Institute. p 1-26.

Hussain M, Hossain M, Janaiah A. 2001. Hybrid rice adoption in Bangladesh: a socio-economic assessment of farmers' experiences. Monograph #18, BRAC, Dhaka, and IRRI, Philippines.

Janaiah A, Ahmed MI, Viraktamath BC. 1993. Hybrid rice: an opportunity for food security in India. Yojana 37(20):7-9.

Janaiah A. 1995. Economic assessment of hybrid rice potential in India: an ex-ante study. Ph.D. thesis (unpublished). Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India.

Janaiah A. 2000. Economic impact of crop management on productivity and profitability of hybrid and inbred rices in India: evidences from a farm-level study. Indian J. Agric. Sci. 70(2).

Janaiah A, Hossain M. 2000. Hybrid rice for food security in the tropics: an evaluation of farm level experiences in India. Paper presented at the 3rd International Crop Science Congress held in Hamburg, Germany, 17-22 August 2000.

Janaiah A, Hossain M, Hussain M. 2002. Hybrid rice for tomorrow's food security: Can the Chinese miracle be replicated in other countries? Outlook Agric. 31(1):27-37.

Janaiah A. 2002. Hybrid rice for Indian farmers: myths and realities. Econ. Political Weekly 37(42):4319-4328.

Janaiah A, Hossain M. 2003. Can hybrid rice technology help productivity growth in Asian tropics? Farmers' experiences. Econ. Political Weekly 38(25):2492-2501.

Janaiah A. 2003. The seed delivery system in Andhra Pradesh: institutional and policy issues. Indian J. Agric. Market. 17(2).

Janaiah A, Hossain M. 2004. Partnership in the public sector agricultural R & D: evidence from India. Econ. Political Weekly 39(50):5327-5334.

Janaiah A, Otsuka K, Hossain M. 2005. Is the productivity impact of the Green Revolution in rice vanishing? Empirical evidence from TFP analysis for rice. Econ. Political Weekly 40(53):5596-5600.

Janaiah A, Hossain M, Otsuka K. 2006. Productivity impact of the modern varieties of rice in India. Dev. Econ. 44(2):190-207.

Kumar P, Rosegrant MW. 1994. Productivity and sources of growth for rice in India. Econ. Political Weekly 29(53):A183-A188.

Mohanty S. 2008. Rice crisis: the aftermath. Rice Today 7(4).

Pingali PL, Hossain M, Gerpacio RV. 1997. Asian rice bowls: the returning crisis? Oxon, Wallingford (UK): CAB International.

Rao NGP, Singh A, Sivasubramanian V, Murthy KS, Mukhopadhyay AN, Abraham CC. 1998. Rice research and production in India: present status and a future perspective. Quinquennial Review Report. Directorate of Rice Research, Hyderabad, India.

Ramesha MS, Hari Prasad AS, Revathi P, Senguttuvel P, Viraktamath BC. 2009. Rice hybrids released in India. Technical Bulletin No. 40. Directorate of Rice Research (ICAR), Hyderabad, India.

Sampath S, Mohanty HK. 1954. Cytology of semi-sterile rice hybrid. Curr. Sci. 23:182-183.

Notes

Authors' addresses: Aldas Janaiah, School of Agribusiness Management, Acharya N.G. Ranga Agricultural University, India; Fangming Xie, International Rice Research Institute.

Acknowledgments: This report was prepared based on a joint study commissioned by the Hybrid Rice Development Consortium hosted at the International Rice Research Institute (IRRI) and Acharya N.G. Ranga Agricultural University (ANGRAU). Dr. Achim Dobermann, deputy director general for research of IRRI, is the key person who helped originate and complete the study. Dr. D.S. Brar, head, Plant Breeding, Genetics, and Biotechnology Division at IRRI, and Dr. Sam Mohanty, head of the Social Sciences Division (SSD) at IRRI, provided useful guidance and support. Dr. Mahabub Hossain, former head of IRRI's SSD and executive director of BRAC, has been a key source of inspiration in carrying out the study successfully. Ms. Ellaine Cabrera, researcher at SSD of IRRI, has provided useful support in data processing. The students of SABM, ANGRAU, helped in conducting field surveys in the study areas. Dr. Bill Hardy of IRRI edited the report. This study was supported by the Hybrid Rice Development Consortium at IRRI.

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE
DAPO Box 7777, Metro Manila, Philippines