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Policy Support Needs of Hybrid Rice Technology in Asia

S.S. Virmani, M. Hossain, and T. Bayarsaihan, Editors

Proceedings of the Regional Workshop for the Development and Dissemination of Hybrid Rice Technology

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

ADB
Asian Development Bank

LIMITED PROCEEDINGS

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Contents

FOREWORD

Hybrid rice technology aims to increase yield potential in rice beyond the level of high-yielding, semidwarf inbred rice varieties, the backbone of the Green Revolution. Four decades ago, China started to develop this technology; it has now been successfully commercialized in about 50% of rice area (15 million ha) annually, producing about 60% of its total rice production. In the tropics, rice yield per unit area per unit time must increase to meet the future demand of producing more rice on less land with less water and labor. The International Rice Research Institute (IRRI), in collaboration with several national programs, has provided leadership to develop and disseminate hybrid rice technology in the last 25 years. Since 1998, the Asian Development Bank (ADB) has supported two projects at IRRI that aimed to sustain food security through increased rice production in several Asian countries using hybrid rice technology. Through these projects, IRRI, working with the Food and Agriculture Organization (FAO), the Asia Pacific Seed Association (APSA), and China, has helped enhance the pace of development and dissemination of hybrid rice technology in nine Asian countries—Bangladesh, India, Indonesia, Myanmar, Philippines, Republic of Korea, Sri Lanka, Thailand, and Vietnam.

As a part of the second project, a regional workshop was organized in June 2005 by IRRI and ADB to discuss technological and policy issues influencing development and dissemination of hybrid rice technology and to identify areas for policy support so that hybrid rice technology may be disseminated further in rice-growing countries in Asia.

The main objectives of the workshop were to discuss the key results achieved so far and the challenges faced by hybrid rice programs in improving food security in Asia and assess the roles of government policies, public-private-sector partnership, and technology advances in promoting hybrid rice technology. The participants presented the process and challenges of hybrid rice dissemination in national programs and identified issues related to commercialization of hybrid rice technology in their respective country. Farmers' experiences with the adoption of hybrid rice technology were also shared to identify areas of policy support in national programs.

The workshop was attended by 56 participants from 15 countries, including representatives from FAO and ADB. Experts in hybrid rice research and development and staff involved in the seed industry and technology promotion from both public and private sectors were present. A unique feature of the workshop was the participation of policymakers (at the level of vice minister or government secretary) from Bangladesh, India, Philippines, Sri Lanka, and Vietnam.

The workshop provided specific information on i) the role of hybrid rice in sustaining food security and in protecting the environment; ii) potential gains from investment in the development of hybrid rice technology; iii) organization and facilities required to implement an efficient hybrid rice development and dissemination program; iv) general and country-specific problems associated with hybrid rice commercialization, along with the areas of further investments; and v) areas needing stronger policy support or government interventions for development and dissemination of hybrid rice technology. Issues of public-private sector partnership affecting hybrid rice commercialization were also identified and the role of international collaboration in the development of hybrid rice technology was specified.

The outputs of the workshop included a better understanding among policymakers, development practitioners, and researchers about the potentials and issues related to hybrid rice adoption and policy recommendations to promote hybrid rice to help achieve food security in Asia.

This book is expected to be a valuable source of information on hybrid rice promotion for the coming years. We are grateful for the financial support provided by the ADB to IRRI's Hybrid Rice Project that enabled the conduct of this workshop and the publication of its proceedings.

R.S. Zeigler
Director General

Policy support needs for technology generation and dissemination

From the presentation and deliberations, issues and concerns on hybrid rice with implications on government policy interventions emerge. The following recommendations on policy interventions, classified into five categories, were made in the workshop.

General recommendations

- National governments should make strong commitments and adequate investments to accelerate efforts in hybrid rice R&D, technology adaptation, training, and extension. The governments should lead as well as serve as catalyst in the development and dissemination of the technology.
- A country should consider its size and the economies of scale when developing its hybrid rice R&D programs.

Technology generation

- Large countries with substantial scientific capacity may consider establishing a national institution exclusively for hybrid rice R&D.
- IRRI should continue to carry out strategic research to develop improved parental lines and hybrids, improved seed production technology, and agronomic management guidelines and make these freely available to public, private, and NGOs operating in the countries.
- IRRI should continue to test hybrids coming from both public and private sectors under the auspices of INGER.

Technology dissemination

- A carefully crafted subsidy program should be developed to disseminate the technology in the initial phase with a clear exit strategy when the adoption process takes off. However, subsidy should not be given on seed. Support should be given on the a) development of hybrid rice varieties in the public sector to make them freely available to the private sector, b) testing of nationally produced and imported varieties through multilocation trials, and c) training of farmers and extension officials on hybrid rice seed production.
- The government should provide the infrastructure for seed processing and cold storage for small seed companies and farmers' cooperatives.
- The government may consider abolishing import duty on agricultural grade gibberellic acid, an important input in hybrid rice seed production.

Public-private partnership

- The countries should recognize the importance of public-private partnership in the development and dissemination of hybrid rice technology. The strength of each sector should be harnessed by developing a carefully crafted, mutually acceptable model at appropriate levels of implementation in national programs. The aim of such a partnership should be to develop a "win-win" situation for each sector and not to ease out the private sector from the hybrid rice market, such as by artificially reducing the seed price for farmers.
- The national government should identify constraints to public-private sector partnership and take steps to tackle them.
- The public sector should negotiate with interested private-sector companies the terms for sharing seeds of parental lines. If they both agree, a ceiling price of hybrid seed may be fixed.
- Public-sector staff should offer training courses on seed production and processing to private-sector personnel.
- The government should strengthen its seed regulatory agency to ensure quality standards of hybrid seeds.

- The government should enforce PVP and IPR laws to attract private-sector investment and to ensure that farmers are not exploited.

Trade on hybrid rice seed across countries

- A policy on importation of hybrid seeds should be seriously considered by smaller countries where economies of scale and available know-how and infrastructure may not be conducive for developing a self-sufficient hybrid rice program, at least in the initial stage.
- Hybrid rice seed-importing and -exporting countries should develop appropriate quarantine capabilities to facilitate import and export.

Hybrid rice for sustaining food security in Asia

M. Hossain and T. Bayarsaihan

Rice is the dominant staple food for 3 billion people, mostly in the developing countries, including 2.6 billion Asians. It is the major economic activity in rural areas in the humid tropics and an important source of income and employment for rural households. In many low-income countries in Asia, such as Cambodia, Bangladesh, Indonesia, Laos, Myanmar, and Vietnam, it contributes to 60% of the total calorie intake of the people. Being an important component of the food basket, many social upheavals and political discontent can be traced to scarcity in rice supply and sudden increase in rice prices. Therefore, the development of the rice sector has remained a priority for national governments in Asia for economic growth, food security, and political stability.

Achievements

Asia has done remarkably well in meeting the food needs of the growing population, since the initiation of the green revolution in the mid-1960s. Rice production has increased at 2.1% per year during 1970-2004, keeping pace with population growth and income growth-induced changes in per capita food consumption (Fig. 1). The growth was satisfactory in all Asian regions, including South Asia, where per capita income level is low and the incidence of poverty is high. Indeed, the per capita rice consumption has increased significantly to a level where there is no further income growth inducing the demand for rice. Population growth is now the dominant factor that affects the growth in demand for rice. More than 85% of the increase in production was due to increase in rice yield, made possible through gradual replacement of traditional varieties by modern varieties developed in rice research stations. As the growing food needs could be made from the increase in land productivity, the pressure of expansion of cultivation to marginal lands eased. In Asia, the cropped area under rice has increased by only 0.3% per year, mainly due to increase in rice cropping intensity through cultivation of a second rice crop in the dry season, as irrigation facilities expanded. Without development of high-yielding modern rice varieties, the rice cropped area would have to increase by another 35 million ha to meet the growing rice needs of the Asian people. Considering the above factor, the technological progress in rice cultivation contributed to environmental protection.

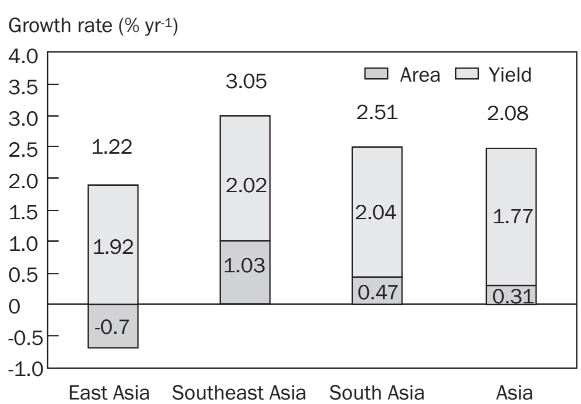

Fig. 1. Growth in rice production, 1970-2004.

As rice supply has increased faster than demand and as the unit cost of rice cultivation has declined due to technological progress, the price of rice has increased at a slower rate than the general price index. The rice price in the world market declined sharply in the early 1980s and in the late 1990s (Fig. 2). A large part of the decline is due to the large devaluation of the Asian currencies during these periods. But the price of rice in the domestic market, adjusted for inflation, also had a downward trend in most Asian countries (Hossain 2004). The progress in poverty reduction observed for the Asian countries over the last three decades can be traced to the downward trend in the price of rice. Since rice is a major component of the food basket for the low-income people, the decline in the price of rice has empowered the rural landless, marginal farmers, and the urban labor class who constitute the majority of the poor, to access their basic food need from the market, still leaving a part of their meager income for children's education, health care, and housing.

Concerns

The impressive growth in rice production and the downward trend in the real price of rice have generated a sense of complacency regarding Asia's ability to meet the growing demand for staple food. The growth in demand for rice has slackened with the increase in the proportion of middle- and high-income consumers who can afford a diversified diet. The per capita rice consumption has started declining in the middle- and high-income countries and has stopped increasing in the low-income countries. Many Asian countries have also achieved respectable progress in population control. As a result, the demand for rice is projected to increase at about 1.1% per year over the next quarter century compared with about 2.2% per year over 1970-2000 (Sombilla et al 2002). As a result, many Asian governments have reduced public-sector investment for expansion of irrigation and rehabilitation and maintenance of the existing systems, leading to a degradation of irrigation infrastructure. Also, there has been a decline in the support for agricultural R&D for international and national public-sector research institutions, with the exception of China.

But the struggle to maintain the food-population balance is not yet over in many parts of Asia. Due to the expanded base of the population, the absolute increase in the number of people over the last three decades will remain as large as that over the last three decades (Fig. 3). For example, in South Asia, the population increased by 698 million during 1970-2000, where the projected increase in population over

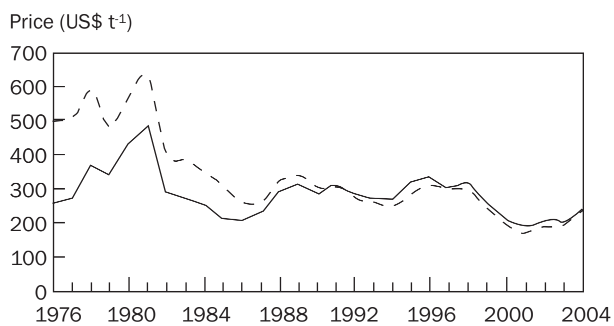

Fig. 2. Trend in world rice price, 1976-2004.

Region	1970-2000	2000-30
Asia	1,530	1,277
East Asia	494	217
Southeast Asia	235	198
South Asia	698	722
West Asia	102	140
Africa	437	696
Latin America	234	204
Developed regions	183	26
World	2,366	2,214

Source: UN, (2002)

Absolute increase (million persons)

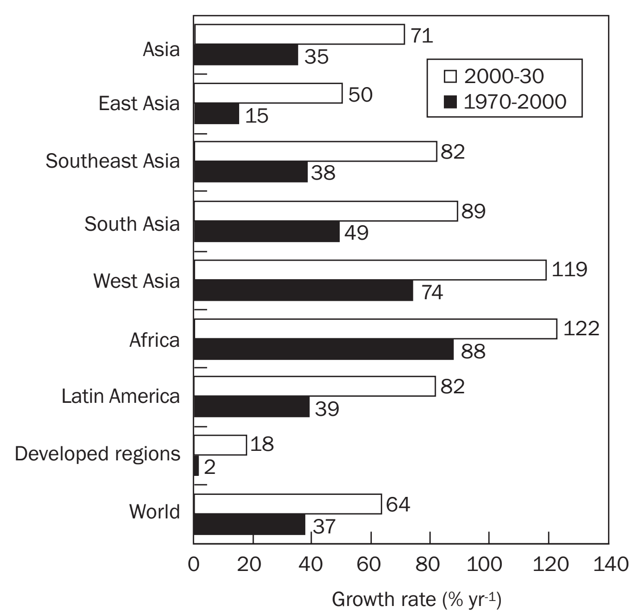

Fig. 3. Increase in population (%), 1970-2000 and 2000-30.

the 2000-2030 period is 706 million. It is only in East Asia, including China, where the additional number of mouths to be fed is going to be substantially lower in the future compared with what they have been in the past.

Additional concern is brought about by the ongoing rapid urbanization in Asia. Asia is still the least urbanized continent with only 33% of the population living in cities. But the proportion of urban population is projected to increase to 61% by 2030. All the additional population over the next three decades is going to be located in urban areas. There is also a movement of labor force from farming to nonfarm activities within rural areas. It implies that fewer and fewer farmers will have to produce increasingly larger marketable surplus for meeting the food needs. We cannot expect it to happen unless the business of food production becomes profitable. In the past, the subsistence motive was the main force behind the increase in food production. The decline in rice price that contributes to increase in food security for the poor is going to negatively affect farmers' incentives to increase rice production in the long run.

On the supply side, the easy means of increasing food production has been over. The prime agricultural land is being diverted to meet the needs for housing, commercial establishment, and infrastructure development. Within agriculture, the land is diverted from rice cultivation to the production of fruits, vegetables, and livestock feed, the market of which grows stronger with economic progress. Water, which was once considered an abundant resource in Asia, is getting scarce with population growth and strong demand for water in nonagricultural uses. So, the expansion of irrigated area through the conversion of rainfed lowland to irrigated land will be limited in the future. In some parts of South Asia, private-sector investment in shallow tube wells has recently contributed to expansion of irrigation infrastructure, but it has led to overexploitation of ground water and deterioration in water quality. The tightness of the rural labor market and the rising wage rates have increased the cost of rice cultivation, reducing profits and thereby dampening farmers' incentives for sustaining the growth in production. The diffusion of modern technologies has almost reached its limit in the irrigated environment, and the yield gap in the irrigated ecosystem has almost disappeared (Fig. 4). The growth in rice yield has already slackened substantially since the early 1990s. In Asia, the growth in rice yield has declined from 2.7% per year during 1970-90 to only 1.1% during 1990-2004 (Fig. 5). The deceleration in growth was mainly due to substantial reduction in yield growth in the irrigated ecosystem. The decline in the growth in yield has been very sharp for China, India, and Indonesia, the three giant rice economies in Asia (see table).

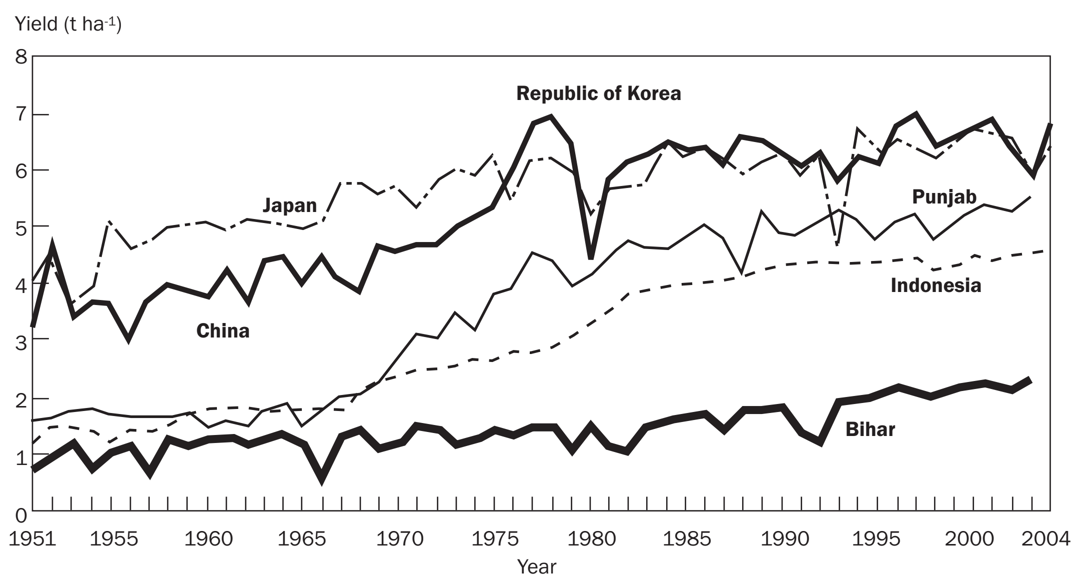

Fig. 4. Long-term trend in yield , selected countries, 1951-2004.

Recent trends in the growth of production and yield, selected Asian countries.

Country	Production		Yield	
	1970-90	1990-04	1970-90	1990-04
China	2.67	-0.34	3.16	0.71
Korea, Republic of	1.82	-0.59	1.57	0.44
Indonesia	4.71	0.97	3.35	0.25
Philippines	3.33	3.17	3.49	1.54
Vietnam	3.23	4.54	2.13	1.18
India	2.93	0.90	2.36	0.76
Bangladesh	2.52	3.59	2.12	2.81
Thailand	2.24	2.62	0.57	1.49
Myanmar	3.51	3.98	3.76	2.04
Cambodia	2.11	5.69	0.24	3.77
Nepal	1.80	3.23	0.75	2.05
Laos	3.13	6.28	3.49	2.80

Source: Own estimates using data from FAO database, 2005.

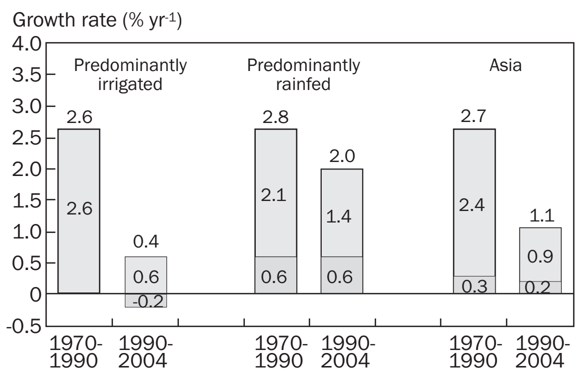

Fig. 5. Sources of growth in rice production.

The potential for raising yield in the rainfed systems is still vast, as the current yield is only about 2.2 t ha^{-1}, compared with 5.5 t ha^{-1} in the irrigated ecosystem. Rice is still grown on nearly 45% of the land in Asia under rainfed conditions. But the rainfed ecosystems are subjected to the vagaries of nature, such as drought, floods, temporary submergence from heavy rains, and typhoons. A large proportion of the area also suffers from problem soils. Traditional low-yielding varieties have developed traits through centuries of evolution that enable them to withstand those stresses and avoid complete failure of the crop. Rice scientists had limited success in identifying those traits and incorporating them into high-yielding modern varieties through conventional breeding. Farmers still use traditional low-yielding varieties in a large proportion of such area, and use inputs in suboptimal amounts when they adopt modern varieties, due to the uncertainty of returns from investments and the limited capacity of risk taking at the subsistence level. These are the reasons behind the low yield and the large yield gap in the rainfed systems.

The recent advances in molecular biology, genomics, and the application of biotechnology tools have increased the probability of research success in developing appropriate high-yielding varieties for the rainfed systems. The success will depend on the investment in biotechnology research in public-sector institutions and on how the national governments and the international rice research community address the issues of patenting and intellectual property rights. There is also the issue of the social acceptability of biotechnology product and genetically modified food. So, it might take a long time before improved technologies reach the farmers and make a substantial contribution to increase in rice production. Therefore, over the next decade or so, the burden of increasing rice production for maintaining the demand-supply balance may fall largely on the irrigated ecosystem.

There is a compelling need to increase the productivity of rice-based systems by advancing the yield potential of rice for the irrigated system and reducing the yield gap for the rainfed systems. More productive and sustainable rice-based systems can contribute directly and indirectly to achieve the millennium development goals to reduce extreme poverty and hunger, child mortality, improving maternal health, gender disparity, achieving universal primary education, and ensuring environmental sustainability.

Opportunities

Among various options, policymakers and research managers in tropical Asia considered hybrid rice as a readily available technology to reverse the declining trend in productivity growth in the irrigated environment. They have been particularly impressed by the history of the hybrid rice development and adoption in China. Hybrid rice has a yield advantage of 15–20% over currently inbred varieties (Yuan 1994, Virmani 1998). The yield advantage over inbred rice varieties is even higher under certain moderately stressed rice ecosystems—rainfed lowland shallow, drought-prone, or salinity-prone. In China, hybrid rice spread to almost half of the total rice land during 1976-90, which was the major source behind the rapid growth of rice production during that period (Lin 1994). China's miraculous success with hybrid rice has inspired Asian governments to invest in R&D for hybrid rice since the early 1990s. The governments are also seeking assistance from Chinese scientists in their efforts to develop suitable varieties for the specific agroecological situations, for training for seed production program to reduce the seed cost. India, Vietnam, the Philippines, and Bangladesh already developed and released many hybrid rice varieties suitable for the tropics with assistance from IRRI and Chinese scientists. However, the hybrid rice research and seed production program is still at its infancy, except in India, Vietnam, and the Philippines. There is an opportunity for private-sector involvement in seed production, marketing, and extension, which has not yet been realized.

The rate of adoption of hybrid rice in the tropics is proceeding at a slow pace (Janaiah and Hossain 2003). The experience of the current ADB-IRRI project, and socioeconomic assessments of farmers' initial experience with hybrid rice adoption have identified the following constraints to fast-tracking the extension of hybrid rice technology:

- Dwindling funding support of international and national R&D for hybrid rice
- Weak institutional base in hybrid rice seed production
- Nonavailability of commercial hybrids in some member countries
- Inadequate public-private-sector partnerships
- Lower price of hybrid rice compared with inbreds
- Inferior eating and keeping quality of cooked rice of available hybrids

Research and policy support are needed to address these constraints.

Conclusion

If hybrid rice were adopted in 55% of the rice area, which covers the irrigated ecologies in Asia, rice production would increase by another 11%, about a third of the rice requirement over the next 25 yr. Thus, the development of hybrid rice varieties for irrigated as well as certain moderately stressed environments, which suit the tastes of consumers in different countries, and their diffusion to farmers with effective public-private-sector collaboration should be taken as a crucial element in the strategy for achieving and sustaining food security in Asia. We must therefore address the constraints to slow adoption of hybrid rice in the tropics through identification of appropriate R&D strategy and policy support. We hope that this workshop will go a long way to convince the policymakers on the potential of hybrid rice in sustaining the growth in rice production in the humid tropics and adoption and implementation of an R&D strategy to realize the potential.

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Past achievements and future opportunities in the development and dissemination of hybrid rice technology in Asia

S. S. Virmani

Hybrid rice technology aims to increase the yield potential of rice beyond the level of semidwarf high-yielding rice varieties by developing and using F_1 rice hybrids which manifest hybrid vigor for various agronomic traits. The technology has already been used extensively in China, where about 50% the total rice area is covered with hundreds of rice hybrids that yield, on average, 1.5 t ha^{-1} higher than inbred high-yielding varieties (5.5 t ha^{-1}). Outside China, IRRI has taken the lead since 1979 in developing and disseminating this technology in collaboration with China and selected national programs and international organizations (FAO and APSA). Since 1998, the Asian Development Bank (ADB) has provided financial support through two regional technical assistance (RETA) projects to IRRI to expedite the development and dissemination of hybrid rice technology in selected member countries. IRRI's role in the development of tropical rice hybrids and the associated seed production and agronomic management guidelines is highlighted in this paper. The salient achievements of the IRRI-ADB projects (RETA 5766 and RETA 6005) are also included. The efforts have contributed significantly toward strengthening the national capacity of several countries. In 2004, about 1.4 million ha was covered with hybrid rice varieties in India, Vietnam, Philippines, Bangladesh, Indonesia, and Myanmar, producing an estimated 1.7 million t of extra paddy (worth $255 million). This was achieved through the participation of about 75 public, private, and NGO-based seed industries in the production, processing, and marketing of hybrid rice. This has generated additional rural employment opportunities. Future opportunities exist for further improvements in yield potential, grain quality, and disease and insect resistance in rice hybrids and improvement of seed yields to reduce seed cost. The prospects of developing and using hybrid rice for some moderately unfavorable rice ecosystems are also real. For faster development and dissemination of this technology, national hybrid rice missions or commercialization programs need to be established in coordination with research and extension institutions and the seed industry operating in these countries. The national governments also need to provide full policy and financial support to the technology missions. Only then will hybrid rice make the desired contributions to increased food security, production efficiency, farmers' income, and rural job creation.

Hybrid rice technology aims to increase the yield potential of rice beyond the level of semidwarf high-yielding rice varieties by developing and using F_1 rice hybrids which manifest the phenomenon of hybrid vigor. This technology can help farmers increase their yields, in turn, enabling them to save land and water and practice diversified cropping/farming to increase their income. At the national level, this technology can also help countries produce the required quantity of rice with lesser land and water resources deployed for the purpose. The technology has been extensively used since 1976 in China, where 50% of the total rice area is covered with hundreds of rice hybrids which contribute 60% of the country's total rice production. Their mean yield advantage is about 1.5 t ha^{-1} over inbred HYVs, giving an average yield of about 5.5 t ha^{-1}. Outside China, IRRI has, since 1979, provided leadership in developing and disseminating this technology in collaboration with China and selected national programs and international organizations (FAO and APSA). Since 1998, the Asian Development Bank has provided financial support through two regional technical assistance (RETA) projects to IRRI to expedite the development and dissemination of hybrid rice technology in selected Asian countries. Past achievements and future opportunities in the development and dissemination of hybrid rice technology are presented in this paper.

Past achievements

Development of tropical parental lines and hybrids

Considering the fact that rice hybrids and their parental lines, made available to IRRI from China in 1978-79, did not adapt to tropical conditions, IRRI had to develop tropical parental lines and hybrids from scratch (Virmani 1987). It took a couple of years to confirm the 1-1.5 t ha^{-1} (15-25%) yield advantage in hybrids (derived from elite tropical parental lines) over inbred HYVs' 5-8 t ha^{-1} in the tropics (Virmani et al 1982) and an additional 5 yr to breed the appropriate parental (male sterile, maintainer, and restorer) lines to develop the tropical rice hybrids. The first commercially usable tropical male sterile line (IR58025A) was developed in 1988. It possessed stable male sterility, good phenotypic acceptability, and good outcrossing ability. This line and several restorer lines (male parents) were used to develop several tropical experimental hybrids, which were shared freely with some countries (India, Philippines, Vietnam, Indonesia, and Malaysia) that showed interest in developing this technology (Virmani 1994). From the very beginning, a close linkage was established with IRRI's inbred rice breeding program for the irrigated rice ecosystem; its elite inbred lines were used as parents of the tropical hybrids.

By 1993-94, some elite tropical rice hybrids were identified from IRRI-bred materials in India, the Philippines, and Vietnam. These yielded about 1 t ha^{-1} higher than the inbred check varieties in multilocation trials. Some hybrids—Magat (in the Philippines); APRH-1, APRH-2, KRH-1, and MGRH-1 (in India); and UTL-1 and UTL-2 (in Vietnam) —were released for on-farm evaluation. The latter gave mixed but encouraging results during the next 3-4 yr. In the meantime, several additional rice hybrids were also developed by public and private research institutions, using IRRI-bred parental lines, and released for cultivation in India, Vietnam, and the Philippines (Virmani 1998). The performance of some of these hybrids in on-farm demonstration trials is illustrated in Figure 1 (for the Philippines) and Table 1 (for India).

In the early 1990s, the government of Vietnam initiated a strong hybrid rice dissemination program in the Red River Delta up north by importing some Chinese rice hybrids using financial resources from FAO and technical guidance from Chinese and IRRI experts. By 1997, Vietnam and India covered about 288,000 ha with rice hybrids, yielding about 1 t ha^{-1} higher than inbred HYVs. Since 1998, several second-generation rice hybrids have been developed in India, the Philippines, Vietnam, Bangladesh, and Indonesia using IRRI- and China-bred parental lines. The area planted to hybrid rice increased from 288,000 to 1.5 million ha in these countries, resulting in an increased paddy production of 1.7 million t (worth $255 million). Hybrid rices were found to mature somewhat earlier than parents and, therefore,

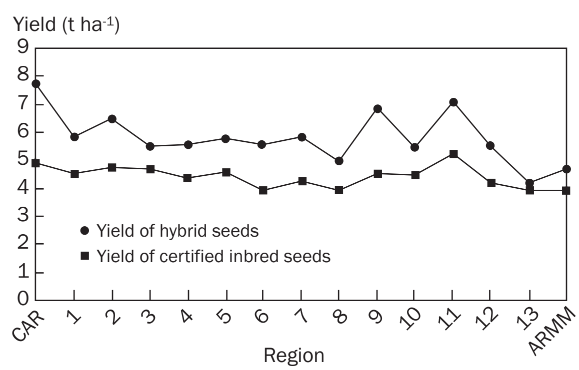

Fig.1. Average yield advantage of hybrid seeds over certified seeds across regions, 2002, Philippines.

Table 1. Compact block frontline demonstrations conducted in India (1999–2002).

State	Hybrids	No. of demos conducted (1 ha each)	Yield advantage (kg ha^{-1})
Maharashtra	Sahyadri, PHB-71, 6201	651	950-2450
Karnataka	KRH-2	550	700-1800
Andhra Pradesh	DRRH-1, APHR-2, PHB-71	475	300-1150
West Bengal	CNRH-3, KRH-2, PHB-71, 6201	410	500-1275
Tamil Nadu	CORH-2, ADTRH-1	330	400-900
Goa	KRH-2, Sahyadri	300	900-2300
Uttaranchal	PSD-1, PHB-71	196	600-1350
Uttar Pradesh	NSD-2, PHB-71, 6201	186	900-2450
Orissa	DRRH-1, PHB-71, KRH-2	130	500-1300
Haryana, Bihar, Gujarat, M.P. Tripura and Delhi	PHB-71, DRRH-1, 6201	88	450-1475
Total		3316	

Table 2. Productivity of inbreds and hybrids, computed as yield in kg d^{-1} to maturity, taken from IRRI Advanced Yield Trial data, 2002 dry season.

Genotype	Maturity (d)	Yield (kg ha^{-1})	Productivity (kg ha^{-1} d^{-1})
PSBRc 28, chk	114.0	7038.0	61.7
PSBRc 52, chk	115.0	7724.0	67.2
Mestizo, chk	124.0	8901.0	71.8
IR79130H	112.0	7613.0	68.0
IR79131H	109.0	7770.0	71.3
IR79174H	114.0	8872.0	77.8
IR79187H	115.0	8407.0	73.1

their productivity per day was higher than those of inbreds (Table 2). More recently, we have found hybrid rices that are better adapted to some unfavorable rice ecosystems such as rainfed lowland shallow, moderately saline soils, and aerobic rice environment (Virmani and Kumar 2004).

Agronomic management of rice

Since 1990, IRRI agronomists have established that hybrid rices require a somewhat different N management strategy compared with inbreds to maximize their yield advantage. Their N use efficiency was also found to be higher than that of inbreds. More recent results also show that, under water-limited conditions, hybrid rices suffer less yield loss than do inbreds. These results indicate an improved production efficiency of rice hybrids. Therefore, strategic, applied, and adaptive research on agronomic management of hybrid rices is very important to harness their yield potential in farmers' fields.

Hybrid seed production technology

Hybrid rice seed production technology involves two major steps: a) multiplication of the male sterile line (female parent) and b) production of hybrid (F_1) seeds. Seed yield obtained from a male sterile line used in a hybrid seed production plot is a function of a) yielding ability of the male sterile line (extrapolated from the yielding ability of its maintainer line), b) proportion of male sterile line to pollen parent, and c) outcrossing rate of the male sterile line. Improvement in any of these components can help increase hybrid rice seed yield.

Extensive research in China, IRRI, and other countries has identified specific guidelines and practices for hybrid rice seed production, which are given in manuals (Yuan 1985, Virmani and Sharma 1993) and research papers (Mao 1988). Using these practices, hybrid seed yields from 0.7 to 4.0 t ha^{-1} (average 1.5 t ha^{-1}) have been obtained in the tropics. In the 2003 dry season, several seed companies in India obtained seed yields of 2-3 t ha^{-1} in Karim Nagar District in Andhra Pradesh.

Economic viability

The availability of good-quality seed at a reasonable price is crucial to the large-scale adoption of hybrid technology in any crop. Economic analyses conducted in India, Vietnam, the Philippines, and Bangladesh have confirmed the hybrids' yield advantage of at least 1 t ha^{-1} over inbred check varieties grown by farmers (Janaiah and Hossain 2000). Profitability, however, depended on whether the farmers received a price comparable with that of inbred rice from the millers/traders. Some hybrid rice varieties introduced to farmers in certain parts of India fetched a 5-10% lower price, which resulted in profitability values lower than those of inbred HYVs. In the Philippines, however, hybrid Mestizo had a 5-10% higher price than check variety IR64, making use of this technology more profitable (Francisco et al 2001; Redoña et al 2003). For a sustained expansion of the technology, it is crucial that the grain quality of hybrid rice be at least comparable with (if not better than) that of check varieties. Additional and up-to-date information on the economic viability of this technology in some member countries will be presented by other participants attending this workshop.

Although the current seed cost of hybrid rice is somewhat high ($\$2$-$2.5\ kg^{-1}$), the increased seed yield and economies of scale would reduce the cost of production and thereby allow seed companies to sell hybrid seed at a lower price to farmers. The growing competition in the seed business would also let seed companies reduce the selling price of hybrid rice seed over time (Janaiah and Hossain 2001).

The production of hybrid rice seed is labor-intensive, but it is viable enough to attract private or NGO-based seed companies. Seed production can be organized in countries where labor is available at a reasonable price and hybrid rice seed demand is created among farmers. Almost 75 seed companies in the public, private, and NGO sectors are working in Asia to produce and market hybrid rice seeds. These companies have a forum —the Special Interest Group on Hybrid Rice, which meets under the auspices of the Asia Pacific Seed Association (APSA)—in which they discuss issues related to commercialization of the technology.

Salient achievements of the IRRI-ADB projects

The IRRI-ADB project on hybrid rice was launched in 1998 at IRRI with funds made available by ADB to expedite the development and use of this technology in tropical Asia. Three international agencies (IRRI, FAO, and APSA) and six member countries (Bangladesh, India, Indonesia, Philippines, Sri Lanka, and Vietnam) collaborated in the project. China also joined as a collaborating partner in 2000. The major achievements during the first phase, which lasted until 2001, were

1. An effective international hybrid rice network established.
2. NARES capacity strengthened for research, seed production, and technology transfer of hybrid rice through financial support, sharing of germplasm, and consultancy services.
3. Technology generated by breeding hybrids and developing agronomic management guidelines for seed production and hybrid rice cultivation.
4. A coordinated international hybrid rice yield trial formulated.
5. Hybrid rice seed industry in member countries strengthened by providing germplasm, information, and training.
6. Member countries assisted in developing a national policy on hybrid rice through workshops.

In the second phase of the project (2002 to June 2005), the following salient achievements have been made:

1. The international network expanded to nine member countries with the entry of Myanmar, the Republic of Korea, and Thailand.
2. Hybrid rice breeding materials continued to be shared extensively with public and private research and development institutions working on hybrid rice.
3. A mechanism developed to include private rice hybrids in the coordinated international hybrid rice yield trial.
4. Elite rice hybrids for Bangladesh, India, Philippines, Sri Lanka and Vietnam identified.
5. Numerous review and consultancy missions conducted in member countries to review project activities and make specific recommendations to improve technology generation, evaluation, seed production and technology dissemination activities on hybrid rice.
6. A few international but mostly in-country training courses organized in member countries using local resource persons (but,

in some cases, Chinese and/or IRRI resource persons).
7. Awareness of the technology enhanced by conducting frontline demonstrations and field days. Model action plans developed for some targeted areas in some member countries in consultation with policymakers, extension experts, the private sector, NGOs, millers, and farmer representatives.
8. Public-private partnership facilitated to promote the technology by co-organizing an international workshop on this subject.
9. Postharvest technological issues investigated.
10. Consultancy advice provided to the Philippines to strengthen capabilities of farmers' seed cooperatives to produce, process, and market hybrid rice seeds on a sustainable basis even after the withdrawal of government subsidy.
11. An international symposium on hybrid rice organized in which 180 delegates from 18 countries and from FAO, APSA, and IRRI participated.
12. Socioeconomic studies conducted in India, the Philippines, and Vietnam to assess the impact of hybrid rice technology.
13. A field visit in China organized for private seed companies to see high-yielding hybrid rice-seed production areas.

Impact

Past achievements on the development and dissemination of hybrid rice technology in the tropics have resulted in motivating 20 countries outside China to invest in this technology. Almost 40 public and private rice hybrids have been commercialized in these countries and these owe their origin to IRRI-bred and China-bred parental lines and/or hybrids. The IRRI-ADB project as well as other national and international efforts have contributed significantly toward strengthening the national capacity of member countries for developing and disseminating hybrid rice technology. More than 75 public-private-, and NGO-based seed companies in Asia have started investing in commercializing hybrid rice technology. Since 1997, hybrid rice area has increased from 287,000 ha to 1.5 million ha. This has increased paddy production by about 1.7 million t (worth $255 million).

Future opportunities and challenges

It is possible to combine the high yield of rice hybrids with acceptable grain quality and acceptable level of disease/insect resistance through appropriate breeding and selection procedures. Opportunities exist for further increasing hybrid rice yields by crossing indica and new plant type lines (Virk et al 2003). Better agronomic approaches and nutrient and pest management strategies are being developed to maximize yield expression and attain consistently high yield from the available hybrids. Genetic improvements are being made constantly to increase the seed production ability of the parental lines of hybrids and reduce their seed costs.

The strong root system of the hybrids enables them to adapt and perform better than inbreds under moderately stressed rice ecosystems—rainfed lowland shallow, rainfed lowland drought-prone, alternate wet and dry, and moderately saline irrigated fields. Higher seed yields and lower seed costs can make hybrid rice economically viable for direct-seeded irrigated conditions found in Japan and Korea.

The dissemination of hybrid rice technology can be further improved by establishing effective mechanisms that can link research, seed production, and technology transfer systems. Perhaps the establishment of hybrid rice missions (commercialization programs) under the ministries of agriculture of the member countries would be very useful. These units can prepare 5-yr action plans for targeted areas in the country in consultation with stakeholders—policymakers, researchers, seed industry, extension experts, millers, and farmer representatives. A clear understanding of the respective roles of the public and private sectors for developing and disseminating the technology should be reached to expand hybrid rice area to the desired extent.

This would help in saving some rice area for crop diversification and/or environment protection. The extensive participation of the seed industry in the production, processing, and marketing of hybrid rice seeds would generate additional rural employment opportunities.

To be successful, the abovementioned efforts for development and dissemination of hybrid rice technology need policy and financial support of policymakers in the national programs. With their support, hybrid rice technology can make an important contribution to increased food security, production efficiency, farmer's income, and rural job creation in a number of Asian countries.

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Process and challenges of hybrid rice dissemination in national programs: Philippines, India, and Bangladesh

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With a 15% yield advantage over semidwarf varieties, hybrid rice presents a viable option to increase rice productivity. The decrease in area for rice cultivation demands a significant increase in production per unit area to meet the needs of the growing population. Wide-scale adoption of hybrid rice will have a significant impact on rice production in developing countries. Hybrid rice is now being commercialized and actively promoted in the Philippines, India, and Bangladesh. Hybrid rice training and other promotional programs are being undertaken to disseminate hybrid rice technology in these countries. Training courses for farmers and extension agents are conducted, demonstration plots are established, and farmers' field days are held. Print and broadcast media are widely used. Most are aimed at farmers and extension agents, while others are intended for government decisionmakers and the general public to create greater awareness about hybrid rice. However, there are still many issues that need to be addressed to increase the adoption of the technology. These are the high cost of seed, inadequate training for farmers and extension officers, pest and disease incidence, and insufficient postharvest facilities. In India, poor acceptability of the grain, lack of manpower, and the state government's lack of enthusiasm limit the adoption of hybrid rice. In Bangladesh, the high price of seed from the private sector and the still unorganized seed program affect the spread of hybrid rice. Traders would rather import than produce seed locally. There is a felt need in Bangladesh to further strengthen its hybrid rice research and development program to support and sustain hybrid rice dissemination efforts. To address these concerns, agencies in the agriculture sector must come together to develop a comprehensive national plan. All rice stakeholders, including government agencies, seed growers and seed cooperatives, private companies in the seed industry, farmer organizations, input suppliers, and lending institutions, have a role in hybrid rice dissemination. The private sector should play a greater role in meeting infrastructure requirements and contributing more to information dissemination. The government, in turn, must create an environment that would encourage hybrid rice adoption. All these can greatly contribute to achieving food sufficiency, increasing farmers' income, and ensuring rice supply at affordable prices.

In developing countries, effective dissemination of hybrid rice technology is crucial to increasing productivity in the face of rising population and decreasing rice area. Hybrid rice technology presents a viable option in addressing the productivity problem. With a yield advantage of at least 15% over traditional varieties, hybrid rice is a key element in meeting the Philippines', India's, and Bangladesh's rice requirements and in ensuring accessible and affordable produce.

Thus, a successful hybrid dissemination program is essential. With a well-organized plan and goal-oriented efforts, government institutions can increase farmers' awareness and knowledge and motivation to engage in hybrid rice cultivation.

Models and accomplishments in hybrid rice technology dissemination

In the Philippines, commercialization of hybrid rice started in 2001, with the implementation of the Hybrid Rice Commercialization Program (HRCP).

The HRCP aims to further promote use of hybrid rice seeds, enhance farmers' productivity and income, and generate employment in the rural areas. The Philippine Rice Research Institute (PhilRice) was tasked as the lead agency in the implementation of the HRCP. Eventually, the HRCP was placed under the *Ginintuang Masaganang Ani* (GMA) Rice Program. PhilRice was mandated to focus on research and development activities and coordinate the procurement, distribution, and storage of hybrid seeds in relation to the program.

The GMA rice program is the lead implementing agency for the development of the rice industry. It aims to achieve rice self-sufficiency, raise farmer's income, reduce production cost, and lower retail prices for consumers.

To do this, the program enlists the help of the Department of Agriculture-regional field units and the DA attached agencies such as the PhilRice, the National Food Authority, the National Irrigation Administration, Agricultural Training Institute, the Bureau of Plant Industry, the Bureau of Agricultural Research, the Bureau of Agricultural Statistics, the Bureau of Soils and Water Management, Bureau of Post Harvest Research and Extension, the Quedan and Rural Credit Guarantee Corporation, and the Agricultural Credit Policy Council. The program is also supported by the Land Bank of the Philippines, local government units, state colleges and universities, and the private sector, particularly seed companies and seed grower cooperatives.

In India, systematic and serious efforts for hybrid rice technology dissemination were initiated in 1999. The Directorate of Rice Research in Hyderabad, India, initiated technology transfer through its cooperating centers, initially with the financial support from the ICAR/UNDP and IRRI/ADB/ICAR programs. A large number of compact block frontline demonstrations were conducted and training programs were organized in the target areas. The private seed sector was also engaged in technology transfer activities.

Meanwhile, hybrids have started becoming popular, particularly in eastern Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, Haryana, and Punjab states. The agriculture departments of the concerned states realized that hybrid rice can help enhance rice productivity. Hence, the Indian government extended great support to technology transfer activities in 2002. The compact block frontline demonstrations on hybrids were held under the auspices of ICAR/UNDP and ICAR/IRRI/ADB projects in 1999. From 2003, these were funded by the Ministry of Agriculture.

In Bangladesh, the government took the lead in technology dissemination. On the part of the private sector, the Bangladesh Rural Advancement Committee (BRAC), a nongovernment organization (NGO), and other people's organizations (PO) imported the parental line. Through this, they produced and sold hybrid (F_1) seeds. Like the government, BRAC also put up technology demonstration areas, conducted field days, and facilitated training programs.

The Philippines, India, and Bangladesh are carrying out the following activities:

- Establishment of technology-demonstration areas, followed by holding of field days;
- Conduct of trainings such as technical briefings on hybrid rice cultivation;
- Procurement and distribution of hybrid seeds;
- Distribution of printed information materials such as brochures, pamphlets, bulletins, posters, newsletters, etc.;
- Making video films available ;
- Holding regular programs on TV and radio;
- Massive advertising by the private seed sector;
- Providing a subsidy for procurement and distribution of seeds (Philippine DA); and
- Holding of interstate visits for farmers and farm women (India)

Establishment of technology demonstration areas. Establishing technology demonstration areas has been a major component in the dissemination efforts. This was the result of collaboration between the government and private seed companies. This intervention presents an opportunity for farmers to get acquainted with hybrid rice technology. Here they are able to learn proper planting techniques and acquaint themselves with possible problems that may occur in the field and thereby try to solve them. This enables them to have a good harvest, which in turn encourages farmer-participants and others in the community to shift to hybrid rice.

The Philippine, Indian, and Bangladeshi governments have given tremendous support for the establishment of "techno-demo" areas, providing farm inputs and technical assistance.

The private sector also played a crucial role in setting up the techno-demo farms. In the Philippines, private seed companies provided hybrid seeds to these farms. In India, the private sector set up techno-demo areas for the technologies that they develop.

From 2001 to 2004, the Philippine DA has established 2,618 techno-demo areas. In India, technology demonstration activities were initiated in 1999 under the ICAR/UNDP and ICAR/IRRI/ADB projects. Subsequently, field demonstrations have been conducted through the funds provided by the Ministry of Agriculture. There have been 9,356 techno-demo sites established from 1999 to 2004. Hybrids have shown a yield advantage of 300 kg up to more than 2.5 t ha^{-1} (Table 1).

In Bangladesh, a number of techno-demo sites were established in the different regions. The highest yield attained in these areas was 10.60 t ha^{-1} in Madaripur District of Barisal region. Hybrid rice yield averaged as high as 9.45 t ha^{-1} (Tables 2 and 3).

Conduct of field days. Field days are farmer visits to technology demonstration areas. This may be done before, during, or after harvesting activities. At this time, farmers and agricultural workers explain to visitors the process of planting hybrid rice. They discuss, among other things, the adequate amount of seeds planted and planting distance, proper amount and right timing in applying fertilizer, problems they have encountered integrated pest management techniques, and proper application of pesticides. During these discussions, the visiting farmers are free to ask about hybrid rice cultivation.

The visit is usually done around harvest time so farmers can observe mature hybrid rice stalks. Furthermore, when average yields are computed, the farmers learn about hybrid rice producing more. This will lead to faster adoption of the technology as farmers realize that this is a way to raise their income.

In India, field days are organized in strategic locations at the appropriate growth stage of the crop on a cluster basis. Each cluster consists of 20-25 demonstrations of 1-ha farms in a compact block. Officials of the state departments of agriculture, the public sector banks, and other lending agencies and agencies that provide agricultural input are invited to these field days.

Table 1. Technology demonstration trials conducted in India from 1999 to 2004.

State	Demonstrations conducted (no.)	Hybrids used	Yield advantage (kg ha^{-1})
Uttar Pradesh	2,940	PHB-71, 6444, 6201, NSD-2, PSD-1	900-2,450
Maharashtra	1,851	Sahyadri, PHB-71, 6444, 6201, KRH-2	950-2,815
Karnataka	1,450	KRH-2, PHB-71, 6444	750-1,600
Tamil Nadu	1,215	CORH-2, ADTRH-1, PHB-71, 6444	450-1,100
Uttaranchal	415	PSD-1, NSD-2, PHB-71, 6444	600-1,250
West Bengal	410	CNRH-3, KRH-2, PHB-71	500-1,175
Andhra Pradesh	475	DRRH-1, APHR-2, PHB-71	300-950
Goa	600	Sahyadri, KRH-2	900-2,515
Total	9,356		

Table 2. Results of pilot testing of hybrids IR69690H and IR68877H, by region, Bangladesh, 2003-04 boro season.

Region	Days to maturity		Yield (t ha^{-1})	
	IR69690H	IR68877H	IR69690H	IR68877H
Jessore	150	145	9.45	8.78
Barisal	159	148	7.93	7.69
Rajshahi	166	161	7.93	6.37
Comilla	154	338	7.97	6.42
Observed range	150-166	138-161	7.25-9.55	6.07-8.78
Mean of the region	157	150	8.40	7.34
SD	6	8	0.87	1.01
Expected range	151-163	142-158	7.53-9.27	6.33-8.35

Table 3. Yields of BRRI Hybrid 1 and BRRI Dhan 29 under base line demonstration, Bangladesh, 2003-04, boro season.

Region	Demo. (no.)	Highest yield (t ha^{-1})		Average yield (t ha^{-1})	
		BRRI Hybrid 1	BRRI Dhan 29	BRRI Hybrid-1	BRRI Dhan 29
Dhaka	100	9.0	8.3	7.3	6.9
Comilla	75	9.8	8.7	6.7	6.2
Mymensingh	125	9.8	8.9	6.8	6.1
Rajshahi	94	9.6	8.5	6.8	6.3
Rangpur	75	9.6	8.0	6.7	6.0
Chittagong	20	8.9	8.0	6.6	6.0
	489	9.4	8.4	6.8	6.2

Training programs. Cultivating hybrids requires new and intricate skills. Thus, implementation of training programs is essential. Training programs should be geared to every player in the hybrid rice industry—the seed producers, farmers, and agricultural extension workers (AEWs).

In the Philippines, close to 300,000 farmers, AEWs, research and development personnel, and policymakers were trained in both hybrid rice seed production and cultivation. The briefings were usually done for an entire morning. Farmers are taught how to properly plant and care for hybrids. They also learn about proper fertilizer and pesticide application and are informed of interventions of the DA through the GMA rice program.

In India, more than 20,000 persons have been trained on various aspects of hybrid rice technology in a span of a decade and a half. Among those trained were farmers, seed growers, seed producers, AEWs, officials of state agricultural universities and NGOs. The training programs, lasting 1-5 d, involved both theoretical classes and practical sessions in the field. Each program involves benchmark evaluation and post-evaluation. The difference obtained between these two was taken as knowledge gained.

Interstate visit among farmers and farm women. This particular activity was done only in India. The interstate visits for hybrid rice farmers and farm women were organized to make them aware of the developments in some of the more progressive states. Under the program, farmers and farm women of one state are taken to another state for 1-2 wk. During this time, they interacted with highly successful hybrid rice farmers and seed growers, observing the progress made. These visits were found to be highly effective as many participants became adopters and promoters of hybrid rice.

Distribution of information materials Information materials such as brochures, pamphlets, bulletins, posters, and newsletters on hybrid rice seed production and cultivation and other technologies were published in English and translated into local dialects. These were then widely distributed. Through this, even farmers who have not attended technical briefings and field days were informed of hybrid rice's advantages and proper cultivation techniques.

These information materials were distributed during technical briefings or other training sessions. In the Philippines, these were made available in the different DA-RFUs and PhilRice offices and were distributed by AEWs (Table 4).

Availability of video films and film screenings. Films on proper cultivation of hybrid rice were produced in the Philippines and India. These can be availed of in the DA-RFUs and PhilRice offices. These films have been widely distributed. One video showed the various aspects of hybrid rice technology while another showed proper hybrid rice seed production. These films have been dubbed in seven local Indian languages—Hindi, Telugu, Tamil, Kannada, Marathi, Bengali, and Oriya. There were also efforts to centralize the gathering of data on the rice industry. In India, a website on hybrid rice (http://www.hybridriceindia.org) was launched in 2002. It gave detailed information on the various aspects of hybrid rice technology in India.

The Philippines, on the other hand, posted information on hybrid rice cultivation and statistics on the rice industry at http://www.bas.gov.ph and http://www.philrice.gov.ph. The latter website also contains news and success stories in hybrid rice cultivation. In addition, the DA launched the Open Academy for Philippine Agriculture or *Internet ng Magsasaka* (Internet for farmers) at http://www.openacademy.ph in November 2003. This is an initiative of PhilRice and 18 other national and international institutions. It aims to extend information to farmers and technicians.

Table 4. Number of informational activities conducted under the GMA Rice Program, Philippines, 2001-04.

Information materials/activities	350,000
Print materials	258,135
Audio-video broadcast	963
Media relations	7
Programs produced	1,000
Caravans conducted	32
School on-the-air	6
Conduct of national survey on agriculture and fishery	2
Plugs	570
Special events	161

TV and radio programs and newspaper articles on hybrid rice. Information on hybrid rice was also relayed through conventional media such as newspapers, television, and radio. The topics discussed in the television and radio programs were translated into different dialects and aired over local radio stations. Private organizations also produced programs on rice cultivation and other agricultural activities. Agriculture and local government officials, including model farmers (Table 5) were also interviewed on TV and radio. Newspapers have featured hybrid rice and farmer success stories, thus creating awareness of the technology.

Massive advertising by the private seed sector. The private sector, especially the seed companies, have promoted hybrid rice through advertising. In the Philippines, private seed companies have provided free seeds to the DA for its techno-demo areas, given technical assistance, conducted field days, and given awards to outstanding farmers and technicians.

In India, technology transfer efforts, though on a smaller scale, were focused and effective. The private sector used their extensive marketing network. They also used vehicles for advertising. These vehicles garbed with placards, banners, posters, and loud speakers roamed the village streets and loudly spread the message about their products and services. Seeds were also made available in these mobile vans.

Challenges to hybrid rice dissemination

- Higher cost of hybrid seed. The primary concern of farmers is to have low production cost. They do not give as much importance to higher yields and greater income.
- Intricate care needed in hybrid rice cultivation. This is time consuming and demands a lot of attention from farmers. Some hybrids are very susceptible to pests and diseases.
- Insignificant yield advantage of hybrids over traditional varieties in some areas. With the special care needed for planting hybrid rice, farmers cannot immediately realize the full potential of hybrids. Thus, they attain only a slight increase in yields. Oftentimes, this leads to waning interest, considering the high prices of hybrid seeds.
- Need for retooling of AEWs. This should be done to strengthen interest and increase knowledge on hybrid rice technology.
- Inadequate manpower for hybrid rice dissemination activities. Additional personnel are needed, especially in the regional and provincial levels.
- Need for a comprehensive plan to support seed growers. The government should encourage and provide technical assistance to new seed growers. Farmers, on the other hand, should be given support in terms of adequate infrastructure and sufficient training to enable them to grow their own hybrid seeds.
- In India, some hybrids have grain quality that is unacceptable in the southern states.
- Inadequate policy support.

Table 5. Model rice farmers involved in technology demonstration, Philippines.

Province	Name of farmer	Actual yield	
		Cav ha^{-1}	t ha^{-1}
Magsaysay, Davao Sur	Eulogio Guirra, Sr.	290	14.52
Calintaan, Occ. Mindoro	Mark Ryan Paulino	288	14.40
Tagudin, Ilocos Sur	Antonio Villanueva	262	13.10
San Jose City, Nueva Ecija	Fernando Gabuyo	260	13.01
San Manuel, Isabela	Loreto Asuncion	258	12.93
San Jacinto, Pangasinan	Rosalie Ellasus	255	12.79
Tabuk, Kalinga	Amador Na-oy	254	12.70
Rizal, Occ. Mindoro	Ernesto Pablo	248	12.40
Compostela Valley	Anatalio Rebucas	241	12.07
Victoria, Laguna	Purification Perez	234	11.70
Talavera, Nueva Ecija	Pablito dela Fuente	232	11.60

Policy support needed for dissemination

Sound policies should be in place to ensure successful dissemination of hybrid rice technology. Foremost of the concerns in the Philippines is the gradual phase-out of subsidy for both public and private hybrid seeds. The DA has subsidized the purchase of hybrid seeds since 2001. Due to limited funds, the department is gradually reducing it. Without this subsidy, it would be more difficult to promote hybrids. The gradual phase-out is being implemented in the belief that farmers have been given adequate time to get acquainted with and reap the benefits from growing hybrid rice. It is assumed that the farmer will prefer growing the hybrids and will shoulder the higher production cost.

In contrast, India and Bangladesh did not subsidize the purchase of hybrid seeds. However, farmers in India must be assured of a buy-back program by the Food Corporation of India, in the case of discriminatory pricing of hybrid rice in some regions.

On credit availability, there have been efforts in the Philippines to enhance access to credit of rice farmers. Even individual farmers can avail of production loans through Quedancor, the DA attached agency for credit and guarantee. Majority of these loans are payable upon harvest. This is in addition to the Hybrid Rice Credit Assistance Program (HYCAP) implemented through traders-millers.

Another concern is the strengthening of research and development efforts, especially in creating and testing new rice varieties. Developing new varieties would enable us to maximize the available area for planting. For instance, in the Philippines, we have yet to fully use the existing irrigated and rainfed lowland areas.

There is also a need to hasten the seed testing and certification process in the Philippines. We have yet to put into operation the accreditation of both public and private seed-testing laboratories in addition to the existing ones. The insufficient number of laboratories has slowed down this process.

In Bangladesh, a steering committee on hybrid rice headed by the Secretary of the Ministry of Agriculture was formed a few years ago.

State governments in India where rice hybrids have been found to perform well should devise specific and time-bound programs to popularize the use of hybrid rice in the respective states. The Indian government should encourage processing hybrid rice seeds at competitive prices to farmers. This is also the goal of Bangladesh, which needs to release more hybrid varieties to suit its cropping seasons.

On the training of farmers, there is a need to retool all AEWs to constantly update them with developments in the rice sector, particularly on hybrid seed technology.

The Philippines also has inadequate irrigation facilities, thereby providing insufficient water supply. This lowers productivity, especially during the dry cropping season. High-yielding varieties require the rehabilitation of existing irrigation systems to improve water supply. Unfortunately, the Philippines' National Irrigation Authority was not able to sustain the rehabilitation due to limited funds given to DA yearly. We need to obtain support from local government units and avail of overseas development assistance from foreign donors.

Pursuant to the Philippine DA's goal of lowering consumer prices, we have to lessen the marketing layers between the farmer and consumer. The DA has given credit assistance for the procurement of postharvest facilities. In addition, DA needs to facilitate market linkages between institutional buyers (such as restaurants, food chains, supermarkets, and hotels) and farmers' cooperatives.

Further, the government should recommend hybrid rice varieties suitable to the respective areas. With this, farmers can observe the significant yield advantage of hybrids and encourage them to shift to hybrids.

Moreover, given its limited resources, the government needs to identify specific areas in which hybrid rice technology is disseminated. We have started implementing this in the Philippines. Regions with large irrigated areas and with remarkable performance on hybrid rice cultivation were targeted for expansion. This does not mean that the DA does not encourage other regions to plant hybrid rices; only that they have to wait until new hybrids suited to these areas become available.

Policy support for the private sector in national hybrid rice development and dissemination programs

There is a need for partnership between the government and the private sector. To encourage greater involvement, the government should provide adequate support to private seed growers and companies. This may come in terms of infrastructure and technical assistance. Moreover, there is a need for greater coordination, especially in meeting the country's seed requirements.

In India, there is a need to grant subsidy in the procurement of private hybrid seeds.

In addition, policies on the public sector sharing parental lines and hybrids with the private sector should be formulated. This is for the private sector to fully utilize the parental lines in their development of hybrid varieties.

Efforts in technology transfer between the public and private sectors should be strengthened. This is to facilitate the release of new hybrid varieties and new technologies to aid farmers in growing hybrids.

Conclusions

The Philippines, India, and Bangladesh have made remarkable progress in hybrid rice cultivation. We have observed greater production and higher yields with the use of hybrid seeds.

Credit should be given to the concerned government agencies, the private sector, the mass media, and the farmers themselves. Their efforts have raised self-sufficiency and farmers' income. However, numerous challenges remain. National and local government units must lay down the needed policy support and infrastructure to stimulate private sector participation and sustain farmer interest.

Improvement in rice productivity and income of farmers and other rice industry stakeholders will be addressed more appropriately through a clustering of farmers. Through this, there will be convergence of interventions in focus hybrid rice areas. This, in turn, will make self-sufficiency in rice a reality.

Notes

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Development and dissemination of hybrid rice technology in national rice programs

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Hybrid rice is being developed and disseminated in at least nine Asian countries outside China--Bangladesh, India, Indonesia, South Korea, Myanmar, Philippines, Sri Lanka, Thailand, and Vietnam. These countries recognize the use of hybrid rice technology in commercial rice production as a practical approach for increasing productivity and profitability of rice farming, generating rural employment, and attaining rice self-sufficiency and food security. Thus, the governments of these countries have integrated hybrid rice technology generation and promotion into their national rice programs (NRPs). Assistance for specific activities such as hybrid rice breeding, seed production, integrated crop management technology generation and packaging, capacity building, policy advocacy, and information/technical exchange have been provided by Food and Agriculture Organization (FAO), International Rice Research Institute (IRRI), Asian Development Bank (ADB), the Asia Pacific Seed Association, and China. Major progress has been made in the commercialization of hybrid rice in India, Vietnam, the Philippines, Bangladesh, and Indonesia, resulting in 1.4 million ha being under hybrid rice cultivation by 2004, 1.39 million t additional rice produced worth US$167 million, and higher profits for both farmers and seed producers obtained at the farm level. In some countries, spillover technical effects such as use of lower seeding rates and higher technical precision in rice farming activities, as well as socioeconomic effects such as job generation, organizational/cooperative development, and stimulation of local economies were observed. Hybrid rice technology, with the business and intellectual property protection opportunities it offers, has also encouraged, for the first time in many of these countries, the private sector to invest heavily in and share in alleviating the erstwhile purely government's burden of modernizing the NRPs. To date, about a hundred local and multinational companies, including cooperatives, are engaged in hybrid rice-based business activities, with some promoting integrated 'seed-to-shelf' rice production and post-production systems and modalities. Despite the steady progress, a number of research and development-related issues still need to be addressed across these countries: (1) insufficient research on seed production; (2) inadequate number of technical and extension personnel; (3) weak institutional linkages among public, private, and NGO sectors; 4) high cost of hybrid seed production, (5) inadequate grain quality, (6) low and inconsistent seed yields, (7) susceptibility to pests and diseases, (8) narrow germplasm base, (9) further improvement in extent of heterosis, and (10) inadequate socioeconomic and policy research. International institutions such as IRRI, FAO, UNDP, and ADB may be able to assist the NRPs through activities and programs fostering (1) germplasm exchange, (2) training, (3) international collaboration, (4) consultancy services, (5) coordinated international germplasm evaluation, (6) information sharing and exchange, (7) international meetings, and (8) policy formulation and regional harmonization. The governments of these countries, on the other hand, should manifest strong support to public-and-private sector efforts on hybrid rice, through appropriate policy frameworks, strengthening of human resources, adequate financial support and facilities, and establishment of programs promoting synergistic partnerships among public, private, and civil society sectors.

Asia produces about 520 million t of rice, or 90% of the world's supply that is harvested from 250 million ha. However, the population in the continent continues to grow at 1.8% per year, whereas rice production has increased by only 1.7% per year since the mid-1980s. To address the widening gap between rice supply and demand, the level of productivity should be increased against a backdrop of declining rice lands, water shortage, and labor scarcity. Improving yield levels has been recognized as a practical approach to sustain and stabilize rice production. However, some favorable irrigated areas in Asia are already experiencing productivity decline. Hence, there is a pressing need to adopt promising technologies to further elevate the current yield ceiling.

Hybrid rice technology can increase rice yields by up to 15-30% more than those of conventional high-yielding varieties (HYVs) that sparked the Green Revolution. The technology has been developed and widely adopted in China, where 50% of the total rice area planted to hybrid rice (about 15 million ha) accounts for roughly two-thirds of the national rice production. The sustainable increase in rice production demonstrated in China, through cultivation and commercialization of hybrid rice, has enabled the country to devote other agricultural areas to different production activities. This success has also encouraged other rice-producing countries to develop and adopt hybrid rice technology. However, the transfer of Chinese hybrid technology directly to other Asian countries has not been successful, mainly because of technical problems as well as the cost involved in producing and transporting hybrid seeds. Many Asian countries therefore decided to develop their own hybrid rice programs.

To date, hybrid rice technology is being developed and disseminated in at least nine major rice-producing Asian countries outside China: Bangladesh, India, Indonesia, Myanmar, Philippines, South Korea, Sri Lanka, Thailand, and Vietnam. These countries use hybrid rice technology in commercial production to increase productivity and profitability of rice farming, generate rural employment, and attain rice self-sufficiency and food security. The governments of these countries have integrated hybrid rice technology generation and promotion into their national rice programs (NRPs). Support for specific activities such as hybrid rice breeding, seed production, integrated crop management, technology generation and packaging, capacity building, policy advocacy, information/technical exchange, and infrastructure buildup have been provided by the Food and Agriculture Organization of the United Nations (FAO) through the Technical Cooperation Project (TCP) modality, the International Rice Research Institute (IRRI), and the Asian Development Bank (ADB) through two projects implemented in 1998, the Asia Pacific Seed Association (APSA) through the conduct of international yield trials, and China through its participation in the IRRI-ADB project and the establishment of various institutional and intergovernmental collaborations. The United Nations Development Programme (UNDP), on the other hand, has also provided support to the hybrid rice program of India.

Hybrid rice development

Before 1998, many of the activities in the hybrid rice research programs in tropical Asian countries, with the possible exception of India and Vietnam, were generally limited to the testing of rice hybrids and parental materials introduced from IRRI and China. Of these countries, India was the first to launch a national HRP, establishing in the late 1980s/early 1990s a National Hybrid Rice Network composed of key rice R&D institutions and universities. Vietnam followed suit in 1992, establishing a Hybrid Rice Research Center in 1992 under the Vietnam Agricultural Science Institute. In the late 1990s, the Philippines, Indonesia, and Bangladesh also strengthened their hybrid rice research programs that, heretofore, were imbedded in their respective rice varietal improvement programs. In the Philippines, for example, the Philippine Rice Research Institute (PhilRice) launched a multidisciplinary hybrid rice program and established a center for applied hybrid rice R&D at San Mateo, Isabela. With the launching of the IRRI-ADB project in 1998, six countries—India, Vietnam, Philippines, Indonesia, Bangladesh, and Sri Lanka-- increased their breeding, seed production, and technology dissemination activities.

Breeding new hybrids and parental lines. The development of new cytoplasmic male sterile (CMS) lines (A lines) and hybrid varieties was carried out using germplasm shared by IRRI as well as those generated by in-country research activities. Hybrid rice combinations with good grain quality, resistance to pests and diseases, and short duration, which met the requirements of the various agroecological zones in each country, were identified and evaluated in frontline demonstration plots.

The Bangladesh Rice Research Institute (BRRI) conducted a comprehensive study on the cultural, fertilizer, and pest and disease management of promising hybrids and parental lines over different locations and seasons. By 2004, six CMS lines and eight restorers for the irrigated boro ecosystem were identified. Six experimental hybrids in yield trials were found to be promising. One CMS line for the irrigated boro and lowland ecosystem was developed. Trials to optimize row ratio, GA_3 requirement, and synchronization parameters were also conducted to come up with hybrid rice seed production packages for released and promising hybrids. Based on the results obtained, the seed production packages resulted in seed yields of at least 1.5 t ha^{-1}.

In Myanmar, recent activities involved the identification of suitable parental lines to be used in developing locally adapted hybrids. About 72 restorer or R lines, 60 maintainer or B lines, and 1 CMS line have been developed/identified. The identified R lines were used in experimental hybrid seed production. By 2004, three promising hybrids showed a yield advantage of up to 73.5% over check varieties.

In Sri Lanka, CMS lines adaptable to local conditions have been developed. Breeding materials, including CMS lines adapted to tropical environments, were obtained from IRRI. By 2004, 10 CMS lines from China were also found adaptable to local conditions, and 4 CMS lines and 10 promising hybrids were developed.

Grain quality. Grain quality has been a contentious issue in hybrid rice due to varying consumer preferences for physical and eating characteristics in different countries. For example, aromatic rices, while preferred in the Philippines, are not liked in some parts of India. Moreover, even within a country, taste preferences vary considerably. In Indonesia, for example, inhabitants of northern Sumatra Island have a preference for hard or high-amylose rice, which is not preferred by those from Java Island. Moreover, the first-generation hybrids reportedly had poor milling recovery characteristics. Hence, selection activities of various breeding programs emphasize grain quality in addition to high yield.

In Bangladesh, for example, the grain quality of some promising rice hybrids and parental lines was evaluated. Using local standards, several lines were found to have acceptable traits. Though preliminary results are encouraging, these need to be confirmed further and verified over different locations and seasons.

Two-line hybrids. China and Vietnam lead in the development and commercialization of the two-line hybrid rice system. As originally developed in China, the two-line system avoids the use of maintainer lines, and there is a better chance to develop heterotic hybrids— i.e., 95% of rice germplasm can restore photoperiod-sensitive or thermosensitive genetic male sterile or P(T)GMS lines, as compared with roughly 5% of germplasm that can restore CMS lines. The yield advantage of the two-line hybrid rice is 5-10% higher than the CMS-based or three-line hybrids. In 2002-03, the area planted to two-line hybrid rice in China reached 2 million ha.

In Vietnam, to develop new TGMS lines, TGMS sources were used as donors for crossing with adapted inbred varieties with good quality and tolerance for diseases and insects, and for crossing TGMS lines with adapted maintainer lines. As a result, several TGMS lines have been developed. Among them, 103S and T1S-96 have been used as female parent of VL20 and TH3-3, respectively. These two-line hybrids have been released for commercial rice production in Vietnam.

The use of the two-line system is also being explored in India, where several two-line hybrids have been evaluated. In the Philippines, 31 TGMS lines are in the breeding pipeline of PhilRice. No work is currently reported on two-line hybrid breeding in the private sector, although previous work has been reported in one multinational company based in Thailand.

Resistance to pests and diseases. In Bangladesh, Korea, and Indonesia, hybrid rice research also focused on developing hybrids resistant to pests such as brown planthoppers and diseases such as bacterial blight, blast, and rice tungro virus. In Indonesia, for example, several new CMS lines with improved levels of resistance to both brown planthopper and bacterial leaf blight have been bred and are now being used in developing new hybrids at IRRI. On the other hand, scientists in India and the Philippines are using molecular marker-assisted selection to introgress dominant bacterial leaf blight resistance genes into commercially usable parental lines, including IR58025A, the female parent of several public-and private-sector hybrids released in India, Vietnam, Bangladesh, Indonesia, and the Philippines, including the locally popular Mestizo.

Minimum needs to effectively pursue hybrid rice research in national programs. Based on experience in tropical Asia, hybrid rice research in national programs will be effective if these were present: strong government commitment and support from top-level policymakers; adequate number of trained human resources; adequate and upgraded research facilities; unimpeded access to and exchange of germplasm, technologies, and information related to hybrid rice; intensive training programs for hybrid breeding and hybrid seed production; publication of research findings; strong involvement of and collaboration with the private sector from R&D to commercialization; and collaboration with international institutions/agencies.

The program of India, for example, was developed with the strong backing of the director general of the Indian Council of Agricultural Research, the coordinating body for all agricultural research activities in the country. The program of Vietnam expanded with the support of the Minister of Agriculture. The case of the Philippines is a unique example. The hybrid rice program has drawn support from three Philippine presidents and seven secretaries of the Department of Agriculture since 1998. Under the current administration of President Arroyo, a Hybrid Rice Commercialization Program was established. It has become the Philippine government's banner program for agriculture since 2001.

Hybrid rice dissemination

Capability to produce adequate quantity and quality of seeds. The public, private, and NGO sectors have undertaken large-scale seed production in India, Vietnam, Philippines, Indonesia, and Bangladesh. In some countries such as Bangladesh, Myanmar, and Vietnam, the supply of hybrid seed heavily depends on seed importation. A total of 73 major companies and institutions have been involved in hybrid rice development and commercialization (see table). NGOs are most active in Bangladesh, whereas, in the Philippines, more than 33 farmers' cooperatives were trained on hybrid seed production by PhilRice. They now supply about 60% of the seeds used in the country's commercialization program.

Seed companies (no.) participating in hybrid rice development and dissemination.

	Private	Public	NGO	Cooperatives/associations	Total
Bangladesh	5	1	2		8
India	15	7	2		24
Indonesia	7	3			10
Philippines	5			8	13
Sri Lanka	2				2
Vietnam	4	4	8		16
Total	38	15	12	8	73

In Bangladesh, the public sector (BADC) and NGOs (BRAC) initiated a large-scale seed production. Four private seed companies involved in seed production have resorted to seed importation to augment the local seed supply.

In India, there were 20 private-sector companies and 8 public-sector institutions involved in hybrid seed production. Five public hybrids and three proprietary hybrids have been released for commercialization. The area under hybrid seed production increased from 1, 635 ha in 2001 to 4, 350 ha in 2004 with seed yields of 2 t ha^{-1} being regularly attained. Moreover, hybrid seed production generated employment in the rural areas, particularly among women.

Hybrid seed production in Vietnam, on the other hand, was carried out by three economic sectors— government-controlled central and provincial seed companies, private seed companies, and agricultural cooperatives that have been assisted by government technicians—contracting with farmers. Seeds produced by farmers were used to meet local demand. The surplus was sold to local seed companies or other agricultural cooperatives upon request.

In Indonesia, several seed companies are producing hybrid seeds of released and promising hybrids. Some companies have also collaborated with Chinese hybrid rice commercial outfits for evaluation of Chinese hybrids locally, breeding new hybrids using local and introduced germplasm, and developing high-yield seed production technologies. By 2004, at least two private companies (PT KNB Mandiri and PT Makhmur Sejatera) had developed seed production technology packages that yielded 2-3 t seed ha^{-1} under the supervision of Chinese hybrid rice experts.

With hybrid seed being available, major progress has been made in the commercialization of hybrid rice in India, Vietnam, the Philippines, Bangladesh, and Indonesia, resulting in 1.5 million ha being placed under hybrid rice by 2004, 1.39 million t additional rice production worth US$167 million, and higher profits for both farmers and seed producers at the farm level. The area under hybrid rice commercialization in these countries, as well as in Sri Lanka and Myanmar, was expected to exceed 2 million ha by 2005.

However, improvement is still necessary in the area of producing quality seeds of parental lines and hybrids. Systems for the production of adequate amounts of nucleus and breeder seeds of parental lines, for example, have yet to be established in some countries such as Indonesia, Bangladesh, Myanmar, Thailand, and South Korea. Moreover, seed certification standards for both hybrid and parental lines have yet to be developed in these countries, along with appropriate training programs for field inspection and laboratory seed certification. The principle of 'truthful labeling,' particularly for hybrids developed by the private sector, may be worth exploring in these countries.

Private-public partnership in seed production and promotion of hybrids. Public-private sector partnerships are vital to ensure effective, coordinated, and successful development and commercialization of hybrid rice technology at the national level. In the past, promotion of new technologies, including the use of new varieties among farmers, was largely the domain of the public sector. With prospects of high returns for investment in hybrid research and technology development, as well as with the built-in intellectual property protection (exclusive access to maintainer or B line prevents anybody else from producing seed of the particular hybrid), the private sector has been encouraged to join the public sector in investing and promoting the use of hybrid rice, and thus, trigger agricultural modernization. Collaboration with the private sector provides the public sector access to advanced technologies and additional financial resources. In some countries such as Bangladesh, Vietnam, and Sri Lanka, however, the participation of the private sector is still limited. In Myanmar, no private sector is involved in the hybrid rice program.

In Bangladesh, the government has shown strong support and commitment to the hybrid rice program by establishing a national hybrid rice network to strengthen hybrid rice R & D in the country. To augment seed supply, private seed companies are permitted by the government to import good hybrids.

In India, hybrid seed production is dominated by 20 private seed companies, along with seven public seed agencies. There is a sharing of registered germplasm with the private sector, testing of private-bred hybrids in the national network, and training of private-sector seed-production personnel.

In recent years, a vibrant private sector has emerged in Indonesia. Remarkably, private seed companies in the country are investing heavily on hybrid rice technology and are eager to market hybrid rice to farmers, even without government subsidy. There are seven private seed companies involved in hybrid seed production and hybrid development. Hybrids from these companies were first evaluated in public field plots for agronomic characters, pest and disease resistance, and grain quality. Public-private partnerships also involved exclusive licensing agreements that contribute to the wider availability of public sector-developed hybrid seeds among farmers. Seed importation by the private sector is currently allowed for 2 yr after an introduced proprietary hybrid is released.

In the Philippines, central and local government units and other government agencies are involved in hybrid rice technology promotion, while the private sector is focused on R&D and seed production, distribution, and marketing. To further strengthen the hybrid rice program, PhilRice forged 10 formal and 3 informal collaborations with various institutions in China, notably the Yunnan Agricultural University and the Jiangxi Academy of Agricultural Sciences that have helped in hybrid rice breeding and seed production, respectively. Five private seed companies, along with 33 organized seed growers, are undertaking large-scale hybrid seed production. In 2004, these seed grower cooperatives produced about 60% of the hybrid seed requirements of the country. PhilRice, with the assistance of IRRI and the University of the Philippines Los Baños, conducts nucleus and breeder seed production of parental lines used in the HRCP. The seed certification wing of the government has also been adequately trained to conduct seed certification-related activities. Aside from seed production, public-private sector partnerships engaged in germplasm exchange, hybrid evaluation, and conduct of on-farm demonstration of upcoming and released hybrids.

Coordination among research, seed production, and extension agencies. Hybrid rice research, seed production, and extension in the different Asian countries involve the public, private, and NGO sectors, with each sector having its own respective strengths and weaknesses. In a national program, coordinating the activities of these sectors as well as ensuring the continuity of research, seed production, and extension activities across sectors are important not only in promoting the most efficient use of NARES resources but also in attaining commercialization targets. It is important to note that a given sector, on its own, cannot create the market and policy environment to make hybrid rice commercialization a success. The hybrid rice program needs to cater to the needs of farmers, government, rice millers and traders, NGOs, and consumer organizations, among others. To strengthen the capacity of both the public and private sectors, intensive training programs on hybrid cultivation and seed production should be conducted.

It is also important to note that research institutes, universities, and private companies are usually involved in technology generation, whereas public and private seed companies and seed grower cooperatives undertake hybrid seed production. On the other hand, NGO and farmer associations are engaged in technology transfer activities. Hence, strong linkages among the different sectors ensure that technologies generated are attuned to the needs of the market and are thus easier to promote on farm.

Ideally, coordination efforts have to be made by the Department or Ministry of Agriculture or the agency leading the hybrid rice commercialization program of a country. In the Philippines, this is done through the Technical Working Group of the Department of Agriculture's Rice Program as well as through the HR Seed Production Management Committee where the public and private sectors are well represented. Regular meetings and dialogues among the stakeholders are particularly important in addressing existing and potential problems. Other countries such as India and Vietnam also have a well-coordinated hybrid rice program.

Government policy intervention that proved helpful to wider adoption of hybrids. The governments in these nine countries have played, in varying degrees, a catalytic role in the development and dissemination of hybrid rice technology. In some countries, hybrid rice technology generation and commercialization have been integrated into the government's NRP. The government of each country has provided financial support to hybrid rice R & D, seed production, and capacity building. The policy environment in these countries was made conducive for the development and dissemination of hybrid rice technology.

In general, some government interventions proved helpful in promoting hybrid rice among farmers. These included the provision of some form of subsidy to both hybrid rice farmer and hybrid seed producer during the initial stages of the hybrid rice program: the creation of a policy environment to enhance private-sector participation such as tax breaks, sanctioned seed importation, etc.; and support for massive information and public awareness campaign, capacity-building activities, and advocacy/

endorsement of hybrid rice projects to external donors such as FAO and UNDP.

Specific interventions have also been helpful in specific countries. In Vietnam, for example, hybrid rice seed production was carried out by a network of four focal provinces, where farmers gained competence in the new technology and where local leaders fully supported the program. In the early phase of hybrid seed production, the government, through the Department of Agriculture and Forestry Extension gave seed growers parental lines, fertilizer, insecticides, and GA_3, all amounting to \$400 ha^{-1} for free. Also, the government, through its provincial extension system, gave a price subsidy to farmers in purchasing commercial hybrid seeds, equivalent to 30-50% of the true value of the seeds.

As in Vietnam, dissemination of hybrid rice technology in Indonesia has been integrated into the national program. The government supported local seed production and at the same time allowed the importation of hybrid rice varieties by private seed companies. The government also provided extension services, monitored pest and disease incidence, and extended credit assistance to buy seed, fertilizers, and pesticides for commercial cultivation of hybrid rice. Private seed companies also offered to produce public hybrid seed.

Wide-scale adoption of hybrid rice seeds in the Philippines was supported by the government, providing marketing assistance to farmers such as production loans, discounted prices of hybrid seeds, installment payment schemes, and fertilizer support. The government procured hybrid seed produced by both the public and private sectors and assisted the private sector in the marketing of seeds. Until 2003, production inputs such as GA_3, seeds of parental line, and financial assistance were also provided to seed growers for free or at subsidized prices.

Further policy support needs in national programs. Several government interventions in the area of policy formulation could be useful to further develop and promote on-farm use of hybrid rice technology in tropical Asian countries. Among these are (1) the development of food security agenda or rice master plans in some countries and the integration of hybrid rice programs into these plans; (2) the adoption of mechanisms that shall allow for focused targeting in hybrid rice commercialization, limiting the deployment of hybrids only to areas where they hold the highest potential; (3) the determination of options for types and extent of subsidies and their scale down/phase-out, seed pricing, seed procurement and distribution schemes, and measures to strengthen entrepreneurship of cooperatives; (4) the development of a framework for improving the flow of information among the public, private, and NGO sectors, and other stakeholders; (5) the formulation of a framework to mobilize private-sector investment in hybrid rice research, seed production, and technology dissemination; (6) the development of a framework for public-private-sector partnerships that shall include intellectual property access/protection considerations; (7) national capacity enhancement measures; and (8) the development and/or strengthening of hybrid seed regulatory agencies for seed certification and quality control through DNA-based system development, training, regional harmonization, and exploration of the concept of 'truthful labeling.' To devise policy environments supportive of hybrid rice research and production over the next 30 years, both public and private sectors should carefully balance and address the market-driven rice economy, the declining paddy resource base, trade liberalization and globalization, and Asia's economic crisis. Effective plans will depend heavily on adequate information on genetic resources, land use, water availability and irrigation potential, hybrid rice infrastructure, and policy advocacy.

Role of the IRRI-ADB Project

The IRRI-ADB project has been very helpful in developing the capacity of tropical Asian countries for hybrid rice technology development and dissemination. The salient achievements of the project include (1) the establishment of a functional network composed of the nine countries, China, IRRI, FAO, and APSA that gave network members the chance to share germplasm, knowledge, and information useful for expediting the development and use of hybrid rice in Asia; (2) the capacity enhancement of thousands of researchers, seed production personnel, technicians from government, private, and NGO sectors, and farmers in the different member countries on hybrid rice technology development and use; (3) the facilitation of breeding and release of more than 2 dozens of public-sector hybrids for use in commercial rice production; (4) the establishment of a mechanism for international hybrid rice evaluation; (5) hastening the improvement in yields of hybrid seed production plots in several countries to levels exceeding the economic breakeven points, thus making both hybrid seed production and commercial hybrid production profitable; and (6) facilitating of the establishment of small-to medium-scale new business enterprises and cooperatives engaged in hybrid seed production and marketing as a result of commercialization thrusts in several countries, among others.

Expectations from IRRI

To sustain and further strengthen the hybrid rice programs of the NARES in Asia, particularly in view of the completion of the IRRI-ADB project in 2005, and the expected change in IRRI's hybrid rice program leadership, future activities may be tackled in the following areas: (1) parental line development and germplasm exchange; (2) value addition to existing parental lines using tools afforded by genomics/biotechnology (e.g., golden or high-iron hybrids, etc.); (3) training on frontier areas such as marker-aided selection to expedite breeding progress at NARES; (4) organization and/or sponsorship of international collaborations and meetings; (5) consultancy service provision/technical advice or backstopping; (6) coordinated international germplasm evaluation; (7) information sharing and exchange, including the use of information and communication technology; (8) assistance in national policy formulation and harmonization using the experience accumulated across countries; (9) facilitation of IP-related private-public sector partnerships, particularly with multinational corporations; (10) establishment of an international DNA databank for public/private-sector germplasm; and (11) regional policy and socioeconomic studies, including in-country and regional impact assessments.
It is important, however, that IRRI activities be complementary to and synergistic with other efforts on hybrid rice technology development and commercialization. IRRI must bring into a global hybrid rice technology the SWOT (strength, weaknesses, threats, and opportunities) analysis, the dimensions of China, the private sector, and the varying strengths of hybrid rice programs in tropical Asian countries, and must determine future activities likely to deliver the greatest impact.

Challenges and issues for future hybrid rice R&D

A number of R & D-related issues still need to be addressed across countries—(1) the attainment of higher levels of heterosis, (2) durability of resistance to insect pests and diseases; (3) improvement of grain quality, both physical and eating characteristics; (4) stability of hybrid performance across years and environments; (5) biofortification/introgression of value-added traits in hybrids and parental lines; (6) germplasm base diversification; (7) development of integrated crop management systems for both hybrid cultivation and seed production; (8) the attainment of high and consistent seed production yields and/or lowering the cost of seed production; (9) the exploitation of hybrid rice for fragile environments; (10) enhancement of technical capacity in several countries; (11) fostering of institutional linkages among the public, private, and NGO sectors; (12) socioeconomic and policy research; and (13) impact assessment using determination of spillover benefits such as those observed in the Philippines (e.g., use of hybrids under direct seeding, lower seeding rates, generation of additional employment, and easier farmer-adoption of precision-enhancing technologies). The degree of importance of any or all of the above factors varies from country to country and the levels of intervention needed vary accordingly.

Summary recommendations on policy intervention for development and dissemination of hybrid rice

Strengthen government support. Sound and consistent policy frameworks and adequate funding for the development and implementation of hybrid rice programs are needed across the tropical Asian countries mentioned earlier. Also, clear and effective government regulations regarding plant breeders' rights (plant variety protection) and intellectual property rights must be put in place to encourage the private sector to invest more in hybrid rice R & D and provide incentives to public-sector scientists.

Strengthen public-private sector partnership. Public-private sector partnership should be enhanced to ensure effective and successful development and commercialization of hybrid rice technology using less government resources. Seed production infrastructure has to be strengthened and mechanisms put in place so that public-and-private sector efforts on commercialization are tightly linked with hybrid rice breeding institutions and that responsibilities for seed production and commercialization are shared. Hybrid rice technology has, for the first time in many countries, encouraged the private sector to invest heavily in and share in alleviating the erstwhile purely government's burden of enhancing agricultural modernization. This situation needs to be sustained.

Reduce cost of hybrid seed production. Cheaper seed production technology packages should be developed to make hybrid rice seed production economically viable and hybrid seeds more accessible to resource-poor farmers, even without government subsidies for commercial cultivation. The technology for seed production should be within the farmer's reach so they can also benefit from seed production-related activities.

Encourage 'seed to shelf' concepts. All sectors engaged in hybrid rice dissemination should be encouraged to develop and implement 'seed-to-shelf' integrated rice production system. These not only shall ensure both farmers and seed growers of markets but also raise the rice quality standards for consumers, make easier the promotion and dissemination efforts of all concerned sectors, and expedite the adoption of hybrid rice technology on farm.

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Role of the private sector in the dissemination of hybrid rice technology

Ish Kumar

The significance of rice, which is eaten by nearly 2.4 billion people everyday globally, can be well understood. In rice-growing countries, the very word 'rice' means life to the people. On account of the burgeoning population, the world is hard pressed to produce more rice as it is a major staple food. The yield ceiling of rice varieties has been raised through the development of rice hybrids. The seed business involving inbred rice varieties was primarily with the public sector but, with the development of rice hybrids, the private sector now has the opportunity to invest and have a major stake in the hybrid rice business. In India, more than 95% of the hybrid seed is currently produced and marketed by the private sector. Though the private sector has put its efforts and resources in the dissemination of the technology, the huge potential area to be covered under the hybrids in a short span of time necessitates public-sector support and revision in some policies to disseminate this technology faster. The private sector is targeting to increase the area under hybrid rice by about 50% each year. It this context, the organization of hybrid rice seed production and dissemination in private seed companies and desirable linkages of private seed industry with the national and international organizations have been discussed. Although the private sector is now investing heavily in hybrid rice research and dissemination, the following concerns need further discussion: removal of specific constraints or revision of some policies with respect to sharing of germplasm by the private sector with the national programs, involvement of the private sector in seed production and distribution of public-sector hybrids within and across countries, brand naming of public-bred hybrids by the private sector, profit sharing, removal of some constraints to obtaining import permits and phytosanitary clearances, hybrid seed movement from country to country, mechanism of public-private sector partnership in jointly addressing issues of common interest, and others.

Rice plays an integral role, both in sustaining the world's appetite and cultural tradition. It is eaten everyday by nearly 2.4 billion people globally. Rice is the predominant food crop of Asia, where nearly 90% of the total rice is produced and consumed. On account of the ever burgeoning population in most of the rice-growing countries, the challenge to increase rice productivity indeed poses a great pressure on breeders as yield improvement in conventional rice varieties is meager. Currently, the decreasing water resources and the loss of available land to urbanization are major constraints to increasing rice production. Increased rice production is expected to primarily come from the development and dissemination of proven yield-enhancing technologies such as hybrid rice cultivation. Simultaneous improvement in other parameters—land productivity by upgrading irrigation facilities and expanding use of inputs—can also help maintain this increase. In India and many other countries, rice breeders have bred many high-yielding rice hybrids both in the public and private sectors (Table 1). However, only those private-or public sector-bred rice hybrids, the seed production and commercialization of which was undertaken by the private sector, could become commercially popular. The continuous availability of the seed of such hybrids was made possible only with the help of the private sector. On the other hand, the market supply of the certified seed of improved high-yielding varieties was completely dominated by the public sector in many countries. In India, as soon as the government implemented the policy of making quality foundation seed of inbred varieties and/or parental lines of many public-bred hybrids of crops (e.g., corn, sorghum, millet, sunflower, cotton, etc.) available, the private sector was

Table 1. Public-sector and some private-sector rice hybrids announced to be released in India.

Public sector	
Public-sector institutions	APRH-1, APRH-2,CORH-1, KRH-1, CNRH-3., DRRH-1, KRH-2, Pant Sankar Dhan-1, CORH-1, ADTRH-2, Sahyadri, NSD-2, Pusa RH-10
Private sector	
Hybrid Rice International	6201*, 6111, 6444*, 6516, 6129
Pioneer	PHB 71*
Nath	Loknath 505, Golaknath 509
Syngenta	Sahyadri
JK	JK401, RH-10*
Advanta India	PAC 801, PAC 807, PAC 832
Monsanto	RH 204*, RH 664, RH 257
Mahyco Seeds	Suruchi 5629, 5170,5319, 5180
Zuari Seeds	6302,6601
Namradhari seeds	KRH-2
BioSeed	BioSeed 401 and 403
International sector	
IRRI	Mestizo 1,2,3,4, Sahyadri

encouraged to undertake seed production of these public-bred varieties/hybrids. Indeed, with the new seed policy of 1998, many new national and multinational private seed companies entered the seed markets, which, along with many other factors, greatly helped in putting a strong foundation of hybrid seed availability in terms of time and quantity. The availability of hybrid seeds helped in increasing the productivity of the above mentioned crops in the country. In India alone, through the cultivation of hybrid rice in the last 3 yr (2002-04), nearly 1.04 billion ha were planted, from which an additional yield of nearly 1.04 million t could be harvested at 1 additional t ha^{-1}. This additional yield from the same land is worth US$130 million. Currently, the private sector in India alone has more than 95% of the market share in hybrid rice seed production and sale. In hybrid rice, the private sector has played and is bound to play a significant role in the dissemination of this technology in the future too. However, on account of the lack of certain clear policies in some countries and of restrictive policies in others, this technology has not spread as fast as expected, except in certain areas.

Organization of hybrid rice seed production in the private sector

The seed production and distribution of inbred rice varieties are confined to the public sector and not on the private sector for obvious reasons: low profit, low seed requirement, and low seed change ratio every year. In the case of hybrids, seed production has been undertaken mostly by the private sector because it has better profitability and repeat seed demand every season. But the public sector has lost interest in hybrid seed production because of inherent uncertainties and difficulties in seed production and initial failures in getting economically viable seed yields. Moreover, heavy resource-oriented activities (i.e, greater labor requirement) and reduced budget for seed production refrained the public sector from further undertaking such a risky activity.

In the private sector, especially for proprietary hybrids, the nucleus and breeder seed production of commercial/candidate rice hybrid(s) is always a within-company activity and is handled by the breeders concerned. However, for public-sector rice hybrids, commercialization is undertaken by the seed companies once the breeder seed of parental lines is obtained from the public sector. They are later multiplied by the company.

Similarly, in the private sector, foundation seed production is the responsibility of the "supply chain" and is undertaken under direct supervision of company staff. Foundation seed production is also done in the company's own/leased farms, again a strictly internal activity. In many companies, a special task force is constituted to ensure the quality of the parent seed. Although parent seed production is the responsibility of this team, quality check falls under the responsibility of the company's quality assurance department. The conditioned and quality-assured parent seed is packed and distributed to the company's registered seed-producing farmers, either free of charge or fully paid, depending on the specific company's policy.

Commercial hybrid seed production is undertaken at farmers' fields through the supervision of company staff. The production area is organized through 'influential' organizers in the area. The companies appoint their own staff in the field to provide guidance and ensure the implementation of the recommended technology to help farmers achieve higher yield. The major companies even supply GA_3 to the farmers free of cost. (A few companies, however charge for GA_3). The technical guidance for hybrid rice seed production is provided to farmers in any stage at no charge at all. The company field staff monitor the fields for timely rouging, supplementary pollination, and they exclude any field that is not up to the mark for isolation and/or seed purity.

Since hybrid seed is produced in the farmer's field and procured on a per kilogram basis, the increased profit by way of any increase in hybrid seed yield goes directly to the farmer (seed producer). The companies do not reduce the procurement price or charge any guidance fee, even in such cases. Indeed, a symbiotic relationship exists between seed companies and their local contract seed producers. It is exemplary as it is developed over a long period primarily on the basis of mutual trust, integrity, and monetary benefits. The hybrid seed so produced is collected from the farmer's field under a buy-back agreement by the company staff. After proper drying, the seeds are sent to the seed processing center at the company's expense. The company supplies the gunny bags in which the seeds are packed. The first payment is made to the farmer upon pick up of the seed. The final payment is made after seed conditioning and germination clearance for the hybrid seed material is secured.

Hybrid rice dissemination activities by private seed companies

The seed companies promote their products primarily by setting up demonstration plots in farmers' fields through their own staff—i.e., the sales and market development teams. Wherever possible, the help of government agencies in establishing demonstration plots and field days is sought. The hybrid seed for demonstration purposes is supplied free of charge to farmer groups and government agencies. The companies organize field days on selected demonstration plots, arranging visits of farmers, concerned government officials, seed distributors, and dealers. Knowledge on hybrid rice technology is disseminated to the beneficiaries through on-the-spot discussion with experts. Successful and large seed companies also organize meetings with millers in the area, getting feedback and involving them in promoting the products, wherever possible.

The private-sector seed companies, which have accredited hybrids, also participate in the seed subsidy program of the public sector. The private sector also interacts with the public-sector grain procurement agencies to share with them information on their hybrids' grain characteristics so the farmers get a reasonable price for the produce of these hybrids.

Another important factor in product dissemination is providing a timely supply of quality hybrid seed in the market, the mantra of almost all private-sector companies. Most companies keep some buffer stock to seed, producing it one season earlier to ensure a timely supply for the early-season market.

For the new (pre-commercial) hybrids, on-farm demonstrations start one to two seasons earlier than commercialization. This helps create the demand for the new products.

Before the start of the sowing season, companies organize publicity campaigns by meeting with farmers and dealers. The literature on cultivation practices is also developed and distributed among farmers. The large companies provide after-sale service to farmers through their network of agronomist and sales staff.

Desirable linkages of seed industry with national and international hybrid rice institutions

Development of technology and its transfer to the seed sector primarily depend on the developing countries. Some large seed companies, because they have available resources, can develop their own technology. Others can acquire a developed technology though regular license agreements (e.g., *Bt* gene cotton). On account of financial constraints or lack of technical manpower and germplasm, some small countries or many national/local private companies within a country cannot afford to have access to state-of-the-art technology. These companies depend heavily on national organizations/international institutes such as IRRI. So far, IRRI has played a very significant role in freely supplying the germplasm, information, technology, and trained manpower to many countries. Such efforts must be continued.

Because the national and international institutes have the expertise, infrastructure, and germplasm, the seed sector has a keen interest in developing linkages with them on projects of mutual/commercial interest—e.g., development of new CMS lines, seed production for different hybrids, development of insect and disease resistance in parental lines, breaking of seed dormancy, grain milling, seed quality, seed quarantine-related issues, and others.

Public-private sector partnership in disseminating hybrid rice

In the initial years of the hybrid rice project, very few hybrids were available and the major issue then was breeding of acceptable hybrids. With such hybrids now available (Table 1), the major issue is producing the desired quantity of hybrid seeds. In India, seed production of a very few public-sector hybrids has been undertaken by the private sector. In countries like Vietnam, where hybrid rice is also cultivated on a large scale, about 20% of the seed is produced in the country and nearly 80% of hybrid seed is imported from China. There are no special incentives given to the private sector to encourage it to venture into seed production. To meet the seed requirements within the country, public-private partnership can play a major role. The objectives of such a partnership should be a

i) win-win situation,
ii) efficient growth of the hybrid rice sector,
iii) increased income of farmers, and
iv) helping society meet productivity objectives.

The spread of this technology will remain slow until hybrid seed production in a country becomes less expensive. The private sector, in such a case, should be encouraged to produce seed of public-sector hybrids in some other countries/ areas and then just import the seed. Until then, investment by the public sector should focus on research to increase hybrid seed yield. This offers another option to disseminate hybrid rice technology faster.

Issues in hybrid rice dissemination

In spite of the availability of hybrids, dissemination of this technology did not occur as expected. Various issues have cropped up. The philosophy of market intervention at this point should be not to ignore private sector involvement but rather promote it, ensuring the orderly and efficient working of market forces and enabling them to give efficient performance. Policymakers, under such conditions, should work on these principles:

i) Let the good hybrid seed reach the farmers irrespective of place of origin.
ii) The movement of hybrid seed (after meeting quarantine requirements) should occur smoothly to ensure yield stability and proliferation of the seed business.

This would ensure price stability of rice as a commodity in most countries. Since the area to be brought under hybrid rice cultivation is very large, no single agency, either public or private, is sufficient to promote this technology at the desired speed. In areas where the public and private sectors worked together in the past, hybrids have become popular. To further spread hybrid technology, special efforts are needed to put up large-scale demonstration farms in more areas. The large extension personnel of the departments of agriculture of different countries can be strengthened so they can undertake joint testing of popular private-sector hybrids in many new states and even in already developed areas. The help of the public sector in developing new hybrid rice markets in the less developed states, where marketing infrastructure is poor, would be tremendous in achieving faster dissemination of this technology.

During the initial stages of hybrid rice development, commercial produce of hybrid rice (grains) was given a lesser price in the market because of the misconception about it. Now that good-quality hybrids are being marketed, the right price of the commercial produce should be ensured by the grain-procuring agencies. The help of government in procuring these when farmers face marketing difficulties would be crucial in ensuring faster adoption of this technology by farmers.

Seed production issues. Unlike in the past, availability of a good high-yielding rice hybrid is no longer an issue today. The major factor in hybrid rice dissemination at present is how to produce a large quantity of good-quality seed to meet market demand. In India alone, market demand is increasing and will continue to do so by at least 50% every year. In spite of best efforts, private seed companies in India could not produce the required quantity of seed this year. One of the major deterrents is the shortage of water supply in seed production areas. Revision in policies regarding water and power availability during the crop-growing period in the dry season in identified hybrid rice seed production areas can help produce the required quantity of seed.

Most of the seed production agencies have to import GA_3 from China. Since this essential chemical is expensive, the government should abolish import duty on it. In India, this import duty has been levied in the last 3-4 yr; this was taxed before. This will make GA_3 available at cheaper rates.

Policymakers may also consider other input interventions. These must be made available: a) fertilizers and chemicals; b) farm machinery, especially for harvesting and threshing; c) seed processing units; and d) cold storage for unsold hybrid rice seeds.

Public- private sector linkage issues. Germplasm availability. The private sector realizes the importance of the public sector as source of the needed germplasm. The small-scale and new private-sector companies have always heavily depended on the public sector. Although with their resources, large multinational companies can acquire germplasm from outside, local germplasm is still considered crucial to attain progress. Currently, because of the changed environment and the lack of a clear public-sector policy, the private sector is unable to get improved rice germplasm from national programs. It affects the R & D activities, particularly those of small seed companies. There should be a strong linkage and clear policies for obtaining germplasm for free or on payment basis.

Hybrid branding and profit-sharing issues. The public sector's strength is on germplasm development and breeding of new hybrids, whereas the private sector's strength is on seed production, marketing, and also breeding. The pace of hybrid rice development in the public sector can be greatly enhanced by working with the private sector. Clear policies on a) procurement of public-sector hybrids in the early stages, b) renaming of public-sector hybrids by the adopting seed company (they have a brand image to maintain) and c) profit sharing are needed.

Contract/joint research project issues. A clear mechanism between national/international organizations on one hand and the private sector on the other hand with respect to developing and funding joint projects of mutual interest has to be developed. Currently, the private sector finds it hard to obtain phytosanitary certificates for seed export. The reason for this is that most of the plant quarantine laboratories in the different countries are either not fully equipped or lack the protocol for quick testing to meet the phytosanitary requirements asked for by the importing countries (Table 2). Such joint research projects on seed quarantine can develop time-saving laboratory techniques to ensure quick movement of the seed, which is in the interest of both sectors.

Table 2. Diseases and insects that need to be checked for quarantine purposes.

Aphelenchoides besseyi
Crinkle stunt phytoplasma
Ditylenchus oryzae (stem nematode)
Ephelis oryzae
Fusarium graminearum (scab/node rot)
Heterodera oryzae
Hoja blanca virus
Psedomonas syingae pv. *panici*
Pycularia grisea
Rice dwarf virus
Rice stripe virus
Tilletia barclayana
Trogonoderma granarium
Xanthomas oryzae pv. *oryzae*
Xanthomas oryzicola
Other *Xanthomonas* spp.

Similarly, mechanisms to make use of available germplasm in private and public organizations, even without physically sharing, need to be developed. Using a wide base of germplasm can hasten the breeding of hybrids. Also, there must be mechanisms to train farmers (on-hand) through the joint efforts of the private and public sectors, especially in the new seed production areas. This will help increase productivity in seed production.

Seed export issues. The validation for import permits at present is 3-4 wk. It takes time to complete the formalities for seed export activity. To meet the targeted export requirements, making such import permits valid for 3 mo may be considered. Governments should also equip more plant quarantine laboratories to meet the diverse phytosanitary requirements of the different rice-growing countries at a faster pace.

Seed export in some countries is virtually impossible. To ensure the availability of superior hybrids from other countries, policies to liberalize seed trading across countries have to be reviewed.

Joint evaluation

Private-sector hybrid testing in the different countries is currently done by individual companies. To identify the best hybrids developed elsewhere in the world, a policy to jointly test public- and private-sector hybrids by a neutral agency such as IRRI must be put in place. The joint testing of hybrids was initiated by IRRI last year but, after the end of the IRRI-ADB project, plans to continue this are not yet final.

Notes

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Socioeconomic evaluation of hybrid rice cultivation: the Bangladesh case

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The relative profitability of hybrid over inbred rice cultivation, the contribution of private seed companies to disseminate hybrid rice technology, and farmer's perceptions and constraints to adoption of hybrid rice were studied in Bangladesh. A farm household survey was conducted at three major hybrid-growing locations in Bangladesh: Challan Beel area, Jessore, and Barisal. A total of 120 hybrid rice growers at the three locations were interviewed to obtain primary data; the secondary data were collected from different seed companies of Bangladesh. The results showed that hybrid rice area in Bangladesh has increased from about 10,000 ha to 61,000 ha in the last 6 yr, indicating a slow adoption rate of hybrid rice all over the country. In 2004-05, different companies in Bangladesh produced 392 of hybrid seeds but imported 1,080 t. About 38% of the farmers claimed that hybrid seeds were in short supply, whereas 47% said these were readily available. The availability of hybrid seed, however, has now improved. A common concern is that farmers have to pay more than double (130%) for hybrid seed/seedling over inbred seed. Other variable costs were found to be similar, except fertilizer and pesticide costs. However, farmers obtained 24% higher yield from hybrid rice than from inbred rice varieties. Though the price was 5% less than that of inbred varieties, the farmers still earned almost 32% higher net profit from hybrid cultivation compared with growing of inbreds. About 98% of farmers were convinced of the hybrid's higher yielding ability, but majority of them complained about the lower eating and cooking qualities. Most of the farmers (78%) wanted to grow hybrids in the next season in large areas. The study identified the major constraints to hybrid rice adoption: higher price of seed, poor cooking quality, and higher incidence of pests and diseases. These constraints need to be addressed to ensure wider adoption of hybrid rice in Bangladesh.

Bangladesh, with a population of 130 million in a land area of 144 km^2, is one of the more densely populated countries in the world. Agriculture employs nearly 62% of its labor force and contributes one-third of its gross national product. However, this sector suffers from such various problems as small, unviable, and fragmented landholdings; frequent natural disasters; and limited technological progress and low productivity of resources. The principal crop and dominant food staple is rice, which occupies nearly 75% of total cropped area in the country. The 1960s experienced rapid growth in rice production because of increases in cropping intensity, the change from direct seeding to transplanting, and introduction of modern agricultural inputs such as chemical fertilizers and irrigation by power pumps, promoted under the government's "grow more food production program" (Ahmed 1979). Rice production grew from 12.1 million t in 1959-60 to 16.9 million t in 1969-70, an increase of 40% over a decade. Almost half of this came from the expansion of cropped area. Although high-yielding rice varieties (HYVs) were adopted in early 1968, the rate of adoption remained low until 1975-76. The rapid diffusion of HYVs took place after the mid-1980s, with the liberalization of policies regarding procurement and distribution of agricultural inputs and reduction of import duties on agricultural equipment (Hossain 1996). The rice area covered by modern varieties has now reached nearly 66% supported by an expansion of minor irrigation by tube wells and pumps, which now covered nearly 48% of the cropped area. The increase in domestic production was low, entirely dependent on the growth in rice yield. Indeed, Bangladesh must target a higher rate of growth in yield than the required increase in rice supply to meet the demand and to release land for other crops the demand for which has been growing faster than that for rice.

The United Nations has projected that, even by 2020, the Bangladesh population will grow at 1.2% yr^{-1} and will reach 173 million, 31% higher than the present number. Nearly 46% of the population will live in urban areas in 2020 compared with 27% now. Farmers will have to generate a larger marketable surplus to feed the growing urban population. Although recent household expenditure surveys of the Bangladesh Bureau of Statistics (BBS) show that per capita consumption of rice has started to stabilize in the rural areas and has been declining in urban areas, demand will continue to increase because of population growth. The National Commission of Agriculture projected that, to remain self-sufficient, Bangladesh will need to produce 47 million of paddy (31.6 million t of clean rice) by 2020. This requires a production growth rate of 1.7% a year.

Rice breeders have been trying to develop input-sufficient, pest-resistant, and higher yielding varieties to increase rice yield while sustaining the natural resource base. One innovation is the development of hybrid rice varieties for the tropics. The aim is to shift the yield potential of rice by 15-20% more using the same amount of agricultural inputs. The technology has attracted the attention of research leaders and policymakers in many Asian countries who see it as an opportunity to overcome the yield ceilings reached by many enterprising farmers in the irrigated ecosystem.

Hybrid rice in Bangladesh was initiated in 1993, getting momentum in 1996 onward with support from IRRI. Some private seed companies and NGOs have recently introduced hybrids from India and China, testing these in farmers' fields. BRRI has also recently released a hybrid rice variety named BRRI Hybrid Dhan 1. Little work has so far been done on the socioeconomic aspects of hybrid rice cultivation. Thus, an in-depth study of hybrid and inbred rice varieties at the farm level was done to estimate yield advantage, profitability, and farmers' acceptance of hybrid rice technology.

The study aimed to find out the comparative profitability of hybrid and inbred rice cultivation; identify constraints to hybrid rice production in Bangladesh; know farmers' perceptions about hybrid rice cultivation; and understand the role of private seed companies in the production and distribution of hybrid rice seed throughout the country.

Methodology

The present study used both primary and secondary data in the analysis. Secondary data were collected from different seed companies involved in production, distribution, and importation of hybrid rice seed. To collect primary data, farmer interviews were conducted at three locations in Bangladesh where BRRI-released hybrid rice and other imported hybrid rices were grown in the boro season: Challan Beel area including Pabna, Natore, and Sirajgonj districts; Magura and Jessore districts were under Jessore region; and Barisal District in Barisal region. Purposive sampling yielded 120 sample farmers from the three study sites (40 from Challan Beel, 50 from Jessore, and 30 from Barisal); they were interviewed with the aid of structured questionnaires. Sample size and choice of site were determined by the availability of hybrid rice growers, who were scattered in the study villages. The collected data were then entered, coded, edited, and analyzed using SPSS and MS Excel software. Furthermore, the Tobit model was also applied to identify biophysical and socioeconomic factors that determine adoption of hybrid rice at the farm level.

Results and discussion

Area under hybrid rice cultivation and seed production import

Different seed companies in Bangladesh estimated hybrid rice area on the basis of sales data of hybrid rice. We observed that, from 1999-2000 to 2004-05, the area under hybrid rice increased from about 10,000 ha to 61,000 ha (Table 1), indicating the farmers' gradual acceptance of hybrid rice.

Farmers must buy hybrid seed every year because they cannot produce hybrid rice seed in their own farms. There are five seed companies operating in the country—BRAC, Mollika Seed Company, Supreme Seed Company, Aftab Bahumukhi Farms Ltd., and Cheus Crop. They produce and/or import hybrid rice seed.

The Bangladesh Agricultural Development Corporation (BADC) has also been modestly involved in hybrid see production. Of these companies, BRAC and the Supreme Seed Company produced a large amount of hybrid seed every year. A total of 392 t of different hybrid seed was produced by these companies in 2004-05 (Table 1). Besides production, seed companies also engaged in hybrid seed importation from China. The quality of hybrid rice seed imported by the different companies reached 1,080 in 2004-05. The total volume of hybrid rice seed sold in the same year was 945 t, which was 61% higher than that of the previous year (Table 1). This indicates that hybrid rice was getting popular among Bangladeshi farmers. The sale price of rice hybrids ranged between Tk 160 and Tk 200 kg^{-1}.

Cost of hybrid seed production

The cost of hybrid seed production at the farm level was estimated from one farmer from Barisal region. The cost of seed production of BRRI hybrid Dhan 1 was about Tk 66,319 ha^{-1}. Of this, 68% went to labor. Seed yield was only 395 kg ha^{-1}, a very low figure. Per unit cost of BRRI hybrid seed production was Tk 80.7 kg^{-1}. This cost will certainly go down by at least 50-60% with the improvement in seed yield; up to 1 t ha^{-1} is expected.

Land use pattern

The average farm size of the hybrid growers was 1.28 ha, with most farmers (63%) owning farms in the medium size category. The average farm size of this group was 0.99 ha. The large farmers had 3.23 ha. The large farms were found to devote 17% of the total operated land to hybrid rice cultivation; the small farms allocated about 34%. Although the proportion of hybrid rice area was greater in the small farm than in the large farm, the average land area for hybrid rice was bigger in the case of the large farms (Table 2).

Availability of hybrid seed

Since the concept of hybrid rice cultivation is very new in Bangladesh, we have considered the last 2 yr of hybrid rice-growing season to determine the amount of hybrid seed available. In 2003, about 25% of the hybrid rice growers complained about the supply of hybrid seed; this increased to 38% in 2004. About 47% of the farmers found seed supplied on time and readily available in 2004, an improvement over the previous year.

Yield performance and marketing aspect

The overall yield performance of some marketed rice hybrids and inbred rice varieties in the different study locations in the boro season is presented in Table 3. The highest yield (7.75 t ha^{-1}) of hybrid rice was observed in the Challan Beel area; to inbred rices BRRI Dhan 28 and BRRI Dhan 29 had a yield of 6.55 t ha^{-1}. The lowest yield (6.95 t ha^{-1}) was found in Jessore. The overall yield in all regions was 7.23 t ha^{-1}, while the average yield of inbred boro rice was 5.9 t ha^{-1}. The yield differences between hybrid and

Table 1. Hybrid rice seed production, import, sale and estimated area as reported by different seed companies in Bangladesh, 1999-2005.

Year	Production (t)	Import (t)	Total sale (t)	Seed rate (kg ha^{-1})	Estimated area ('000 ha)
1999-2000	0.30	150	150.0	15.5	9.68
2000-01	26.50	217.0	217.0	15.5	14.00
2001-02	142.85	320.3	320.3	15.5	20.66
2002-03	205.50	521.0	521.0	15.5	33.64
2003-04	181.56	585.8	585.8	15.5	37.79
2004-05	391.66	945.0	945.0	15.5	60.97

Table 2. Land use pattern for rice cultivation.

Farm category	Farmer respondents (no.)	Land operated (ha)	Land tenancy (%)	Area under hybrid rice cultivation (ha)	Area under inbred rice cultivation (ha)	Percent of hybrid area
Small (<0.5 ha)	23 (19)	0.37	23.7	0.13	0.23	33.8
Medium (0.5-2.0 ha)	75 (63)	0.99	33.6	0.22	0.54	22.7
Large (>2.0 ha)	22 (18)	3.23	10.4	0.5	1.62	16.9
Total/av	120 (100)	1.28	27.5	0.25	0.68	19.5

[a]Numbers in parentheses indicate % of total respondents.

Table 3. Yield performance and marketing aspects of hybrid and inbred rice in Bangladesh, 2004 boro season.

Item	Challan Beel area		Jessore		Barisal		All locations	
	Hybrid	Inbred	Hybrid	Inbred	Hybrid	Inbred	Hybrid	Inbred
Av yield (kg ha^{-1})	7,750.47	6,554.64	6,953.15	5,332.72	7,232.59	5,937.46	7,228.78	5,891.21
Av market price (Tk kg^{-1})	7.38	7.44	7.57	8.18	6.91	7.35	7.34	7.72
% of produce sold in the market	66.97	47.24	84.22	48.10	10.50	24.97	60.05	42.03
% of produce kept for home consumption	33.03	52.76	15.76	51.90	89.50	75.03	39.95	57.97

Table 4. Yield comparison of different hybrid and inbred rice varieties, by farmer's education and location.

Location	Education level	Hybrid yield (kg ha^{-1})	Inbred yield (kg ha^{-1})	Difference	t value	Level of significance
Challan Beel area	No education	7870.76	6403.02	1467.74	3.875	0.002
	Primary (1-5 yr)	7443.22	6183.77	1259.45	1.964	0.107
	Higher secondary (6-10 yr)	7745.15	6788.43	956.72	2.402	0.032
	College/university (>10 yr)	7801.06	6686.53	1114.53	3.008	0.024
Jessore	No education	6878.13	5385.02	1493.11	3.962	0.002
	Primary (1-5 yr)	6823.64	5103.44	1720.20	5.734	0.000
	Higher secondary (6-10 yr)	6952.9	5379.21	1573.69	5.650	0.000
	College/university (>10 yr)	7353.95	5484.73	1869.22	4.864	0.005
Barisal	Primary (1-5 yr)	7023.92	6098.20	925.72	1.706	0.149
	Higher secondary (6-10 yr)	7203.27	6054.41	1148.86	3.363	0.003
	College/university (>10 yr)	7594.41	5300.19	2294.22	7.433	0.002
	No education	7374.45	5894.02	1480.43	5.655	0.000
All locations	Primary (1-5 yr)	7037.52	5644.77	1392.75	5.400	0.000
	Higher secondary (6-10 yr)	7251.93	5993.51	1258.42	6.549	0.000
	College/university (>10 yr)	7594.62	5900.84	1693.78	7.308	0.000

inbred rice as per farm category are presented in Table 4. The test results indicate a significant difference between hybrid and inbred rice yield and among different groups of farms the study locations. There was no significant yield difference among hybrid rice varieties.

Results also showed that the market price of hybrid rice (Tk 7.34 kg^{-1}) was always lower than that of inbred rice (Tk 7.72 kg^{-1}) in all locations (Table 4). Hybrid rice fetched the lowest price in Barisal due to consumer preference for Vojan and other local coarse rice varieties. In contrast, in Jessore region, a higher proportion (84%) of hybrid rice was sold in the market (Table 3).

Economics of hybrid rice cultivation

Profitability is determined by the technology adoption cost, crop productivity, and output price. Table 5 show the results of cost and return analysis for both hybrid rice and inbred rice cultivation in the three selected regions in Bangladesh.

The cost of production included all variable cost items such as fertilizers, pesticides, irrigation water, machinery, and human and animal labor. Hybrid rice cultivation cost was about 90% higher than that of inbred rice cultivation (Table 5). This increased cost was attributed to differences in seed/seedling cost (130%), manure cost (5.6%), fertilizer cost (11%), pesticide and herbicide cost (31%), labor cost (5.2%), and capital cost (9%). Tillage and machinery cost were the same.

Despite the increased cost of cultivation and the reduced grain price of hybrid rice, the gross return from hybrid rice was 17% higher because of the 24% higher grain yield and 5% more straw yield. The net return from hybrid rice was 32.3% higher compared with that from inbred rice (Table 5). Consequently, the unit cost of production of hybrid rice was 12% lower than that of inbred rice. Thus, hybrid rice cultivation was found to be economically more efficient than inbred rice cultivation.

Seed fertilizer use in hybrid and inbred rice cultivation

The average seed rate in hybrid rice cultivation was 15.5 kg ha^{-1} (range 14-22 kg ha^{-1}) compared with 75 kg ha^{-1} (range 72-80 kg ha^{-1}) for inbred rices (Table 6). As to fertilizer use, there was not much difference, except for triple superphosphate and muriate of potash (Table 6).

Farmers' perceptions of hybrid rice

During the field survey, farmer respondents were asked questions about hybrid rice in terms of yield advantage, marketing, quality, and taste and preference. The strengths and weaknesses of hybrid rice were identified. About 98% of the farmers interviewed agreed that hybrid rice yielded higher than inbred rice. Other attributes—greater lodging resistance, less seed requirement, higher tillering efficiency, and shorter duration—were given as strengths of hybrid rice. However, the weaknesses mentioned were the following: need to buy seed every season, higher price, susceptibility to pests and diseases, poor quality of cooked rice, lower market demand, and unavailability of quality seed.

Table 5. Comparison of cost and returns (Tk ha^{-1}) between hybrid and inbred rice cultivation.

Cost item	Hybrid	Inbred[a]	Difference	% difference	t value	Level of significance
Seed/seedling cost (Tk ha^{-1})	2,490.16	1,080.61	1,409.55	130.44	9.796	0.000
Manure cost (Tk ha^{-1})	674.71	638.85	35.86	5.61	0.186	0.852
Fertilizer cost (Tk ha^{-1})	5,231.6	4,711.87	519.73	11.03	1.877	0.063
Pesticide & herbicide cost (Tk ha^{-1})	1,119.51	852.53	266.98	31.32	3.606	0.000
Irrigation cost (Tk ha^{-1})[b]	8,170.29	8,223.49	-53.20	-0.65	-0.054	0.957
Tillage and machinery cost (Tk ha^{-1})	2,914.25	2,940.97	-26.72	-0.91	-0.130	0.896
Human labor cost (Tk ha^{-1})	13,496.56	12,833.14	663.42	5.17	1.157	0.250
Interest of operating capital (Tk ha^{-1})	454.54	416.83	37.71	9.05	1.852	0.067
Total cost (Tk ha^{-1})	34,551.62	31,710.33	2,841.29	8.96	1.684	0.095
Grain yield (kg ha^{-1})	7,288.78	5,891.21	1,397.57	23.72	11.834	0.000
Grain price (Tk kg^{-1})	7.34	7.72	-0.38	-4.92	-6.006	0.000
Straw yield (Tk ha^{-1})	3,173.42	3,019.83	153.59	5.09	129.811	0.000
Gross return (Tk ha^{-1})	56,625.76	48,394.48	8,231.28	17.01	8.561	0.000
Net returns (Tk ha^{-1})	22,074.14	16,684.15	5,389.99	32.31	2.646	0.009
Unit cost of production (Tk kg^{-1})	4.74	5.38	-0.64.	-11.93	-1.838	0.069

[a]Inbred varieties are BRRI Dhan 28, BRRI Dhan 29, other BRRI-released varieties such as Vojan, Ratna, Kajla, Minicate, Noyanmoni, Shawrna, and Surjamuk.
[b]Farmers of Challan Beel area have to pay 1/10th of harvested grain as irrigation cost.

Table 6. Seed rate and fertilizer doses used by farmers in study sites.

Seed and fertilizer rate	Challan Beel area		Jessore		Barisal		All locations	
	Hybrid	Inbred	Hybrid	Inbred	Hybrid	Inbred	Hybrid	Inbred
Seed rate (kg ha^{-1})	14.71	80.36	12.03	72.19	22.35	72.32	15.5	74.81
Fertilizer dose (kg ha^{-1})								
Urea	251.53	247.12	263.99	257.2	248.6	239.78	255.98	249.48
TSP	150.47	130.92	143.82	126.84	167.15	138.26	152.5	131.23
MP	75.1	63.31	89.08	75.53	80.72	72.61	82.41	70.91
Gypsum	84.52	77.61	122.46	127.38	103.02	92.59	110.41	109.08
Zinc	9.05	8.06	11.54	11.17	13.5	11.82	11.58	10.89

Majority of the farmers had problems selling hybrid rice because of the lower demand. However, they can sometimes sell hybrid rice as inbred. Hybrid rice was also mixed with other inbred rice during milling. The problems faced by the farmers in selling hybrid rice were common in the three areas surveyed (Table 7).

The overall perception of farmers about hybrid rice is given in Table 8. Majority of the farmers (78%) wanted to grow hybrid rice in the next season to get higher yield. The best response was obtained for the Challan Beel area. Farmers wanted to grow hybrid rice in about 40% of total rice land (Table 8). About 73% would like to continue hybrid rice cultivation in the next year for better yield, whereas 60% wanted new and better hybrid rice varieties in the future. About 56-83% wanted to grow hybrid rice because it is more profitable than growing inbred rice. However, about 22% of the respondents were disappointed and decided not to cultivate hybrid rice the next time. About 18% of the farmers had a negative attitude toward hybrid rice cultivation because of the higher price seed. Poor cooking quality, less market demand, and higher prevalence of pests and diseases were the other constraints to cultivating hybrid rice.

Factors affecting hybrid rice cultivation

The results of the analysis are presented in Table 9. Age and education of farmers had a significant effect on the adoption of hybrid rice. The coefficient of farm size was found significantly negative, which indicated that adoption of hybrid rice would be higher with farmers with smaller landholdings. Similarly, the positive and significant coefficient of tenancy implies that the area under hybrid rice would be increased if tenancy level is increased. The finding also revealed that hybrid rice adoption would be significantly different among the study locations.

Table 7. Problems faced by farmers in selling hybrid rice.

Problem	Farmers' responses[a]		
	Challan Beel area	Jessore	Barisal
Low market demand	2 (5)	28 (56)	6 (20)
Not immediately accepted by traders	4 (10)	20 (40)	6 (20)
Lower price on account of poor quality	1 (3)	19 (38)	3 (10)
Other constraints	0 (0)	0 (0)	1 (3)
None	36 (90)	23 (46)	23 (77)

[a]Numbers in parentheses indicate percentage of respondents in each loca-

Conclusions

In Bangladesh, hybrid rice cultivation is increasing with the production and distribution of hybrid rice seed taken care of by different seed companies. This is obviously a good sign, as we need to increase total production to meet the increasing demand for rice. We found that hybrid rice was higher yielding by about 24%, which should help improve household food security of resource-poor farmers in Bangladesh. Hybrid rice production was more profitable than inbred rice production in all study locations. But there are some problems to be threshed out—high price of hybrid seed, taste of cooked rice, and low market demand for the currently available rice hybrids. Hence, the concerned institutions and organizations must take the necessary measures to overcome these problems.

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Table 8. Farmers' opinion about growing hybrid rice in the next boro season.

Item	Farmers' responses[a]			
	Challan Beel area	Jessore	Barisal	All locations
Farmers who will cultivate hybrid in the next boro season	37 (93)	36 (72)	21 (70)	94 (78)
Percentage of rice area to be cultivated	46	38	31	40
Reasons for growing hybrid in the next season				
Higher yielding ability	35 (88)	33 (66)	20 (67)	88 (73)
Hoping for better new hybrid	22 (55)	34 (68)	16 (53)	72 (60)
Higher pricing in the market	19 (48)	11 (22)	3 (10)	33 (28)
Higher profitability	33 (83)	28 (56)	17 (57)	78 (65)
Better taste/cooking quality	2 (5)	6 (12)	9 (30)	17 (14)
Better adaptability	7 (18)	14 (28)	7 (23)	28 (23)
Suitability for raw rice	12 (30)	8 (16)	5 (17)	25 (21)
Suitability for parboiling	5 (13)	3 (6)	4 (13)	12 (10)
Better resistance to lodging	11 (28)	19 (38)	14 (47)	44 (37)
Better resistance to pests/diseases	2 (5)	18 (36)	17 (57)	37 (31)
Greater water savings	2 (8)	0 (0)	1 (3)	4 (3)
Any other quality	2 (5)	0 (0)	0 (0)	2 (2)

[a]Numbers in parentheses indicate percentage of respondents in each location.

Table 9. Tobit regression model for hybrid adoption in all study locations.

Variable	Estimated coefficient	Standard error	t statistics	P [I Z I z]	Mean of X
AGE	0.457892	0.085976	5.326	0.0000	42.075000
EDUCATION	0.829713	0.388769	2.134	0.0328	6.516667
FARMSIZE	-2.687805	1.422948	-1.889	0.0589	1.280491
TENANCY	0.130495	0.054945	2.375	0.0175	27.452291
LOCATION	-9.184816	4.582812	-2.004	0.0450	0.250000
Sigma	18.944660	1.222873	15.492	0.0000	

Development and dissemination of hybrid rice technology: lessons from China

Xiqin Fu and Longping Yuan

The hybrid rice program in China was initiated in 1964. The first rice hybrid with a marked yield potential was developed in 1974 and released to farmers in 1976. It has been shown that hybrid rice cultivars can outyield modern, semidwarf inbred varieties by more than 20%. In recent years, hybrid rice has covered 50% (or 15 million ha) of the total rice area in China. The national average yield of hybrid rice is 7 t ha^{-1}, about 1.4 t higher than that of inbred varieties (5.6 t ha^{-1}). A yearly increase in rice production in China from growing hybrid rice can feed 60 million people each year. Because of increased yields, hybrid rice farmers can have higher income than farmers who cultivate inbred varieties. Similarly, hybrid rice seed producers can have higher income than seed producers of inbred varieties because of higher returns from hybrid seed. Since hybrid rice involves labor-intensive production, processing, and marketing of hybrid seed every crop season, it results in more employment in the rural areas. Since 1996, good results have been achieved in developing super hybrid rice varieties—they have a further yield advantage of around 20% and superior grain quality as well. Besides the advanced technology being developed by scientists, the success in the development and dissemination of hybrid rice in China is greatly attributed to strong support of the government, strong research team and integrated efforts, well-organized operating system, development of improved hybrid seed production technology and system, seed laws, effective seed quality control, and a well-established extension system. The Chinese experience in the development and dissemination of hybrid rice technology can also be duplicated in other developing countries. The hybrid rice experts in China's National Hybrid Rice R&D Center are willing to help other countries to further speed up the development and promotion of hybrid rice in collaboration with FAO, ADB, and IRRI and thereby contribute toward ensuring food security worldwide in the 21st century.

The hybrid rice program in China was initiated in 1964. The first rice hybrid with a higher yield potential than inbred rice was developed in 1974 and released to farmers in 1976. Since then, hybrid rice varieties have spread rapidly in farmers' fields. Over the years, rice hybrids have outyielded modern, inbred high-yielding varieties (HYVs) by more than 20%. In the last 10 years, hybrid rice covered half of the total rice area in China, 15 million ha. The national average yield of hybrid rice is 7 t ha^{-1}, which is about 1.4 t higher than that of inbred HYVS (5.6 t ha^{-1}). Consequently, China was able to feed 60 million people each year with the increased production brought about by hybrid rice. Hybrid rice has thus played a critical role in solving China's food problem. The higher yield from rice hybrids resulted in higher income of farmers who grew them compared with those who cultivated inbred varieties. Similarly, hybrid rice seed producers had higher income than seed producers of inbred varieties because hybrid seeds were sold at a higher price. Since hybrid rice seed production, processing, and marketing is labor-intensive, it generated additional rural employment opportunities every crop season.

China has made steady progress in the development of hybrid rice technology. Following the success of three-line hybrid rice in the 1970s, two-line hybrid rice was successfully commercialized in 1995. The two-line hybrids have shown a 5-10% yield advantage over the commercially cultivated three-line rice hybrids.

Besides, this system was able to lower the cost of F_1 seed production significantly. Also, the two-line hybrid rice breeding system allowed the use of japonica rice lines to develop super hybrid rice varieties since the initiation of the super rice research program in 1996. Several pioneer super rice hybrids have shown an additional 20% yield advantage over current commercial three-line hybrids. Some of these hybrids have higher consumer acceptability because of their superior grain quality. The success of super hybrid rice is attributed to the strategy of combining plant type improvement with utilization of intersubspecific heterosis.

Besides the technology improvement done by hybrid rice scientists, the success in the development and dissemination of hybrid rice technology in China may also be attributed to several factors.

Strong support of government

The process of developing and disseminating new technologies requires a conducive institutional and policy environment. The support of the Chinese government has played an important role in this process, which has been one of the important programs of Chinese agriculture to achieve its overall goal of national food security. Both its National Committee of Science and Technology and the Department of Agriculture have given top priority to hybrid rice technology in the national plan for agricultural research. Therefore, the manpower, equipment, and facilities, as well as funds needed for research and extension work on hybrid rice were well provided, especially during the early phase of technology dissemination. Encouraged by the successful large-scale and multilocation demonstration of hybrid rice in 1975, the central government provided 8 million yuan (equivalent to $4 million) for a 4,000-ha hybrid seed production project in Hainan Island to accelerate commercial production of hybrid rice.

A strong research team and integrated efforts

A strong team of hybrid rice experts responsible for core research work was organized. They worked closely with institutes and experts, forming a well-organized network. The members of the team were required to have not only a wide range of knowledge and rich practical experience in hybrid rice technology but also confidence, enthusiasm, and commitment to the cause of hybrid rice research and development. Principal scientists developed the national medium-term hybrid rice program with clear and achievable goals, appropriate strategies, and action plans to ensure the success of hybrid rice technology in China.

Well-organized operating system

The operating system to support hybrid rice research and development in China had three levels: decisionmaking, management, and implementation (Fig. 1). Principal scientists, leaders of government, and heads of relevant government departments are responsible for decisionmaking. The primary scientific strategies are proposed by principal scientists. These become important guides for government leaders who make the decisions and give instructions to the relevant government departments, which, in turn, provide support for research and development.

The leading group office is responsible for gathering and processing information. It

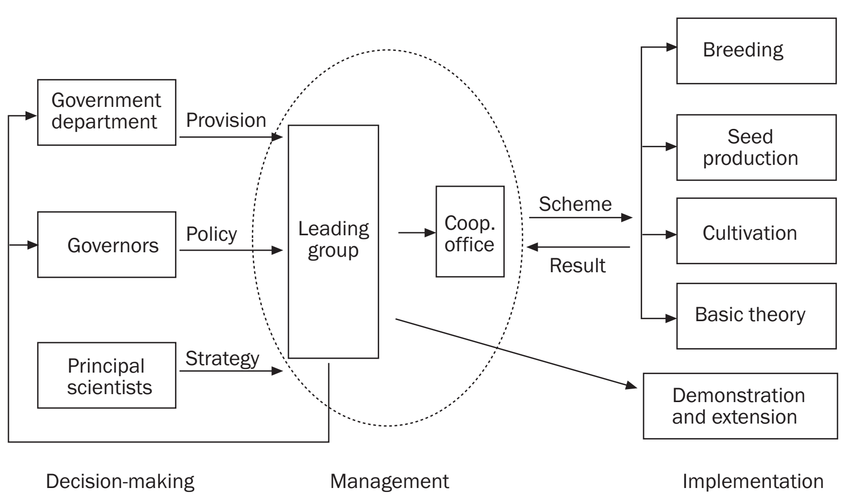

Fig. 1. The operating system of hybrid rice research and development in China.

organizes and manages the hybrid rice programs. Research schemes are made by the office on the basis of leaders' decision, proposed by the principal scientists' strategies, and government departments' provisions. Research projects are implemented by various research groups in a cooperative mode.

Demonstration and extension activities to promote new hybrid rice varieties are also undertaken by the leading group office with financial support from the government in the early years.

Hybrid seed production system and improved technology

Hybrid rice seed production is a very important link between commercial production and the breeding programs. The system of hybrid rice seed production in China operates at three levels: 1) the provincial seed company is in charge of purification of parental lines and production of foundation seeds; 2) the prefecture seed company is responsible for multiplication of maternal line seeds; and 3) the county seed company organizes the production and sale of most F_1 hybrid seeds to the farmers.

After successfully developing parental lines and their combinations, Chinese scientists went to great lengths developing the basic guidelines and protocols for hybrid seed production technology. Over a 20-yr period (1976-96), China was able to raise the average F_1 seed yield from 270 kg ha^{-1} in 1976 to 2,000 kg ha^{-1} in 1986 and to 2,500 kg ha^{-1} in 1996 (Fig. 2). Consequently, seed production cost was reduced from \$5.96 kg^{-1} to \$0.79 kg^{-1}.

The early hybrid varieties such as Nanyou 2 showed very strong hybrid heterosis and high yield potential. The seed demand increased rapidly because of the excellent performance in farmers' fields. To meet the increasing seed demand, seed companies expanded the area devoted to hybrid rice seed production. Hectarage peaked in 1978; it then decreased because the early-developed combinations became susceptible to the yellow dwarf disease.

In 1985, Weiyou 6, a new hybrid variety with high yield and resistance to yellow dwarf disease, was released. Consequently, seed production area again increased. The area of seed production reached a second peak in 1990. The seed production brought much more profit, which stimulated seed companies to expand further the production area. There was an oversupply in the seed market in 1991. With the increase in seed yield and some decrease in total rice production area from the 1990, the area for hybrid seed production was maintained at 100,000 ha (Fig. 3).

Seed laws and strict quality control of hybrid seeds

Agricultural legislation has been strengthened in China to improve agriculture. In the past two decades, the Chinese government has promulgated a series of laws and regulations—e.g., Law on Agriculture of the People's Republic of China, Law on Agricultural Technical

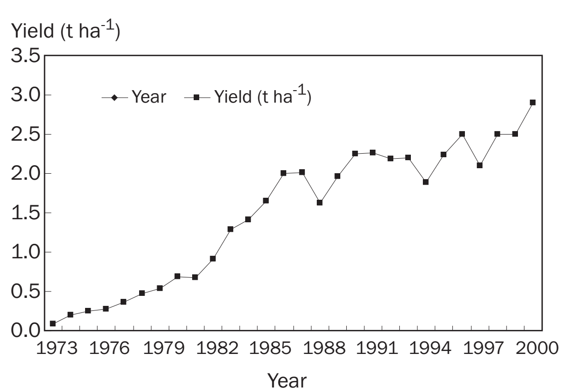

Fig. 2. Yields of hybrid rice seed in China.

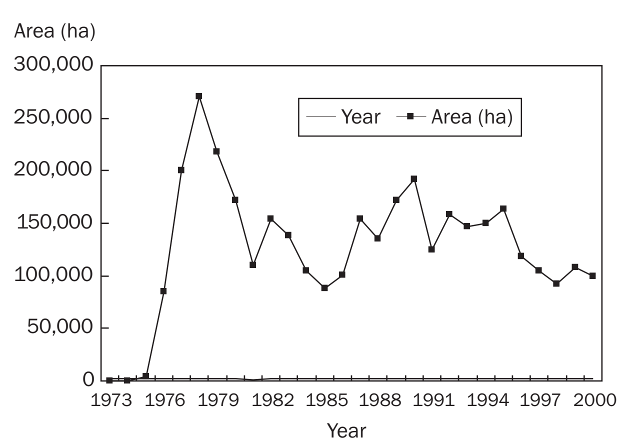

Fig. 3. Hybrid rice seed production area in China.

Extension, and the Seed Law of the People's Republic of China.

In China, seed production and commercialization must be in compliance with the Seed Law (made effective in 2000 and revised in 2004, this replaced the Regulations for Seed Management of the People's Republic of China issued in 1989) and regulations promulgated by local government units. Before commercial release, a newly developed hybrid should pass a multilocation yield trial, a regional yield trial, and a production demonstration. It should then be approved by the Crop Variety Appraisal Committee.

Seed purity is an important factor that affects yield potential of hybrid rice varieties. The yield of hybrid rice decreases by about 80-100 kg ha^{-1} for every 1% decrease in the purity of hybrid seed. China has a well-established hybrid rice seed industry and well-instituted national standards for hybrid rice. Poor purity seeds are not allowed for commercial production. Seed quality standards are in place and being followed very strictly (Tables 1 and 2).

Well-established extension system

China has 230,000 extension units at the township level and beyond, forming a nationwide agro-tech extension network. A specific system for disseminating hybrid rice technology was well-established. After certification and before the release of a new hybrid, high-yield demonstration fields and on-the-spot meetings were arranged to convince farmers as well as policymakers and leaders at all levels. Primary demonstrations could also help identify or monitor problems that scientists must address. Extension technicians were trained to promote the new hybrids and undertake hybrid seed production. Farmers were also educated on hybrid rice technology through educational films. Millions of wall charts, atlases, pictures, posters, and booklets were published to rapidly popularize hybrid rice technology in China.

Appropriate policy support for capital investment in the extension system has helped achieve the rapid progress of hybrid rice production. In the late 1970s, seed companies producing hybrid seeds were tax-free. Subsidies were sometimes given to seed companies when their seed yield was poor.

Private seed companies such as Longping High-tech and Yahua Seeds actively participate in the development and promotion of hybrid rice technology, playing a more important role in the commercialization of hybrid rice. The hybrid

Table 1. Seed standards for parental lines and F_1 hybrids.

Seed grade	Purity (≥ %)	Cleanliness (≥ %)	Germination (≥ %)	Moisture (≤ %)	Weed seeds ≤ grains kg^{-1}
A line					
Foundation	99.9	99.0	90.0	13.0	0
1st class	99.5	99.0	90.0	13.0	0
2nd class	99.0	97.0	85.0	13.0	5
B line					
Foundation	99.9	99.0	96.0	13.0	0
1st class	99.5	99.0	96.0	13.0	0
2nd class	99.0	97.0	93.0	13.0	5
R line					
Foundation	99.8	99.0	96.0	13.0	0
1st class	99.5	99.0	96.0	13.0	0
2nd class	99.0	97.0	93.0	13.0	5
F1 hybrid					
1st class	98.0	98.0	93.0	13.0	0
2nd class	96.0	97.0	90.0	13.0	5

[a]Criteria set by the Ministry of Agriculture through the China National Criterion Bureau. 1st class and 2nd class seeds are certified seeds.

Table 2. Criteria for parental multiplication in the field and hybrid seed production.

Grade	Unwanted plants (panicles) ≤ %
A line	
Foundation	0.01
1st class	0.05
2nd class	0.08
B line	
Foundation	0.01
1st class	0.05
2nd class	0.08
R line	
Foundation	0.01
1st class	0.05
2nd class	0.08
F1 hybrid	
1st class	0.10 (A + R)
2nd class	0.20 (A + R)

[a] Criteria set by the Ministry of Agriculture through the China National Criterion Bureau. 1st class and 2nd class seeds are certified seeds. Identification made at full heading stage.

seed industry has been running these private companies following the system of a market economy; the market risks are no longer shared by the government since 1999.

The Chinese experience in the development and dissemination of hybrid rice technology can also be adapted in other developing countries. Experts in the China National Hybrid Rice R&D Center are willing to help other countries develop their own hybrid rice programs. Hybrid rice can play an important role in ensuring global food security in the 21st century using scientific and technological advances and harnessing the expertise of the Food and Agriculture Organization (FAO), the International Rice Research Institute (IRRI), the Asian Development Bank (ADB), the Asia Pacific Seed Association (APSA), and public and private institutions operating in the national programs.

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Farmers' experience with adoption of hybrid rice in India

D. Singh

In India, rice is grown in about 44 million ha, accounting for about 20.3% of the total cropped area and 31% of the total area under food grains. The share of irrigated rice is only 45%; the rest (55%) is rainfed. Rice is cultivated throughout the year during winter and summer as well as in the rainy season in different states of India under diverse agroecological conditions. Therefore, problems of productivity are also diverse and need to be tackled state- and seasonwise. The socioeconomic impact of hybrid rice cultivation in different states has clearly shown that hybrid rice is superior in terms of yield and profitability in all states. Because of diverse climatic changes, rice production decreased from 89.04 million t in 1999-2000 to 78.64 million t in 2000-03. On the other hand, area and production of hybrid rice have remained almost intact, an indication that farmers still chose hybrid rice even under adverse production conditions.

Area, yield, and production of hybrid rice

The area (ha), average yield (t ha^{-1}), and production (t) of hybrid rice in India from 1995 to 2004 are shown in Table 1.

All three parameters had shown continuous increases since 1995. The area under hybrid rice, which was only 10,000 ha in 1995 has increased to 0.56 million ha in 2004. The average yield during the same period also increased form 4.5 to 5.5 t ha^{-1}. These trends in area and productivity of hybrid rice in India reflect the positive performance and accelerated adoption of hybrid rice.

Productivity of hybrid rice and HYVs

Two studies to assess the comparative yields of hybrid rice and traditional high-yielding varieties (HYVs) in different states of India were conducted by the India Institute of Management in Ahmedabad and the Society of Management of Agri-Rural Project in Kanpur. Comparative productivity values of hybrid and HYV are shown in Table 2.

Average yield of hybrid grain ranged from 4.9 t ha^{-1} in West Bengal to 7.5 t ha^{-1} in Karnataka and 7 t ha^{-1} in Haryana and Punjab. The average grain yield (t ha^{-1}) of hybrid rice was 6.37, whereas that of HYV was 5.17 ha^{-1}, a difference of 1.2 t ha^{-1} in favor of hybrid rice. The average benefit derived from hybrid rice over HYV in

Table 1. Area, average yield, and production of hybrid rice seed in India, 1995-2004.

Year	Area (ha)	Av yield (t ha^{-1})	Total production (t)
1995	10,000	4.50	45,000
1996	60,000	4.85	291,000
1997	90,000	5.10	459,000
1998	110,000	5.25	577,500
1999	125,000	5.40	675,000
2000	150,000	5.45	817,500
2001	180,000	5.45	981,000
2002	200,000	5.50	1,000,000
2003	280,000	5.55	1,554,000
2004	560,000	5.50[a]	3,080,000
Total	1,765,000	5.26	8,580,000

Table 2. Productivity of hybrid rice (HR) and HYVs in different states of India.

State	Grain yield (t ha^{-1})		Difference (HR-HYV)	% difference (HR-HYV)
	HR	HYV		
Bihar	5.9	4.4	1.5	34.09
Eastern Uttar Pradesh	6.2	5.1	1.1	21.56
Western Uttar Pradesh and Uttarachal	6.5	5.5	1.0	18.18
Haryana	7.0	5.8	1.2	20.69
Punjab	7.1	6.1	1.0	16.69
Karnataka	7.5	6.0	1.5	25.00
Maharashtra	5.7	4.0	1.7	42.50
Tamil Nadu	6.7	4.9	1.8	36.73
West Bengal	4.9	4.7	0.2	4.26
Andhra Pradesh	6.2	5.2	1.0	19.23
Av	6.37	5.17	1.2	23.21

terms of grain yield came to 23.21%. A minimum additional benefit of 4.26% had been estimated in West Bengal, where productivity of HYV was quite near that of hybrid rice.

Cost of cultivating hybrid rice and HYVs

Because of the diverse agroecological and socioeconomic conditions, the cost of rice cultivation differed form one state to another (Table 3).

The cost of cultivating hybrid rice was more than the cost of growing HYVs in all states—the average for hybrid rice was Rs 21,238 ha^{-1} against HYV's Rs 19,444. There was an additional cost of Rs 1,794 for hybrid rice. The farmer had only 9.22% additional cost to cultivate hybrid rice. A comparative use of major inputs in the cultivation of hybrid and HYVs in different states of India is shown in Table 4.

For both hybrid and HYVs, farmers spent most in irrigation, followed by labor and fertilizer application.

Table 3. Cost (Rs ha^{-1}) of cultivating hybrid rice HR and HYVs in different states of India.

State	HR	HYV
Bihar	16,219	15,241
Uttar Pradesh	18,586	16,409
Haryana	27,269	25,143
Punjab	23,668	23,217
Tamil Nadu	20,812	18,410
West Bengal	21,686	19,520
Maharasthra	18,840	17,210
Karnataka	21,848	19,776
Andhra Pradesh	22,258	20,069
Av	21,238	19,444

Profitability of hybrid rice and HYVs

Generally, profitability is calculated on the basis of cost of cultivation and gross income received from the main product and byproduct. The price is an important factor in determining profitability. The comparative grain prices of hybrid rice and HYVs in different states of India are given in Table 5.

The grain price of HYV was higher than that of hybrid rice, except in Maharashtra and Jharkand, where hybrid rice fetched a higher price because some hybrids had better quality than popular HYVs in these states. The price differences were big in Tamil Nadu, Andhra Pradesh, and Karnataka. In northern India, prices of hybrid and HYVs were either the same or slightly different (Rs 200 t^{-1} in favor of HYV was estimated). A marketing inquiry indicated that the government in the procurement program and the big rice millers buy hybrid rice and HYV at the same price. However, the small millers and traders offered a higher price for HYV, while spreading rumors about hybrid rice's high breakage and low rice head recovery. The comparative economics of hybrid and HYV cultivation in different states of India is shown in Table 6.

Total input cost, average yield, total gross income, and net income related to hybrid and HYV cultivation in India differed from state to state. On aggregate basis, the average yield per hectare, total gross income, and therefore,

Table 4. Cost (Rs ha^{-1}) of major inputs in the cultivation of hybrid rice (HR) and HYVs in different states of India.

State	Seed		Labor cost		Manure		Fertilizer		Chemical		Irrigation		Total	
	HR	HYV	HR	HYV	HR	HYV	HR	HYV	HR	HYV	HR	HYV	HR	HYV
Bihar	1750	360	5190	5350	600	170	2460	1711	920	820	3080	3080	16219	15241
Uttar Pradesh	1200	500	8150	7750	100	60	2619	1580	785	785	3050	2450	18586	16409
Haryana	1100	420	4480	4480	--	--	2624	2185	585	585	11850	11850	27269	25143
Punjab	1140	300	4560	4440	--	--	3166	2749	627	627	9600	9600	23668	23217
Tamil Nadu	1154	996	5396	3268	823	510	3065	2671	511	202	6500	6500	20812	18410
West Bengal	849	820	7672	5984	1130	770	2214	2195	919	475	6000	6000	21686	19520
Maharasthra	1425	1000	4201	3950	941	900	2231	2100	245	162	6700	6700	18840	17210
Karnataka	1051	905	6595	6072	2671	920	2982	2936	246	222	6400	6400	21848	19776
Andhra Pradesh	1621	904	6360	5856	1355	1250	3367	3215	755	673	6800	6800	22258	20069
Total	11290	6205	52604	47150	7620	4580	24728	21342	5493	4551	59980	59380	191186	174995
Av	1254.44	689.44	5844.89	5238.89	846.67	508.89	2747.55	2371.33	610.33	505.67	6664.44	6597.78	21238	19444
Percentage	5.9	3.5	27.5	26.9	3.98	2.62	12.93	12.93	2.87	2.60	31.37	33.93		

Table 5. Comparative prices of hybrid rice grain and HYV in different states of India.

State	Grain price (Rs t^{-1})		Difference (HR-HYV)
	Hybrid rice	HYV	
Bihar	5,100	5,300	-200
Uttar Pradesh	5,100	5,300	-200
Haryana	5,300	5,300	--
Punjab	5,300	5,300	--
Tamil Nadu	5,284	5,760	-476
West Bengal	4,429	4,434	-5
Maharasthra	4,901	4,852	+49
Karnataka	5,007	5,415	-408
Andhra Pradesh	5,143	5,610	-458
Jharkhand	5,200	4,850	+350

Table 6. Comparative economics of hybrid rice and HYV cultivation in different states of India.

State	Hybrid rice	HYV
Bihar		
Total input cost (Rs ha^{-1})	16,219	15,241
Average yield (t ha^{-1})	5.9	4.4
Total gross income (Rs ha^{-1})	31,860	23,760
Net income (Rs ha^{-1})	14,770	8,519
Uttar Pradesh		
Total input cost (Rs ha^{-1})	18,586	16,409
Average yield (t ha^{-1})	6.3	5.3
Total gross income (Rs ha^{-1})	33,480	27,540
Net income (Rs ha^{-1})	14,894	11,131
Haryana		
Total input cost (Rs ha^{-1})	26,269	25,143
Average yield (t ha^{-1})	7.0	5.8
Total gross income (Rs ha^{-1})	37,850	31,320
Net income (Rs ha^{-1})	11,58	16,177
Punjab		
Total input cost (Rs ha^{-1})	23,668	23,217
Average yield (t ha^{-1})	7.1	6.1
Total gross income (Rs ha^{-1})	38,168	32,868
Net income (Rs ha^{-1})	13,500	9,651
Tamil Nadu		
Total input cost (Rs ha^{-1})	20,812	18,410
Average yield (t ha^{-1})	6.7	4.9
Total gross income (Rs ha^{-1})	32,515	27,447
Net income (Rs ha^{-1}) 1	1,703	9,037
West Bengal		
Total input cost (Rs ha^{-1})	21,866	19,520
Average yield (t ha^{-1})	4.9	4.7
Total gross income (Rs ha^{-1})	23,019	22,241
Net income (Rs ha^{-1})	1,413	2,721
Maharashtra		
Total input cost (Rs ha^{-1})	18,840	17,210
Average yield (t ha^{-1})	5.7	4.0
Total gross income (Rs ha^{-1})	28,376	19,612
Net income (Rs ha^{-1})	9,536	2,402
Karnataka		
Total input cost (Rs ha^{-1})	21,848	19,776
Average yield (t ha^{-1})	7.8	6.0
Total gross income (Rs ha^{-1})	39,627	33,262
Net income (Rs ha^{-1})	17,779	13,486
Andhra Pradesh		
Total input cost (Rs ha^{-1})	22,258	20,069
Average yield (t ha^{-1})	6.2	5.2
Total gross income (Rs ha^{-1})	33,910	30,145
Net income (Rs ha^{-1})	11,652	10,076

net income for hybrid rice were quite higher than those of HYV. Total input cost though was relatively higher in hybrid rice. The great advantages of hybrid rice cultivation in India were higher production and higher net income per hectare.

Changes in cropping pattern

In northern India, hybrid rice was replacing rainy-season maize because of its high profitability.

Profitability of hybrid rice seed production

The productivity and profitability of hybrid and HYV rice seed in India differed from season to season and from state to state (Table 7, 7 [a]).

The average yield of hybrid seed ranged from 0.8 t ha^{-1} in Uttar Pradesh to 2.5t ha^{-1} in Andhra Pradesh. The average yield of hybrid rice was 1.0 t ha^{-1} in Tamil Nadu and 1.6 t ha^{-1} in Karnataka. A net income of Rs 54,763.00 among hybrid rice seed growers was estimated by Karnataka farmers because of the high buy-back offered by the public sector.

In Andhra Pradesh, the average price of hybrid rice seed was lower but the high average yield caused net income to be high (Rs 57,535 ha^{-1}). Total input cost in the production of hybrid rice seed was Rs 29,695 ha^{-1} against Rs 20,331 ha^{-1} for HYV rice seed. Total gross income from hybrid rice seed was Rs 64,532 ha^{-1}, while that from HYV was Rs 27,170 ha^{-1}. Average net income from hybrid rice seed production amounted to Rs 34,834 ha^{-1}; the figure for HYV was Rs 6,830.

Table 6a. Comparative economics of hybrid rice and HYV cultivation in India.

Item	Hybrid rice	HYV
Total input cost (Rs ha^{-1})	21,132	19,444
Average yield (t ha^{-1})	6.37	5.17
Total gross income (Rs ha^{-1})	33,200	27,577
Net income (Rs ha^{-1})	12,068	8,133

Table 7. Comparative economics of hybrid rice and HYV seed production in different states of India.

State	Hybrid rice	HYV
Uttar Pradesh		
Total input cost (Rs ha^{-1})	32,198	18,257
Average yield (t ha^{-1})	0.8	5.0
Total gross income (Rs ha^{-1})	45,820	27,500
Net income (Rs ha^{-1})	13,622	9,243
Haryana		
Total input cost (Rs ha^{-1})	38,577	25,143
Average yield (t ha^{-1})	0.9	5.4
Total gross income (Rs ha^{-1})	47,825	29,700
Net income (Rs ha^{-1})	9,248	4,557
Karnataka		
Total input cost (Rs ha^{-1})	25,237	19,776
Average yield (t ha^{-1})	1.6	5.2
Total gross income (Rs ha^{-1})	80,000	28,600
Net income (Rs ha^{-1})	54,763	8,824
Tamil Nadu		
Total input cost (Rs ha^{-1})	30,000	18,410
Average yield (t ha^{-1})	1.0	4.1
Total gross income (Rs ha^{-1})	50,000	22,550
Net income (Rs ha^{-1})	20,000	4,140
Andhra Pradesh		
Total input cost (Rs ha^{-1})	22,465	20,069
Average yield (t ha^{-1})	2.5	5.0
Total gross income (Rs ha^{-1})	80,000	27,500
Net income (Rs ha^{-1})	57,535	7,431

Table 7a. Comparative economics of hybrid rice and HYV seed production in India.

Item	Hybrid rice	HYV
Total input cost (Rs ha^{-1})	29, 695	20,331
Average yield (t ha^{-1})	1.36	4.9
Total gross income (Rs ha^{-1})	64,529	27,170
Net income (Rs ha^{-1})	34,83	46,830

Buy-back and selling price of hybrid rice seed

The public sector bought hybrid rice seed at a price higher than that offered by the private sector in Karnataka and Tamil Nadu (Table 8). In Uttar Pradesh and Haryana, hybrid rice seed was purchased by public-private sector seed corporations. Because of higher hybrid rice seed production in Andhra Pradesh, the buy-back price given by the private sector was low.

The selling price of hybrid seed set by both public and private sectors was the same in all states, two to three times more than the purchase price. In some instances, in Uttar Pradesh, some hybrids such as PHB 71 and PA 6444 were sold at a very high price of Rs 180-200 kg^{-1}.

Tripartite mechanism: farmers, private, and public sector in hybrid rice production

A cluster of 40 villages was organized by farmers and private companies in Karimnagar District, Andhra Pradesh, to produce hybrid rice seed during the rabi season (winter). Under the system, one worker for each village was provided by the concerned seed company and another one by the farmers' organization to support and monitor the seed production program on farmers' fields. The company provided seed material free of cost but a registration fee of Rs 750 ha^{-1} was charged. The farmer's organization received Rs 2 kg^{-1} as service charge on the quantity of seed purchased by the company to cover the expenses of technical staff and other items.

Farmers' perceptions of hybrid rice production technology

The perceptions of farmers with respect to various components of the rice production technology were collected in a study and classified as more (M), less (L), or the same (S) on the basis of the proportion of farmers expressing their opinion of the specific item (Table 9). Table 9a showed pooled responses regarding specific items on hybrid rice technology.

Most farmers felt that pest and disease incidence, amount of fertilizer required, weed incidence, and amount of labor required were the same for both hybrid and HYV. On lodging, duration, shattering, and grain dormancy more than 60% of the farmers felt that these were the same for hybrid and HYV rice. Almost half (52%) of the farmers said that hybrid rice had the same percentage of chaffy and sterile seed, whereas 39-45% of the farmers felt that head rice recovery, straw yield, and grain size were similar in both. However, in terms of grain price in the market, 54% of the farmers mentioned a lower price of hybrid rice compared with the price of HYV. More than 95% of the farmers said that hybrid rice seed cost more than it should.

Quality perceptions of farmers

Farmers' perceptions of hybrid rice quality in different states of India are given in Table 10 and pooled quality perceptions of farmers about hybrid rice are given in Table 10a.

As to grain appearance, 66.5% of the farmers felt that hybrid rice was better than HYV. However, in terms of taste, aroma, stickiness of cooked rice, and cooking quality, hybrid rice scored low among majority of the farmers. The fodder quality of hybrid rice has been judged better by farmers.

The higher profitability of hybrid rice has changed the attitude of farmers. Many of them had constructed pucca houses and had bought household items such as television, LPG gas, motorcycle, and others. Some of them also started trading jute bags, fertilizers, pesticides, and pump sets to support the hybrid rice seed production program.

Millers' perceptions

The millers saw no marketing problems in Haryana and Punjab. The government procures rice on the basis of coarseness or fineness, not whether it is hybrid rice. However, in Uttar Praddesh and Bihar and some of the southern states, lower price for hybrid rice is offered. A large number of small millers and hullers said that recovery in hybrid rice was lower by 2-3% and breakage was also a little higher in some hybrids. However, there was no difference in the price of rice bran of hybrid rice and nonhybrid rice.

Major constraints to dissemination of hybrid rice

Nonavailability of hybrid rice seed. Hybrid seeds are not available in many states of India. In Uttar Pradesh, Bihar, and Jharkand, a large area under hybrid rice would have been possible if there was sufficient supply of hybrid seed.

Regional recommendations for hybrid rice. Many hybrid rice varieties are not classified by region and by season. Popular hybrids in some regions did not come as strong as expected.

Low awareness of suitable hybrid rice varieties. After regional and seasonal classification of hybrid rice varieties, a strong awareness

Table 8. Buy-back and selling price (Rs t^{-1}) of hybrid rice seed by public and private sectors.

State	Buy-back price		Selling price	
	Public	Private	Public	Private
Uttar Pradesh @ Rs 78 kg^{-1}	75,000	--	120,000	120,000
Haryana @ Rs 40 kg^{-1}	40,000	--	120,000	120,000
Andhra Pradesh @ Rs 28 kg^{-1}	--	28,000	--	100,000
Karnataka @ Rs 50 kg^{-1}	50,000	40,000	115,000	100,000
Tamil Nadu @ Rs 50 kg^{-1}	50,000	40,000	100,000	100,000

Table 9. Farmers' perception of hybrid rice production in different states of India.[a]

Item	Bihar			Uttar Pradesh			Haryana			Punjab			West Bengal			Tamil Nadu		
	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S
Pest and disease incidence	20	10	70	15	10	75	10	10	80	15	8	77	22	7	71	0	50	50
Amount of fertilizer required	15	0	85	25	0	75	20	0	80	0	0	100	0	7	93	0	0	100
Weed incidence	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Amount of labor required	10	90	15	85	0	0	100	0	0	100	33	0	67	100	0	0		
Lodging	10	20	70	10	10	80	5	10	85	7	8	85	22	22	56	60	0	40
Duration	0	30	70	0	26	74	0	21	79	0	24	76	33	0	67	18	64	18
Grain yield	60	0	40	70	0	30	80	0	20	80	0	20	43	7	50	100	0	0
Shattering	20	5	75	15	7	78	22	8	70	23	10	72	11	22	67	60	0	40
Grain dormancy	28	0	72	30	0	70	35	0	65	33	0	62	0	0	100	67	0	33
Chaffy/sterile grain	25	0	65	30	0	70	40	0	60	38	0	62	36	19	45	67	0	33
Straw yield	0	0	100	0	10	90	0	75	25	0	15	85	50	36	14	64	27	9
Head rice recovery	10	70	20	0	70	30	0	75	25	0	15	85	0	33	67	80	0	20
Grain price in the market	0	70	30	0	65	35	0	60	40	0	58	42	0	29	71	0	91	9
Grain size	40	10	59	10	20	70	30	15	55	30	10	60	50	0	50	50	33	17
Seed cost	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	83	17	0

[a]M=more, L=less, S=same.

Table 9. Perception of farmers about hybrid rice production in different states of India.

Item	Maharashtra			Karnataka			Andhra Pradesh		
	M	L	S	M	L	S	M	L	S
Pest and disease incidence	15	11	74	0	31	69	0	40	60
Amount of fertilizer required	4	3	93	13	6	81	0	20	80
Weed incidence	4	4	92	7	0	93	0	0	100
Amount of labor required	11	4	85	33	7	60	33	33	34
Lodging	20	33	47	30	40	30	0	50	50
Duration	63	5	32	21	29	50	0	0	100
Grain yield	65	15	20	92	0	8	0	0	100
Shattering	19	19	63	65	21	14	0	0	100
Grain dormancy	8	42	50	40	30	30	0	0	100
Chaffy/sterile grain	28	36	36	23	31	46	50	0	50
Straw yield	85	10	5	57	29	14	100	0	0
Head rice recovery	26	37	37	27	55	18	50	0	50
Grain price in the market	16	31	53	0	78	22	50	0	50
Grain size	41	14	45	32	25	43	50	50	0
Seed cost	68	9	23	93	7	0	100	0	0

[a]M=more, L=less, S=same.

Table 9a. Pooled farmers' perceptions about different components of hybrid rice technology (%).

Item	More	Less	Same
Pest and disease incidence	10.00	19.67	70.33
Amount of fertilizer required	10.89	4.00	85.11
Weed incidence	1.22	0.44	98.34
Amount of labor required	26.11	4.89	69.00
Lodging	18.22	21.45	60.33
Duration	15.00	22.11	62.89
Grain yield	65.56	2.44	32.00
Shattering	26.11	9.56	64.33
Grain dormancy	26.78	8.55	64.67
Chaffy/sterile grain	37.44	10.67	51.89
Straw yield	39.56	15.22	45.22
Head rice recovery	21.44	39.45	39.11
Grain price in the market	7.33	53.56	39.11
Grain size	37.00	18.67	44.33
Seed cost	94.78	2.66	2.56

Table 10. Quality perceptions of farmers about hybrid rice in different states of India.

Item	Bihar			Uttar Pradesh			Haryana		
	Better	Same	Poor	Better	Same	Poor	Better	Same	Poor
Grain appearance	67	27	6	70	29	1	77	23	0
Taste	0	30	70	0	20	80	0	23	77
Aroma	20	30	50	22	32	46	19	31	52
Cooking quality	0	30	70	0	35	65	0	28	72
Stickiness of cooked rice	0	35	65	0	30	70	0	25	75
Fodder quality	52	25	23	55	30	15	51	29	20
	Punjab			**West Bengal**			**Tamil Nadu**		
	Better	Same	Poor	Better	Same	Poor	Better	Same	Poor
Grain appearance	60	30	10	62	0	38	100	0	0
Taste	0	15	85	38	46	16	0	50	50
Aroma	12	28	60	62	8	30	25	25	50
Cooking quality	0	25	75	46	23	31	0	50	50
Stickiness of cooked rice	0	20	80	23	8	69	0	33	67
Fodder quality	53	31	16	50	14	36	83	0	17
	Maharashtra			**Karnataka**			**Andhra Pradesh**		
	Better	Same	Poor	Better	Same	Poor	Better	Same	Poor
Grain appearance	67	10	23	46	16	38	50	50	0
Taste	79	0	21	69	12	19	50	50	0
Aroma	73	9	18	69	19	12	0	50	50
Cooking quality	32	20	48	20	16	64	33	0	67
Stickiness of cooked rice	27	46	27	21	29	50	100	0	0
Fodder quality	57	26	17	67	13	20	50	44	6

Table 10a. Pooled quality perceptions of farmers about hybrid rice (%).

Items	Better	Same	Poor
Grain appearance	66.55	20.56	12.89
Taste	25.12	28.44	46.44
Aroma	33.46	25.68	40.86
Cooking quality	14.55	25.22	60.23
Stickiness of cooked rice	19.00	25.11	55.89
Fodder quality	57.55	23.56	18.89

campaign needs to be launched by the extension staff of government, private companies, and public technical institutions.

Public technical institutions (SAUs) are not fully involved. The SAUs with strong extension system that operate in almost all state districts are not fully involved either in hybrid rice seed production or promotional activities.

High price of hybrid rice seeds. The price of hybrid rice seed in India is very high in relation to cost of production. The private companies are selling hybrid rice seed at a price two to three times more than the purchase price paid to the seed growers.

No action against misinformation on hybrid rice. A large number of small traders and millers are spreading rumors about the "poor" quality of hybrid rice seeds. A strong information campaign to dispel wrong perceptions about hybrid rice quality is needed.

Seed production of hybrid rice limited to southern India. At present, 95-98% of the hybrid rice seed is produced in south India only. This is why the pace of disseminating hybrid rice is slow. Seed production areas in different states should be identified and a production program be put in place.

Hybrid rice see production in south India is limited to rabi season. The possibility of producing hybrid rice seed during kharif (rainy) season, especially in north India where rain water is abundant, should be explored.

Limitation of irrigation water in south India. Irrigation water is a major limitation to increasing hybrid rice seed area during rabi (winter) in south India. Hence, possibilities in other states have to be examined.

Suitable varieties for shallow water. Large areas of rice exist under shallow, waterlogged conditions. At present, hybrid rice varieties suitable for such conditions are not yet identified. The hectarage under hybrid rice will increase rapidly if suitable hybrid rice varieties for shallow waters were developed.

Policies and strategies

Quality traits. Quality traits such as aroma, taste, cooking quality, and stickiness of cooked rice appear to be inferior in hybrid rice grains. These traits should be at par with those found in HYV.

Establishment of Krishi Vigyan Kendras (KVK). The government of India (through ICAR) is establishing one KVK in each district of India. Each has a team of scientists and the needed infrastructure, including a 20-ha farm. These institutions are not involved in rice seed production or hybrid rice promotion. The potential of KVKs need to be tapped for hybrid rice programs.

Hybrid rice program treated as source of additional employment. It has been observed that, for each hectare, additional 8-14 mandays for cultivation and 70-90 mandays for hybrid rice seed production are needed. This can raise the income of rural labor, especially the female workers.

Price of hybrid rice seed. The price of hybrid rice seed should be regulated using the minimum support price set by the Government of India. This policy will protect hybrid rice seed growers from exploitation by unscrupulous seed companies/institutions.

Standardization of hybrid rice seed production technologies. Hybrid rice seed production and cultivation technology shall be standardized by state, region, and season to increase production and reduce cost.

In-depth study on quality parameters. There is a need to initiate in-depth studies to examine the quality parameters of hybrid rice and HYVs in different regions and states in India.

Linkage between farmer organizations and private seed companies. A linkage mechanism similar to that between growers and the private seed sector operating in Andhra Pradesh may be introduced in other states too.

Better performance under drought conditions. It was observed that hybrid rice seeds had greater resistance to drought than HYVs during

2003 kharif in the northern states of India. This observation suggests the need for screening of hybrid varieties for drought conditions, especially for the rainy season.

Technological gaps not being addressed. The technological gaps identified in the different seasons and states should be addressed in the strategies developed to promote hybrid rice.

Electricity subsidy in agriculture. Private seed companies reduce the purchase price of hybrid seed according to the amount of electricity consumed in the production process. Thus, the advantage of free electricity goes to the seed company and not to the growers. This situation must be examined.

HYV seeds supplied as hybrid rice seeds in some states. During field visits in different states, some farmers reported that some private companies supply seeds of HYV, claiming these are hybrid rice seeds. Productivity is low. There should be some mechanism to stop such a practice.

Modernization of hullers and mini rice mills. The percentage of breakage ranges from 4 to 6% when paddy is milled through these obsolete machines. The total availability of rice will increase if breakage is reduced.

Conclusions

In India, the superiority of hybrid rice in terms of yield and profitability is established. However, for further growth, certain administrative, educational and research policies have to be established and implemented to improve seed production; standardize state- region- and season-specific technology; encourage participation of the public sector, linkage mechanism among the public-private sectors and farmers; and regulate seed price, promotional activities, and HRD programs.

Notes

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Farmers' experience with adoption of hybrid rice in the Philippines

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Hybrid rice is being promoted aggressively in the Philippines through its national hybrid rice commercialization program (HRCP) to increase rice production. From 5,000 ha in the 2001 wet season (WS), the total area planted to hybrid rice in the country increased to around 120,000 ha in the 2004 WS. The paper presents farmers' experiences in adopting hybrid rice based on results of farm surveys in major hybrid rice-producing provinces. We found that hybrid rice yielded higher than inbred on average. This yield advantage varied by season, by farmer, and by province. On the other hand, despite the higher costs incurred in hybrid rice production, more farmers got a higher net income from hybrid rice than from inbred. The average incremental rate from hybrid rice was 76% and 20% during DS and WS, respectively. The average yield of individual seed growers of Mestizo 1 was 700-800 kg ha^{-1}. At the current seed price and with a guaranteed market, hybrid rice seed production was more profitable than inbred. We conclude that focusing promotion and commercialization of hybrid rice in more suitable areas ensure adoption and improve productivity. In less suitable areas, research and development (R&D) activities on new varieties, adaptation trials to determine which variety is suitable in specific locations, and crop management research must be sustained. The lower prices of seed will probably increase the demand for hybrid rice from farmers. Even if seed subsidies were phased out, farmers will continue to plant hybrids, provided they perform better and give more profits than other varieties. Finally, providing technical support to hybrid seed growers and encouraging the participation of private seed companies in marketing and R & D for new hybrids should be continued.

To significantly augment local rice production and ensure food security, hybrid rice is being promoted aggressively in the Philippines through its national hybrid rice commercialization program (HRCP). The main components of the program are seed production, certification and distribution, credit facilitation, marketing assistance, extension and communication, research and development, and strengthening of interagency linkages. Six hybrid rice varieties (*Mestizo 1, Mestizo 2, Mestizo 3, SL8, Bigante,* and *Rizalina*) are now commercially available for planting. The first three varieties are public-bred hybrids, while the latter were developed by private companies. Mestizo 1, the most popular, is aromatic, soft, and has an eating quality comparable with that of Philippine-preferred IR64 variety.

The area planted to hybrid rice has exponentially increased since the inception of HRCP. From only around 5,000 ha in the 2001 wet season (WS), the total area planted to hybrid rice in the country increased gradually to around 120,000 in the 2004 WS (DA-FOS 2005). The program has directly benefited about 250,000 hybrid rice farmers and 2,000 local seed growers (Gonzales et al 2005). Isabela Province in Region 2 has the largest area planted to hybrid rice, reaching more than 20,000 ha in 2004. The area devoted to hybrid seed production was also largest in this province. The other major sources of hybrid rice seed are Davao Oriental, Davao del Sur, and Nueva Ecija.

This paper presents an analysis of the farmers' experiences with hybrid rice in the Philippines hoping to contribute to an understanding among policymakers, development workers, and researchers of the constraints and issues related to hybrid rice adoption. Farmers' experiences and perceptions are the best gauge of the potential and actual effects of a technology.

Yield advantage of hybrid over inbred rice

Data gathered from the Department of Agriculture (DA) based on 2001-04 provincial monitoring reports showed that, on the average, the sustained yield advantage of hybrid over inbred rice in the program areas was 27% during the WS and 39% during the dry season (DS) (Table 1). The provincial average yield advantage of hybrid rice over inbred, however, ranged widely from a –33% to 123% in the seasons covered. In 2004 WS, for example, the highest reported provincial average yield advantage of hybrid was 80% (Quirino), while the lowest was 0.9% (Antique). The standard deviation across provinces of hybrid rice yields (0.81 to 1.17) was almost double that of inbreds (0.49 to 0.63), which suggests that yield varied more across locations for hybrid rice.

Two separate random farm surveys covering program and nonprogram areas reached similar conclusion. Data from a survey of 4, 112 hybrid and inbred rice farmers covering 15 provinces (conducted by the Bureau of Agricultural Statistics and the GMA Rice Program Directorate of DA) showed that the yield advantage of hybrid over inbred certified seeds in program areas was statistically significant with an average of 28% during the 2003 DS and 16% during the 2003 WS. The average yield advantage per province, however, ranged widely from – 70% to 56%. Of the 15 provinces surveyed, hybrid rice performed well in both seasons in the provinces of Kalinga, Mindoro Oriental, Albay, Camarines Sur, and Leyte, on average. It did not perform well, however, in Nueva Vizcaya, Iloilo, and Surigao del Norte. In terms of percent distribution of rice yields, in most provinces, more hybrid rice farmers attained yields greater than 5 t ha^{-1}, both during WS and DS (Fig. 1).

The PhilRice Socioeconomics Division (SED) and the STRIVE Foundation also conducted a detailed farm-level survey of around 500 farmers from five major hybrid rice-growing provinces (Isabela, Nueva Ecija, Iloilo, Davao del Norte, and Davao del Sur), covering 2002 WS to 2004 DS. The survey results showed that hybrid rice gave a highly significant yield advantage of 13% during the DS and 9% during the WS on average. More hybrid rice farmers than inbred farmers attained yields greater than 5 t ha^{-1}. the standard deviation of hybrid rice yields across farmers was also relatively higher (1.5 to 2.4) compared with that of inbred yields (1.2 to 1.7). Hybrid rice, particularly Mestizo 1, performed better than inbred in Davao del Norte and Isabela but less consistently in Iloilo, Nueva Ecija, and Davao del Sur.

The data from the SED-STRIVE survey showed that farmers used relatively higher levels of inputs for hybrid rice. One can then argue that the yield advantage may not necessarily be due to the use of hybrids but to greater input use. Regression analysis confirmed the yield advantage of hybrid, even after accounting for the effects of greater input use. However, after accounting for input use, this yield advantage was statistically significant only in the DS.

Table 1. Area planted and average yield, GMA program areas, by variety and season, 2001-04.[a]

Year/ season	Area planted (ha)	Hybrid yield (t ha^{-1})		CS inbred yield (t ha^{-1})		Yield difference (t ha^{-1})	Yield advantage (%)
		Mean	Std dev	Mean	Std dev		
2001 WS	5,442	5.52	1.17	4.34	0.59	1.18	27
2002 WS	21,089	5.78	0.96	4.46	0.57	1.32	30
2003 WS	52,113	5.93	0.90	4.53	0.54	1.40	31
2004 WS	111, 697	5.62	0.82	4.65	0.52	0.97	21
Av							27
2002 DS	6,832	6.85	1.30	4.43	0.57	2.42	55
2003 DS	25,245	6.05	1.08	4.41	0.63	1.64	37
2004 DS	77,450	5.98	0.81	4.77	0.49	1.21	25
Av							39

[a]Source of basic data: Department of Agriculture-Field Operations Service (DA-FOS).

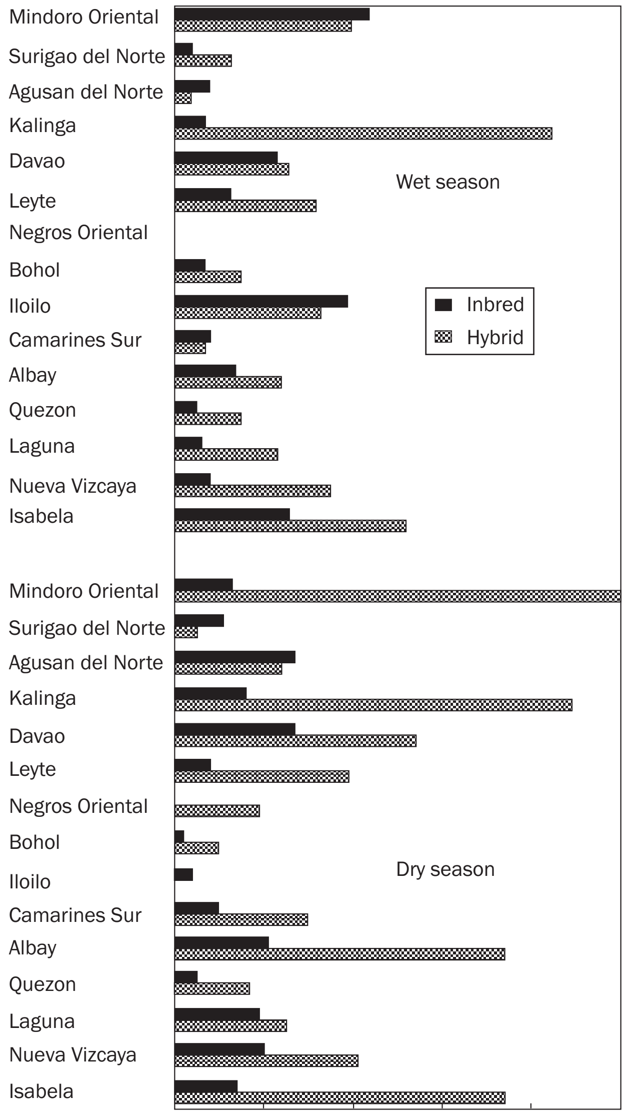

Fig. 1. Percentage of hybrid and inbred rice farmers with yields >5 t ha,$^{-1}$ by province.

To summarize, multiple farm surveys conducted in many different provinces showed that the hybrid rice gave significantly higher yields than inbred rice on average. More hybrid rice farmers also attained yield levels greater than 5 t ha^{-1}. On the other hand, the yield advantage was not consistent: it varied from farmer to farmer and from province to province. Focusing promotion and commercialization of hybrid rice in the more suitable areas would help farmers in these areas improve their productivity. In less suitable areas, research and development activities on new hybrid rice varieties, adaptation trials to determine which hybrid variety is suitable in specific locations, and crop management research for hybrid rice must be sustained for hybrid rice to have a greater impact on productivity.

Profitability of hybrid rice over inbred rice

The PhilRice SED-STRIVE study found that in the five covered provinces, the average output price was consistently higher for hybrid rice than for inbred by around P0.30 kg^{-1}. With yields also higher for hybrid, this translated to consistently higher gross returns for hybrid. In 2004 DS, the average gross value of production for hybrid rice, given an average 5.3 t ha^{-1} yield and P9.00 kg^{-1} farmgate palay price, was around P48,000 ha^{-1} (Table 2). This was about P6,200 ha^{-1}, significantly higher than the gross value of production for inbred varieties. The total cost of production, on the other hand, was about P28,000 ha^{-1} for hybrid rice compared with around P27,000 for inbred rice. Thus, although the production cost of hybrid rice was higher than that of inbred, the net profit from hybrid rice production was significantly higher than that from inbred rice during DS. During the WS, especially in provinces with distinct WS and DS, there was higher variability in yield and profits from hybrid rice compared with inbred. Thus, although the net profit was still higher with hybrid rice in the WS, the profit advantage was less than in the DS and was not statistically significant. Nevertheless, compared with inbred income, a greater number of hybrid rice farmers obtained higher net income levels, even during WS.

The data showed that the higher production cost of hybrid was due largely to higher seed and hired labor cost. The subsidized price of hybrid seeds during the start of HRCP was P1,200 per 20-kg bag (50% of true seed price), which is good for 1 ha, while the price of a 40-kg bag of certified seeds is P650. Hired labor cost was higher for hybrid rice due to the higher crop establishment cost (only one seedling per hill was planted) and the higher harvesting and threshing shares due to higher yields. Hybrid rice farmers also incurred relatively higher fertilizer and pesticide costs. The higher fertilizer cost for hybrid was mainly due to the higher use of organic fertilizers.

Table 2. Mean comparative costs and returns of hybrid and inbred rice production, five provinces, 2000-04.[a]

Item	2002 WS		2003 DS		2003 WS		2004 DS	
	Inbred	Hybrid	Inbred	Hybrid	Inbred	Hybrid	Inbred	Hybrid
Yield (kg ha^{-1})	4,589	5,119**	5,023	5,726***	5,077	5,496***	4,834	5,344***
Farm price (P kg^{-1})	7.95	8.26***	7.99	8.32***	7.81	7.83	8.64	9.00***
With subsidy								
Gross returns	36,483	42,285***	40,123	47,683***	39,653	43,033***	41,762	48,098***
Production cost	23,577	26,660***	23,793	27,531***	24,664	26,477***	26,925	28,209**
Net returns	12,906	15,625*	16,330	20,107***	14,989	16,556	14,837	19,889***
Incremental rate of return		88%		101%		86%		393%
Without subsidy								
Gross returns	36,483	42,285***	40,123	47,638***	39,653	43,033***	41,762	48,098***
Production cost	23,577	28,173***	23,793	28,922***	24,664	27,730***	26,925	29,643***
Net returns	12,906	14,112	16,330	18,716*	14,989	15,303	14,837	18,455**
Incremental rate of return		26%		47%		10%		133%

[a] *, **, *** significantly different at 1%, 5%, and 10% level of significance, respectively. Source of data: PhilRice SED-STRIVE survey, 2002-04.

Even if seed price were not government-subsidized, hybrid rice production would still give higher returns than inbred, given the yield advantage calculated from the SED-STRIVE survey of about 0.5 t ha^{-1} (Table 2). The profit advantage was greater in the DS than in the WS. On average, the incremental rate of return for using hybrid ranged from 10% to 26% during the WS and 47% to more than 100% in the DS, even without the seed subsidy. In some selected provinces, particularly in the WS, the incremental profit from hybrid was not enough to offset the incremental cost.

Factors affecting hybrid rice adoption

Results of initial analysis using the linear probability adoption model and corroborated by simple ranking of the reasons given by adopters for planting hybrid rice indicated that price factors such as paddy price and price of labor were significant determinants of hybrid rice adoption. (In this case, a farmer was considered an adopter if he planted hybrid rice more than twice.) An increase in the price incentive will increase the likelihood of a farmer adopting hybrid rice. Higher price, which indicates higher quality rice, was also one reason given by farmers for continuing to plant hybrid rice (Table 3). On the other hand, if a farmer faces higher wage rates, he will more likely not adopt hybrid rice, especially with labor comprising the bulk of production cost, and with the perception that hybrid rice cultivation is more laborious than growing inbred rice (Relado et al 2005). The seed price, which is supposed to be a major determinant, was not captured in the adoption model, possibly owing to the similarity of prices because of the seed subsidy. Many farmers, however, listed high seed cost as one major reason for not continuing to plant hybrid rice.

Yield and farm area were also highly significant determinants of hybrid rice adoption. Yield was not only significant in the adoption model but the single most frequently mentioned reason for continually planting hybrid rice. On the other hand, farm area also came out as a significant factor in adoption. The larger farms have a higher probability of adopting hybrid rice. Finally, some other factors such as tenure status, attendance in hybrid training, and household size all had significant positive coefficients. Hybrid rice was adopted more by farmers who own the land they cultivate, have trained on hybrid rice production, and have more family members. In a study of early farm-level experiences, age, education, farmers' experience, and source of farm financing were also significant factors (Casiwan et al 2002, Sombilla et al 2004) influencing initial adoption.

Table 3. Reasons for continuing and not continuing to plant hybrid rice, five provinces, by season.

Reason	2003 DS	2004 WS	2005 DS	2005 WS
	Ranked (based on frequency)			
For continually planting hybrid rice				
Higher yield	1	1	1	1
Higher income	5	2	3	2
Higher output price	2	5	4	4
Good eating quality	3	3	2	3
Try new variety/trial	3	4		5
Planted by neighbors/co-farmers	4	5	3	4
To avail of gov't program/subsidy	4	5	3	
For not planting hybrid rice during the season				
No available/late supply of seeds	3	6	3	2
Not suitable for the season	5	1	6	1
Low yield/failure last season	4	5	1	2
Low profit/same profit with inbred	1	4	5	6
Susceptible to pests/diseases	3	3	1	1
Variety rotation	6	7	3	4
Costly seed/costly labor/no capital	5	2	4	3
Insufficient water supply	2	6	2	7
Low price/marketing problem	5	8	2	5

Source of data: PhilRice-STRIVE survey, 2002-04.

Role of seed subsidy in initial hybrid rice adoption

The seed if hybrid rice was higher than that of inbred, and initial and continuing adoption of hybrid rice was, to some extent, attributed to the current seed subsidy given to farmers. Since the start of the HRCP, a 50% seed subsidy was given to farmers under schemes such as "plant now, pay later." Subsidy in the form of input subsidies and guaranteed market were also initially provided to seed growers and seed cooperatives. With the expansion and increasing capability and efficiency of seed grower cooperatives, these subsidies, including seed procurement and distribution, were gradually removed, except for technical assistance and credit linkage, and other forms of incentives, such as soft loans on machineries and seed cleaners.

With the limited budget of the government, the progress of commercialization, and the evidence of significant hybrid rice yield advantage in farmers' fields, gradual, clear, and firm plan of reducing farmers' subsidy is now being contemplated. The phase-out schedule should be done in a way that will not bring to a standstill the gains posted by the current commercialization program. In the scheduling, it is important to consider that at the yield advantage, output price, and costs during the WS given in Table 2, the removal of seed subsidy will still give a reasonable incremental rate of return, but net returns will not be significantly different from those of inbred rice cultivation on average. At current yields and prices during DS in favorable areas, the data show financial viability even without seed subsidy.

Role of the government

Basic research on parental lines, development of hybrid rice variety, and on-farm adaptive research on location-specific crop management in hybrid cultivation and seed production must be sustained in the long run. For efficient hybrid rice R & D, adaptive research can be done in collaboration with state colleges and universities, the regional research centers of the DA, and capable local government units. These agencies, when strengthened can also continue doing adaptive location-specific research in the long run that will ensure hybrid rice yield advantage in their specific regions.

Also, to ensure quality standards in hybrid rice seed production, the role of the government as a regulatory agency must be strengthened.

The National Seed Industry Act, particularly the seed importation provision, should be revised to ensure that farmers will be able to avail of quality, tested, and proven superior hybrid rice seeds at the most reasonable price. In the long run, for economic development, the government should continue to provide technical support and a favorable policy environment to enable the local hybrid rice seed industry to grow and improve its efficiency.

Sustaining the hybrid rice industry

In the end, the success and sustainability of the hybrid rice industry will greatly depend on the sustained demand for hybrid rice seeds and the participation of private seed companies and seed cooperatives. With the average yields of individual seed growers now at 700-800 kg ha^{-1} and with seed yields among private companies even higher at around 1.0 t ha^{-1}, lower prices of hybrid rice seeds can be expected. This will probably increase the demand from farmers for hybrid rice, thereby helping to lower seed cost. Even when seed subsidies are eventually phased out, farmers will continue to plant hybrids, provided they are better and more profitable than other varieties. Farmers do accept new varieties: for example, PSBRc 82 was released in 2000 and had already been adopted by 10% of the farmers less than 2 yr later.

Efforts at encouraging the participation of private seed companies should thus continue, not only in hybrid rice seed production and marketing but also in R&D activities to develop new hybrids. There is much to learn from the promotion and marketing strategies that have led to the marketing success of the *Bigante* hybrid. Continued technical support, training, and assistance to smaller hybrid rice seed growers and seed grower cooperatives should also be sustained to enhance seed quality and efficiency. This should be done, however, in a way that will encourage and not stifle their marketing capacity.

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Hybrid rice dissemination in Vietnam

L. H. Nhu

Hybrids intended for commercial cultivation were first introduced from China to the northern provinces of Vietnam in 1992. Several of the hybrids were found adapted and were soon used commercially. Since then, several locally developed rice hybrids have also been released and grown. In 2004, the area planted to hybrid rice reached 600,000 ha, increasing production by an estimated 800,000-900,000 t. Statistics show that hybrid rice yielded about 1.5 t ha^{-1} higher than conventional varieties. Seed production sites have been identified where average seed yield reached 2.5-3.2 t ha^{-1}. Because of the country's proximity to China, the ease of transport, and the lack of tariff for hybrid seed, nearly 80% of hybrid seeds are imported. Only the remaining 20% are locally produced. There is ample competition in the hybrid seed market. The national program, mainly through the Hybrid Rice Research and Development Center, is engaged in breeding and has identified new high-yielding hybrids with good quality and resistance to diseases. Successful hybrid rice dissemination could be largely attributed to the priority and substantial investment by the government on promotion of hybrid rice. In addition, the government has promulgated policies favorable to further the development of hybrid rice in Vietnam. The Ministry of Agriculture and Rural Development (MARD) is closely managing the hybrid programs, which is being implemented through several collaborating agencies. Crucial are the institutional linkages. Found effective in the program implementation are demonstration trials, training, and giving assistance to farmers through the provincial, district, and communal extension network. Research in Vietnam is closely linked to what is demanded by farmers in actual production and to what is needed by the seed industry. Domestic and foreign-owned seed business units are important partners in transferring improved seed production technology to farmers. Major government policy and financial support to hybrid rice dissemination were made in the following areas: 1) establishment of a center for hybrid rice research and development ; 2) launching a national seed program; and 3) strengthening the hybrid rice extension program. Other policies favorable to wider adoption of hybrid rice included no levy on imported seeds, seed subsidies for ethnic minorities, and supporting investments in irrigation and drying facilities. Collaboration with China, India, IRRI, and FAO made significant contributions to the success of hybrid rice. There is a good prospect of increasing the area planted to hybrid rice to 800,000 or 1,000,000 ha and producing locally 50-60% of the seed by year 2010. The national program will continue to conduct research to identify new improved hybrids and develop the local seed industry.

Hybrid rices were first introduced into Vietnam in 1992 from the southern provinces of China through the bordering northern provinces. Several introduced hybrids were found adapted, especially during the winter season. Subsequently, rice hybrids were also developed locally in collaboration with IRRI and China. By 2004, the hybrid rice area in the country increased to about 600,000 ha, which increased rice yields by 1.5 t ha^{-1} and production by 800,000 to 900,000 t in the north, central, and the mountainous provinces.

This paper describes briefly how this was achieved.

Large-scale introduction of selected rice hybrids from China

With the help of FAO, a Technical Cooperation Project was launched to import hybrid rice seeds along with an invitation for Chinese experts who helped in explaining as well as sharing the technology. The F_1 seed production of hybrids—Tapgiao 1, Tapgiao 3, and Tapgiao 4 (Luat et al 1990), Shan You 63, Shan You 99, Shan You Quang 12, and Pyo You 64 and the associated parental line purification was started in the initial stages. These hybrids yielded 6.5-8.5 t ha^{-1}, which was 13-14% higher than local check variety CR203. Through this project, a hybrid rice scientist from IRRI was also invited as a consultant to provide guidance in the development and dissemination of hybrid rice technology in Vietnam. The IRRI expert recommended the establishment of a strong hybrid rice team to develop local rice hybrids and produce hybrid rice seeds in the country, while promoting the rice hybrids introduced from China. The FAO and IRRI experts also proposed close cooperation of Vietnam with China, IRRI, and India.

Government priority and purpose

Once some good results on the performance of rice hybrids were obtained (Luat et al 1994, 1995), the government of Vietnam identified hybrid rice technology as a priority and provided substantial support for its seed production and dissemination locally. The Extension Wing of the Ministry of Agriculture and Rural Development (MARD) was given the responsibility and authority to promote the technology in close collaboration with the research institutions and provincial-level departments of agriculture and rural development, departments of science and technology, and the departments of agriculture. The provincial government played a key role in program implementation, taking the lead in putting up hybrid rice demonstrations, staff training and farmer training to produce hybrid rice seeds and cultivate hybrid rice. In Vietnam, the cooperation between the central and the provincial governments is very strong and well-designed to promote hybrid rice technology.

Close linkage between research and seed industry

The government established a close linkage with research institutions that develop and/or identify the best adapted rice hybrids and seed production agencies that are responsible for importing and/or producing seeds of the most suitable hybrids. The government also encouraged close ties between research and private seed industry and allowed research institutions (such as Hanoi Agricultural Technology [HAU]) to sell the parents of its hybrid, VL 20, to the private sector for commercial production of hybrid seeds. The Hybrid Rice Research and Development Center (HRRDC) is negotiating the sale of parental lines of several new rice hybrids—HYT 83 and HYT 100 (developed locally from IRRI-bred CMS lines)—with local and foreign private seed companies.

Channels for hybrid rice dissemination

The central and provincial governments have, for the past 12 years, provided significant investment through the central, provincial, and district agricultural extension network for training farmers in hybrid rice production. Three strategies have been used to transfer the technology to farmers: a) develop farmers' field schools, b) conduct long-term and short-term training courses and put up demonstration models, and c) use mass media to educate the farmers.

Staff in research institutions have been transferring F_1 seed production technology by purification and multiplication of parental lines through the central and local technical units. These tasks involve very complicated steps that are successfully handled by HRRDC, HAU, and some advanced provincial seed companies. These institutions multiply and provide parental lines to hybrid rice seed production units.

Domestic and foreign-owned seed companies also play a key role in the transfer of hybrid rice technology. These companies sign a contract with cooperatives and farmer groups for the supply of hybrid seeds. They provide parental lines, chemicals, along with technical instructions, and procure hybrid seeds at an agreed price.

The projects funded by FAO, IRRI-ADB, and some NGOs were also instrumental in the transfer of hybrid rice technology in Vietnam.

Government policy support

The government of Vietnam has provided support to the hybrid rice program in the following ways:

1. Establishment of the Center for Research and Development of Hybrid Rice
   This center was established in 1994 under the Vietnam Agricultural Science Institute (VASI) 2 yr after the introduction of hybrid rice technology in the country. This center also coordinates the hybrid rice research network and links hybrid rice technology with production.

2. Establishment of Hybrid Rice Seed Project under the National Seed Program
   Within the National Seed Program, the hybrid rice seed project was given top priority. In the first phase (2000-05), the government has invested US$1 million to ensure the supply of hybrid rice seed. The infrastructure and the technical capacity have been developed to produce the required quantity and quality of parental lines to produce F_1 seeds in the country. In the second phase (2006-10), seeds will be produced locally to meet the hybrid rice seed demand.

3. Establishment of the Hybrid Rice Extension Program
   Since 1993, the government of Vietnam has provided financial support to the agricultural extension system to promote hybrid rice—more than US$2 million for extension-related activities such as training hybrid rice seed production, on-farm demonstrations, and public awareness. An adequate number of technical staff and farmer-adopters became available in the country to promote the technology in targeted areas.

4. Other policy support
   Besides the abovementioned investments, the government of Vietnam has also provided policy support to create favorable conditions for the promotion of hybrid rice. These include i) providing preferential treatment to foreign investors to encourage them to engage in the development of the seed industry in Vietnam, ii) waiving duty on imported rice seed, iii) granting of seed subsidy to ethnic minorities who live in remote areas, and iv) supporting investment in irrigation and seed drying facilities in hybrid rice seed production areas. These policies have made a positive impact on promoting hybrid rice in Vietnam.

Future oppurtunities

Notwithstanding the adequate financial and policy support give to hybrid rice in Vietnam, this technology has covered only about 8% of the total rice area during the past 10 years. To cover larger areas, the country needs to do the following:

1. Improve the infrastructure and the capacity of the seed industry to produce hybrid rice seeds locally.
2. Develop rice hybrids possessing grain quality that is comparable with that of inbred rice.
3. Develop rice hybrids and associated agronomic management (including low seed rate), suitable for direct-seeded conditions in the Cuu Long River Delta.

Currently, Vietnam produces 20% of its hybrid rice seed requirement from 600,000 ha in its northern, central, and highland regions. In the next 5 yr, the government would increase this area to 1 million ha, producing at least 60% of the total seed requirement. This is a challenging task because the seed industry in Vietnam has to compete with the well-established seed industry in China from where hybrid rice seeds can continue to be supplied at very competitive prices.

Vietnam is committed to meet these challenges with the help of private seed companies, IRRI, FAO, China, and APSA .

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Vietnam's experience with hybrid rice cultivation: an economic assessment

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Rice cultivation is a prime economic activity in rural Vietnam and a major source of foreign exchange earnings. Rice occupies nearly 60% of the cropped area in Vietnam. About 85% of the lands allocated to food crops are currently utilized for rice cultivation, which contributes almost 90% of total output.

Vietnam has achieved rapid growth in rice production after launching the economic liberalization policies (*doi moi*) in 1987 (Fig. 1). During 1970-90, the production growth of rice was 3.2% per year, which is accelerated to 4.5% during 1990-2004 (Table 1). An intensification of rice cultivation with the availability of short-duration modern varieties and higher productivity are the main contributing factors to the impressive growth in rice production. The rapid growth in rice production turned Vietnam into the second largest exporter of rice in the global market.

The progress in rice production has been uneven across region (Table 2). Most of the increase in production came from the Mekong River Delta in the south and the Red River Delta in the north. The growth in rice production has been disappointing for the northern mountainous regions and the central highlands and also the central and southern coastal regions of Vietnam, mostly due to predominance of unfavorable rice production environments (i.e., uplands with poor soils and cold stresses and rainfed lowlands with drought stress and acidic and saline soils). The share of these regions in total rice production has decreased from 37% in 1985 to 25% in 2000. As a result, the regional disparity in per capita rice production has grown over time.

According to recent statistics, per capita rice production in Vietnam is 427 kg annum^{-1}, which is much higher than the norm of 300 kg for comfortable food security at the household

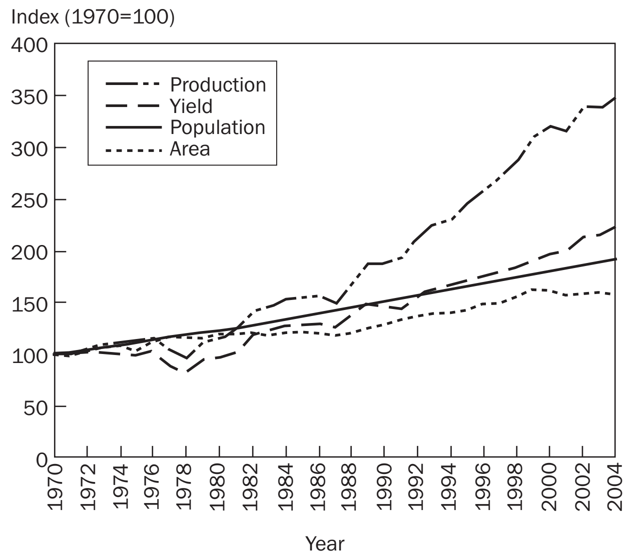

Fig. 1. Trends in rice area, production, and yield, 1970-2004 (FAOSTAT 2005).

Table 1. Sources of growth (% yr^{-1}) in rice production (FAOSTAT, 2005).

Period	Area	Yield	Production
1970-1990	1.10	2.13	3.23
1990-2004	1.45	3.08	4.53

Table 2. Per capita rice production on different regions in 2003 (GSO 2004, Statistical Yearbook).

Region	Rice production (000 t)	Population (million)	Per capita production (kg person^{-1})	Rice yield (t ha^{-1})
Red River Delta	6,489	17.6	369	5.5
Northeast	2,464	9.2	268	4.4
Northwest	484	2.4	202	3.5
North central coast	3,218	10.4	309	4.6
South central coast	1,867	6.9	270	4.6
Central highlights	734	4.6	160	3.8
Southeast	1,738	12.9	135	3.6
Mekong River Delta	17,524	16.9	1,036	4.6
Vietnam	34,518	80.9	427	4.6

level. The number is highest (1,036 kg person^{-1}) in the Mekong River Delta and lowest (135 kg person^{-1}) in the southeastern region (Table 2). Consequently, while surplus rice in the Mekong River Delta is procured for export, a large number of provinces in the central and northern regions suffer from food deficit. Therefore, food security is still a major issue for many provinces in the northern and central regions of Vietnam. To achieve household-level food security, Vietnam has to produce more rice in regions where average farm size is small and rice needs are difficult to meet through trade because of difficult terrain, underdeveloped infrastructure, and poor marketing skills.

Under these circumstances, diffusion of hybrid rice is considered an important component of the government's strategy in achieving food security in these regions. The Vietnam government has recognized that the exploitation of 16-20% yield gains of hybrid rice over the inbred varieties (Yuan 1994, 1998; Virmani 1998) would help the food-deficit northern and central regions reduce their dependence on rice imports from the surplus south Vietnam. The present study had been undertaken to understand the prospects of hybrid rice production and to find out the comparative profitability of hybrid and inbred rice cultivation. It also assesses farmers' perception of hybrid rice cultivation to identify constraints to faster diffusion of hybrid rice technology.

Data source and methodology

The study was based on both primary and secondary data. Secondary data were collected from different sources such as the General Statistics Office, the Ministry of Agriculture and Rural Development of Vietnam, and the FAO electronic database. To assess the profitability in hybrid rice cultivation and compare it with inbred rice, primary data have been generated through farm-household surveys. A sample survey was primarily conducted for an economic assessment of the potential hybrid rice production in 2001 (Ut and Hossain 2002). A repeat survey was conducted in 2005 to generate comparable data. The samples were selected using a multistage random sampling method. A district was randomly selected from 14 districts in 2001 and six districts in 2005. A village was then randomly selected from each of the districts. All households in the selected villages that cultivated both hybrid and inbred rice were selected using a structured questionnaire. The sample consisted of 391 farmers in 2001 and 146 farmers in 2005.

Results and discussion

Progress in hybrid rice cultivation

Hybrid rice cultivation was initiated with imports of seeds from China in the northern regions of Vietnam, which have similar agroecological and socioeconomic conditions as in southern China. Vietnam is the only country in the humid tropics in Asia where the rate of hybrid rice adoption is fast growing (Janaiah and Hossain 2003). Coverage under hybrid rice in 2004 reached 600,000 ha, about 7% of the total area. This has expanded very rapidly in the dry season, but progress has been slow in the wet season mainly because of high incidence of pests. The adoption of hybrid rice did not make any headway in the Mekong Delta rivers because of the widespread practice of direct seeding. Since the price of hybrid rice seed is very high, the high rate used in the direct seeding method makes hybrid rice cultivation less profitable for the south.

The rate of expansion of hybrid rice cultivation has slowed down in recent years. The main reason appears to be the stagnant yield in the production of hybrid compared with the continuous increase in yield in the cultivation of inbred varieties (Fig. 2). Also pest pressure is much higher in hybrid rice cultivation than for inbreds. Farmers mentioned that the pest incidence in hybrid rice cultivation has been growing over time. Many farmers who previously reduced spraying of insecticides following an integrated pest management training have reverted to spraying four or five times to save the hybrid rice crops.

Import dependency for hybrid rice seeds

It was earlier stated that the hybrid rice program was initiated in 1992 with seeds imported from

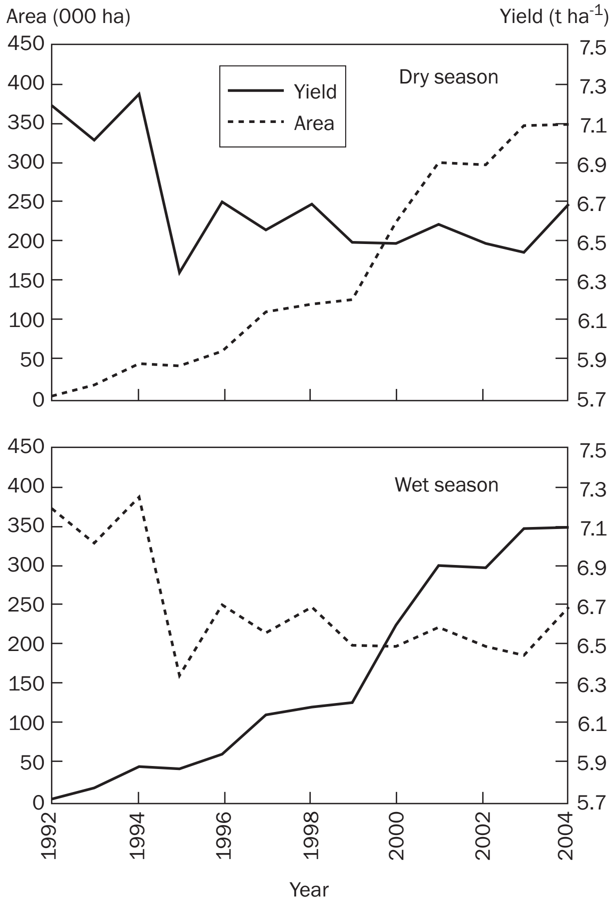

Fig. 2. Progress in hybrid rice cultivation, MARD, 2004.

Table 3. Sources of hybrid seed, 1998-2003.

Year	Sources of seed			Share of imports (%)
	Domestic production (t)	Imports (t)	Total (t)	
1998	750	4156	4,906	85
1999	773	8157	8,930	91
2000	1,426	13,482	14,908	90
2001	2,400	11,660	14,060	83
2002	3,840	12,682	16,522	77
2003	3,458	12,113	15,598	78

Table 4. Yield of hybrid and inbred rice varieties in different seasons and years.

Survey[a] year and season	Hybrid varieties ($t\ ha^{-1}$)	Inbred varieties ($t\ ha^{-1}$)	Percent gain
Dry season			
2000	6.33	5.25	21
2004	6.31	5.75	10
Wet season			
2000	6.07	4.99	22
2004	5.42	5.33	2

[a]Sample survey of hybrid rice growers. Sample size: 391 in 2000 and 146 in 2004.

China. With the expansion of hybrid rice area, the government stated investing in research for the development of hybrid rice varieties and for seed production within the country. In 1994, the Vietnam Agricultural Science Institute was given the responsibility to coordinate all hybrid rice research and seed production programs. It established a Hybrid Rice Research Center (HRRC) to coordinate the activities of the extension agencies at the provincial level, universities, and the public sector seed companies engaged in research training and seed production. In 2000, the national seed program funded a hybrid rice seed project (US$1 million) for implementation by HRRC (An 2002). The agricultural extension network has been providing guidance and assistance to farmers in various provinces for the production of hybrid seed.

Seed yield has increased substantially from 1.0 t ha^{-1} in 1995 to 2.1 t ha^{-1} in 2004. The domestic seed production infrastructure is not, however, adequate to meet the growing demand for hybrid rice seed. The production of hybrid rice seeds has increased from 750 t in 1998 to 3,458 t in 2003 (Table 3). But the share of imported hybrid rice seed has decreased only marginally, from 85% in 1998 to 78% in 2003. Thus, Vietnam is still highly dependent on China for hybrid rice seed.

Economic performance at the farm level

Yield advantage of hybrid rice. The data collected through sample surveys of farmers showed a yield gain of 1.08 t ha^{-1} compared with the inbred in both dry and wet seasons in 2000. In other words, farmers gained almost 22% higher yields from hybrid rice cultivation (Table 4). But yield gain was reduced during the 2000-04 period. The yield of hybrid rice remained almost stagnant from 2000 to 2004, but the yield of inbred increased in both dry and wet seasons. In 2004, yield gain of hybrids was reduced to only 10% over inbred varieties in the dry season and to only 2% in the wet season. Under these circumstances, more research and development programs for increasing the yield of hybrid rice are needed to maintain the yield gains and sustain farmers' interest in continuing hybrid rice production.

Price of hybrid rice seed. For hybrid rice, the seed has to be produced in separate fields every year. Farmers cannot keep the seeds from their own harvest as in the case of inbred varieties. Moreover, hybrid seed production involves intensive care and requires substantially higher investment in labor and chemicals. As a result, the price of hybrid rice seed is substantially higher (five to eight times) than that of inbred seed. The purchase prices of some prominent hybrid rice seeds as obtained from the survey are presented in Table 5. The price of seed for the inbred varieties was only US\$ 0.28 kg^{-1}, while the price was found to be US\$ 1.94 kg^{-1} for Chinese variety Bo You 253, and US\$ 1.30 kg for II you 838. The price of hybrids produced in Vietnam (Trang Nong 15, Ve 1) was even higher than that of Chinese variety II You 838. Thus, in spite of the increased seed yield, the Vietnamese varieties cannot compete with the imported cheap Chinese varieties.

Seed cost for hybrid rice cultivation. As price of hybrid rice seed is five to eight times higher than that of inbred varieties, farmers would have to pay a substantial amount of money on account of seed. In view of the high seed price, researchers have developed a management system that requires a lower seeding rate. Seeding rate used in hybrid rice cultivation is one-fifth that of inbred varieties, which helps to reduce seed cost. In spite of economizing on the use of seed quantity, seed cost in the cultivation of hybrid rice seed is still almost double that of inbred varieties (Fig. 3). Besides the high cost, access to credit and cash for buying seeds is also an issue. The high seed cost is one of the major constraints to adoption of hybrid rice cultivation, particularly among the commercial farmers in Vietnam.

Output price of hybrid rice. In the 2000 survey, we found that hybrid rice fetched a price in the market almost 4% lower than that of inbred varieties. The low price of hybrid varieties could be due to the perceived low quality of the hybrid rice grain (Hossain et al 2003). At the initial stage of cultivation, the market price of a commodity could also be lower because the quality is not acceptable to traders and millers. But the quality of Chinese hybrids has improved over time so the new hybrids have a better chance of getting accepted. It should be mentioned here that HRRC had developed hybrid seed of HYT 56 and HYT 57 (CMS line from IRRI) with high grain quality. In the 2005 survey, however, farmers still reported obtaining lower price for the hybrid (Table 6). The price difference has, however, narrowed down by 2004, indicating an improvement in grain quality of recent hybrid rice varieties.

Net returns of hybrid rice cultivation. Despite the higher production cost and lower market price, hybrid rice cultivation was still profitable compared with inbred cultivation in 2000. Farmers got an additional net return of US\$72 and US\$56 ha^{-1} from hybrid rice cultivation in 2000 and 2004, respectively, in the dry season

Table 5. Prices of hybrid seed of different rice varieties, 2005.

Variety	Purchase price (US\$ kg^{-1})
II You (Chinese)	1.30
Do You 527 (Chinese)	1.75
Bo You (Chinese)	1.94
Trang Nong (Vietnamese)	1.65
Ve 1 (Vietnamese)	1.47
Inbred varieties	0.28

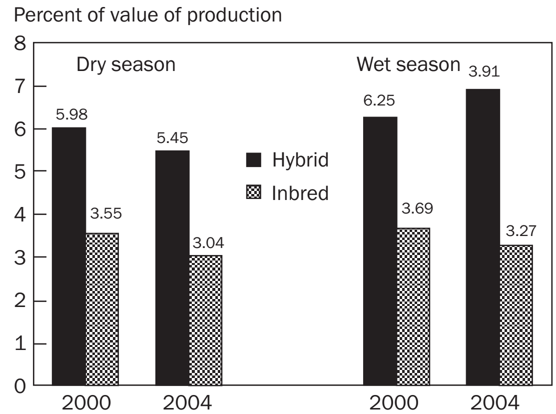

Fig. 3. Comparative seed cost of hybrid and inbred rice in different seasons and years.

Table 6. Grain price of hybrid and inbred rice in 2000 and 2004.

Survey year and season	Price (US$ t^{-1}, unhusked)		Difference (percent)
	Hybrid rice	Inbred rice	
Dry season			
2000	124.40	128.44	-4.0
2004	133.74	136.84	-2.3
Wet season			
2000	118.01	123.67	-4.6
2004	136.00	139.03	-2.2

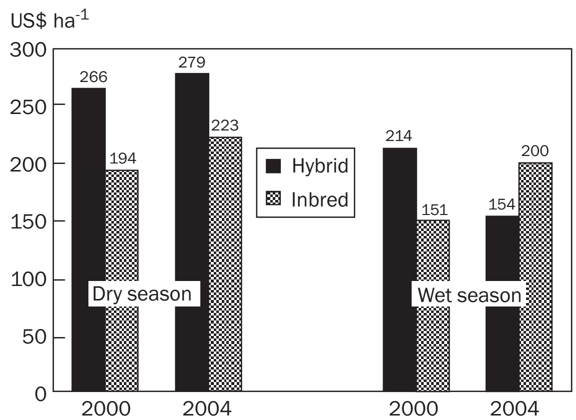

Fig. 4. Net return (US$ ha^{-1}) of hybrid vs inbred rice in 2000 and 2004.

(Fig. 4). But the profitability gain for the wet season, which was positive in 2000, turned to be marginally negative in 2004. The lower return dampened farmers' incentives to expand hybrid rice cultivation in the wet season. This finding suggests that the recent slow down in the expansion of hybrid rice cultivation in Vietnam could be due to economic factors.

Constraints to diffusion of hybrid rice. The survey also collected qualitative information regarding the merits and demerits of hybrid rice cultivation as farmers see them. In general, most of the farmer respondents said that hybrid rice has a high yield potential, which is attractive to small and marginal farmers. But there are some constraints to the diffusion of hybrid rice that the farmers for the central region reported (i) poor quality of hybrid rice grain, (ii) high seed cost, (iii) lack of funds to buy seeds, and (iv) withdrawal of subsidy in the purchase of hybrid rice seed. In the southern region where hybrid rice is yet to be adopted, the constraints identified were (i) inferior grain quality, (ii) longer growing season (compared with inbred) thus hindering cropping intensification, and (iii) direct seeding method of crop establishment that requires high seed rate and inflates seed cost.

Conclusions

Adoption of hybrid rice is largely confined to the northern and central regions of Vietnam. The predominance of small and marginal farmers and the subsistence nature of rice farming in these regions make hybrid rice technology attractive to meet the deficits n household food requirements from rice production in their own farms. Although hybrid rice cultivation is expanding with government's support in the north and central regions, its sustainability depends upon the availability of new hybrid rice with higher heterosis and better grain quality. The farmers had almost 22% higher yield from hybrid rice over inbred and, despite the higher production cost and lower market price, hybrid rice cultivation was still shown to be more profitable, particularly in the wet season. For the wet season, the main disadvantage of growing hybrids is the high and growing pest pressure that reduces yield and profitability.

The following policy implications may be drawn from these findings to promote hybrid rice research and development:

- More attention must be given to breeding for better grain quality, shorter maturity, and pest resistance.
- Focus on in-country seed production with improvement of seed yield.
- Promote public-private sector partnership for seed production and marketing.
- Provide access to credit for purchasing hybrid rice seeds.

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Notes

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Moving hybrid rice to farmers' fields: lessons learned from successful programs

Nguu Van Nguyen

Reducing hunger and alleviating poverty are the key UN development goals for the millennium. This was the main reason behind the UN declaration of 2004 as the International Year of Rice. The world population is growing steadily, while land and water resources are on the decline. Increasing the productivity of rice systems, therefore, is essential for the food security of more than half of the world population. Experiences in hybrid rice cultivation demonstrated beyond doubt the contribution of hybrid rice to food security and other developmental goals. The rates of hybrid rice adoption in Asian countries outside China, however, are still low and the full potential of hybrid rice has not been well utilized for reducing hunger and poverty. A review of the successful hybrid rice programs in China, Vietnam, India, and the Philippines indicates that, to be successful, national hybrid rice programs should include the following factors: a) a bold initiative to move hybrid rice to farmers' fields as the Chinese program did in 1975, the Vietnam program in 1991 and, recently, the Philippine program in 1999; b) substantial funding support during the initial phases of the program. The governments of China, Vietnam and, recently, the Philippines provided funding support, subsidies to F_1 seed production, and commercial cultivation of hybrid rice. The Indian program received a large funding support from FAO-UNDP; c) an established national institution solely for hybrid rice research and development only; and d) adequate quantity of F_1 seed, the most limiting factor for wide adoption of hybrid rice. In India, the private sector contributed to a great extent to the production of F_1 seed. Experiences in China and recently in other Asian countries show that strong private sector participation will be needed for a sustainable adoption of hybrid rice. FAO will continue to provide technical support to national programs in the development and use of hybrid rice through information dissemination and by providing a forum for information exchange and other collaborative efforts. If requested, FAO can also assist in the formulation and implementation of national hybrid rice programs.

Reducing hunger and alleviating poverty are the key UN development goals for the millennium. They were also the main reason behind the UN declaration of 2004 as the International Year of Rice. The world population is still growing steadily, while land and water resources are on the decline. Increasing the productivity of the rice systems, therefore, is essential for the food security of more than half of the world population. The Chinese experience with hybrid rice cultivation demonstrated beyond doubt the contribution of hybrid rice to food security and other developmental goals. Thanks to the large adoption of hybrid rice (about 50% of total rice area), Chinese rice production has increased sustainably from 128 million t in 1975 to 191 million t in 1990, while rice harvested area was reduced from 36 million ha in 1975 to only 33 million ha in 1990 (Nguyen 2004). The success of the hybrid rice program in China encouraged other Asian countries to establish their own hybrid rice programs during the 1980s. In the 1990s, the commercial cultivation of hybrid rice has expanded into a number of Asian countries outside China. The rates of hybrid rice adoption in Asian countries outside China, however, are still low and the full potential of hybrid rice has not been well utilized for reducing hunger and poverty. This paper attempts to analyze the factors behind the successful programs of hybrid rice development and use in Asia. It also presents briefly the challenges the hybrid rice programs face amidst changes in global climate. It likewise describes the FAO hybrid rice program for food security and livelihood improvement in Asia and elsewhere.

Successful programs for hybrid rice development and use

The success of the Chinese hybrid rice program is beyond doubt. Outside China, hybrid rice was commercially cultivated in 2004 on about 1.5 million ha in seven Asian countries—Bangladesh, India, Indonesia, Myanmar, Philippines, Sri Lanka, and Vietnam (Table 1). Vietnam's hybrid rice program ranked first in terms of planted area and percentage of hybrid area to total rice area. The Indian program ranked second in terms of planted area but ranked third in terms of percentage of hybrid area. The reverse was true for the Philippine program.

What are the main reasons behind the success of these programs in China, Vietnam, India, and the Philippines? An understanding of these factors would help other countries in their efforts to develop and use hybrid rice for food security and poverty alleviation. A review of the successful hybrid rice programs in these countries point to several elements.

Bold initiative to move hybrid rice to farmers' fields

Farmers' adoption is the best measure of the success of a program on hybrid rice development and use. Moving hybrid rice varieties to farmers' fields, therefore, is essential. However, an early demonstration of hybrid rice in farmers' fields sometimes requires bold initiative and determination. In China, the first few three-line hybrid combinations (or varieties), which were developed in 1974, were demonstrated in 1975 on 373 ha of farmers' fields. This bold initiative was taken though the basic technique for F_1 seed production was still being established (Ton-That and Tran 1989). In fact, the yield of F_1 seed was less than 400 kg ha^{-1} in 1976 (Xizhi and Mao 1994).

In Vietnam, taking advantage of the similarities in agroecosystems, the program imported several hybrid rice varieties from its neighbor China. The varieties were Shan-you 63, Shan-you-gui 99, and Bo-you 64. These were tested together with two locally developed varieties UTL 1 (IR58025A/IR29723R) and UTL 2 (IR62829A/IR2723R) in 22 cities and provinces. In 1991, commercial cultivation of hybrid rice was done on about 100 ha in farmers' fields. (Nguyen 1994). In the Philippines, although three hybrid varieties (Magat, Mestizo, and Panay) were released for cultivation between 1994 and 1998 (Obien et al 2001), adoption began only after a series of large-plot demonstrations of the released varieties on farmers' fields nationwide in 1999. In India, multilocational trials to evaluate experimental hybrid combinations were carried out from 1990 to 1994 by the national hybrid rice research network involving 12 centers all over the country (Siddiq 1994, and Ahmed 1997).

Substantial funding support during the initial phases

Recent experiences in the Philippines confirmed the fact that the good performance of hybrid rice in farmer's fields made it popular among farmers, which eventually led to strong government support. The last three presidents of the country led in the transplanting of hybrid rice at different occasions during their terms. In 2002, the government launched the Hybrid Rice Commercialization Program and provided funding support to hybrid rice commercial production and F_1 seed production to 11 public and private companies and nongovernment organizations (NGO). In addition, contracts were established with Chinese institutions to produce in China the F_1 seed of released hybrid varieties to meet popular demand (Redoña 2004). Substantial commercial hybrid rice production was recorded in 2002 (27,943 ha). Since then, adoption of hybrid rice by farmers has increased rapidly and within 2 yr, the area under commercial hybrid rice cultivation increased to 192,000 ha, about seven times that of 2002 (Table 1).

There were similar experiences in China and Vietnam. The low yield of F_1 seed during the initial stage (<400 kg ha^{-1} in 1976) of the Chinese hybrid rice program resulted not only in a small quantity of F_1 seed being available for wide adoption; it also translated into a high price of the F_1 seed. The Chinese government provided 8 million yuan in 1976 (US$4 million at that time) for the production of F_1 seed on 4,000 ha in Hainan Island to accelerate the adoption of hybrid rice (Yuan 2002). Subsequently, funding support was also provided to develop new hybrid rice varieties and especially improve of F_1 seed production through a network of seed companies at the county, prefectural, and provincial levels. Yuan (1992) estimated that the adoption of hybrid rice from 1976 to 1991 had resulted in the production of about 200 million t of extra rice; this value was more than enough to justify the government support and subsidy during the initial phase of the hybrid rice program.

In Vietnam, the results of hybrid rice tests on 100 ha of farmers' fields in 1991 encouraged the government to give funding and policy support to its hybrid rice program. These were given to local F_1 seed producers, while low-interest loans and tax exemptions were provided to companies that imported and distributed F_1 seed to farmers. Moreover, the cost of F_1 seed used in the commercial production of hybrid rice was subsidized at 30% in favorable areas, 50% in difficult areas, and 100% in mountainous areas (Nguyen 2002). The area planted to hybrid rice increased rapidly from 11,340 ha in 1992 to 102,800 ha in 1996 (Quach 1997).

In India, although no report explicitly indicates funding support from the government, activities on the development and use of hybrid rice in the country from 1992 to 2002 received a total funding support of about US$6.3 million from two consecutive UNDP-FAO projects. The approval of these projects was not possible if there were no support from the government.

Table 1. Commercial hybrid rice cultivation in Asian countries outside China, 2002-04.

Country	Hybrid rice area (ha)			National rice area in 2004 (million ha)	% national area covered by hybrid in 2004
	2002	2003	2004		
Bangladesh	-	-	40,000b	11	0.3636
India	200,000[a]	290,000[a]	560,000[a]	42.5	1.3176
Indonesia	-	-	875[a]	11.7	0.0075
Myanmar	1,294[a]	54,656[a]	54,656[b]	6	0.9109
Philippines	27,943[a]	-	192,000a	4	4.8000
Sri Lanka	-	-	15	0.75	0.0020
Vietnam	500,000[a]	600,000[a]	650,000[b]	7.4	8.7838
Total	-	-	1,497,546		

[a]Sources: Country reports at the Concluding Workshop of the IRRI-ADB funded project "Sustaining Food Security in Asia Through the Development of Hybrid Rice Technology."

Strong national institution only for hybrid rice R & D

Superior hybrid rice varieties and improved technologies for F_1 seed production are vital to sustainable large-scale adoption of hybrid rice. In 2004, China and Vietnam had the largest area under commercial hybrid rice. In China, the efficient research and training programs for scientists, seed specialists, and farmers led by the China National Hybrid Rice Research and Development Center resulted in a series of new hybrid varieties being subsequently developed and improved production technologies for F_1 seed being formulated. Yield of commercial of hybrid rice jumped from 4.2 t ha^{-1} in 1976 to 6.6 t ha^{-1} in 1991, while that of conventionally bred rice increased from 3.4 t ha^{-1} in 1976 to 4.5 t ha^{-1} in 1991 (Xizhi and Mao 1994).

In Vietnam, a network of state companies for F_1 seed production was established between 1992 and 1996 and the National Hybrid Rice Research Center was established in 1994. New hybrid rice varieties were locally developed. The yield of local F_1 seed also increased from 302 kg ha^{-1} in 1992 to 1,700 kg ha^{-1} in 2003. The quantity of F_1 seed produced locally increased from only 52 t in 1992 to 3,800 t in 2003 (Nguyen 2004). The commercial hybrid rice area increased steadily, reaching 650,000 ha in 2004 (Table 1). However, the quantity of locally produced F_1 seed is still not adequate to meet popular demand. To be sustainable, priority should be given to improvement of the local F_1 seed production. Moreover, although it was already substantially large, the area under hybrid rice production in the country in 2004 was still less than 9% of the total rice area. This indicates a great potential but it also suggests important constraints to adoption of hybrid rice. In the largest rice area of the country, the Mekong Delta, for example, adoption of hybrid rice is still negligible because of the widespread use of direct seeding. An alternative method of crop establishment needs to be developed for the sustainable expansion of hybrid rice area in the future.

Research efforts on hybrid rice in India were initiated in the early 1980s. In 1989, work was intensified by the Indian Council for Agricultural Research (ICAR) (Siddiq 1994, Ahmed 1997). In recent years, the public research system released 17 hybrid varieties. The yield of F_1 seed production reached nearly 2 t ha^{-1} in 2004 (Mishra 2004), which was economically profitable. In the same year, the total area under commercial hybrid rice production in the country reached about 560,000 ha only about 1.3% of the total (Table 1). The establishment of a national institution with a clear mandate for the development and use of hybrid rice, perhaps, will be needed to accelerate adoption of hybrid rice technology.

The International Rice Research Institute (IRRI) in Los Baños, Philippines, had its hybrid rice program established in 1979. The Philippine Rice Research Institute (PhilRice) was created in 1985 to coordinate rice research in the country. Recently, the PhilRice branch in San Mateo, was assigned as the Hybrid Rice Research Center. The 192,000 ha planted to hybrid rice in 2004 represented about 4.8 % of the total harvested area. The adoption of hybrid rice in the country, however, is at its early stage. It still requires firm funding support from the government to do research and develop improved technology for local production of F_1 seed and to generate new hybrid varieties.

Active participation of the private sector

In the developing countries of Asia, the participation of the private sector in the production of rice seed is very limited in spite of the release of high-yielding varieties and the subsequent Green Revolution. This may be because it is so easy to produce the seed of conventionally developed and pureline rice varieties such as IR8. In planting hybrid rice, however, farmers have to obtain new seed every season. An adequate quantity of F_1 seed, therefore, is the most important factor that limits wide adoption.

In India, the active participation of the private sector in the production of F_1 seed took place during the early stages of the hybrid rice program. In the early 1990s, some private companies produced the F_1 seed of hybrid variety KRH-1 in Karnataka and the F_1 seed of hybrid variety CoRH-1 in Tamil Nadu (Siddiq 1994). In 2001, the public seed companies produced about 200 t of F_1 seed, while private companies produced about 2,900 t (Hazra 2002). In recent years, the private seed companies also developed and released eight hybrid varieties (Mishra 2004).

In the Philippines, one private seed company (Cargill) submitted an experimental hybrid combination to the national coordinated tests under irrigated conditions in 1990. Private companies and NGOs have also actively participated in the government's "hybrid rice commercialization program" since 2002. In China, the yield of F_1 seed in 1991 (2.25 t ha^{-1}) made both F_1 seed production and commercial hybrid rice production economically viable. The wide adoption of hybrid rice by the farmers created favorable conditions that encouraged private companies to engage in the production of F_1 seed and commercial cultivation of hybrid rice. Today, several private companies produce F_1 seed in China, including the Longping High Tech company (Nguyen 2004). Similarly, an increased interest of private companies to participate in F_1 seed production in Vietnam has recently been observed.

Global climate changes and the hybrid rice program

More than 70% of the world's rice are produced and consumed by the people living in the tropical zone—from the Tropic of Cancer to the Tropic of Capricorn. Darwin et al (2005) estimated that the amount of land under *land class* (LC) 6 (the primary land class for rice, tropical maize, sugarcane, and rubber) in tropical areas would decline by 18.4-51% in the next century because of global changes in temperature and precipitation patterns. Under such a situation, the high yield potential of hybrid rice will be an advantage. The productivity of hybrid rice, however, may be limited by the temperature increase. Peng et al (2004) reported that the yield of dry-season rice crops in the Philippines decreased by as much as 15% for every 1 ^{o}C increase in growing-season mean temperature. Similarly, increase in the salt content in water and soil solution, as a result of the seas rising under global warming, would limit the performance of hybrid rice. Salt injury causes stunted growth, rolling of leaves, drying of lower leaves, and grain sterility. Salt content in soil solution at an electrical conductivity (EC) of 8-10 mmho cm^{-1} at 25 ^{o}C usually causes severe damage to the rice crop (Ponnamperuma and Bandyopadhya, 1980). The other potential negative effect of global climate changes on rice (including hybrid rice) production are flood and drought stresses caused by the variability in rainfall and its distribution. Hybrid rice programs, therefore, should consider the possible impacts of global climate changes on the development of new hybrid varieties.

FAO program now and beyond 2005

The 19th Session of the International Rice Commission held in Goiana, Brazil, in February 1990 recommended that FAO and member countries promote the development and use of hybrid rice for food security and livelihood improvement. The FAO regular program has the following activities:

- Collection, analysis, and dissemination of information on hybrid rice and its technologies through technical books, proceedings, newsletters, and internet web page.
- Organization of meetings, workshops, and regular sessions of the International Rice Commission for exchange of information and promotion of collaboration in the area of hybrid rice development and use among member countries. The 20th session was held 23-26 Jul 2002 in Bangkok, Thailand; the 21st session will be held in Peru in 2006.

Since 1992, the FAO field program has provided support to several member countries in the formulation and implementation of projects on hybrid rice development and use (Table 2). Under the framework of INTAFOHR, FAO participated in the formulation and implementation of the Asian Development Bank-funded project "Sustaining Food Security in Asia through the Development of Hybrid Rice Technology."

In December 2004, FAO assisted Sri Lanka in its formulation of a TCP project on hybrid rice development and use. Requests for technical support to formulate projects on hybrid rice were recently received from the Democratic Republic of Korea and Iran.

Concluding remarks

Hybrid rice has the potential to substantially contribute to the attainment of the key UN development goals for the millennium—that of reducing hunger and poverty. A review of the successful hybrid rice programs in China, Vietnam, India, and the Philippines indicates that to be successful, a national hybrid rice program should have the following elements:

- A bold initiative to move hybrid rice to farmers' fields as the Chinese program had done in 1975, the Vietnam program had done in 1991, and the Philippine program had done in 1999.
- Substantial funding support during the initial phase of the program. The governments of China, Vietnam, and the Philippines provided funding support and gave subsidies to F_1 seed production and commercial cultivation of hybrid rice. The Indian program got a large funding support from FAO-UNDP (Table 2).
- An established national institution only for hybrid rice research and development.
- Adequate quantity of F_1 seed. Hybrid rice plays a vital role, but hybrid rice programs would probably face new challenges with possible climate change. FAO will continue to provide technical support to national programs in the development and use of hybrid rice through information dissemination, information exchange, and, if requested, in the formulation and

Table 2. FAO support to national hybrid rice programs in the last decade.

Project	Country	Period	Budget (US$)
FAO/TCP/VIE/2251	Vietnam	5/92 - 12/93	259,000
FAO/TCP/VIE/6614	Vietnam	7/96 - 12/98	296,000
FAO/TCP/MYA/6612	Myanmar	3/97 - 03/99	221,000
FAO/TCP/BGD/6613	Bangladesh	5/97 - 04/99	201,000
FAO/TCP/PHI/8821	Philippines	1/98 - 12/00	275,000
FAO/TCP/INS/8921	Indonesia	1/00 - 12/01	257,000
FAO/TCP/EGY/8923	Egypt	9/99 - 12/01	248,000
UNDP/IND/91/008 (1st phase)	India	1991 - 1996	4,030,000
UNDP/IND/98/140 (2nd phase)	India	2000 - 2002	2,250,000

implementation of hybrid rice projects in member countries.

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Views of panelists on public-private partnership to promote hybrid rice

S.S Virmani – IRRI (an international center's perspective)

The major components in the development and dissemination of hybrid rice technology are technology generation, seed production, extension and policy support. While policymaking is done by the public sector, seed production is best done by the private and NGO sectors. Technology generation and extension can be done by both public and private sectors. For efficient development and dissemination of hybrid rice technology, a good partnership between the public and private sectors is essential. The relative strengths of countries in areas dealing with technology vary considerably. Based on experience in developing countries that grow rice, the public sector is stronger than the private sector in technology generation (through basic strategic and applied research), whereas the private sector is stronger than the public sector in commercial seed production, processing, and marketing, along with adaptive research and technology transfer. The NGOs and farmer cooperatives are well suited for technology transfer since these operate closer to the farms. National policymakers need to engage these sectors in such a way that their strengths are optimally utilized. The various sectors require a clear understanding of a mechanism that will ensure a mutually acceptable model of partnership. This model can be developed by identifying issues constraining public-private sector partnership in each country and discussing these openly in small group meetings in the presence of policymakers and the high-level public-private sector representatives operating in a local government and/or national country level in a country.

An IRRI-ADB study on hybrid rice identified short and long-term issues constraining public-private sector partnership for the promotion of hybrid rice in India and the Philippines. These issues were discussed in a model workshop in India and consensus was reached between the two sectors on many issues. A preferred scenario is one in which the public sector is made responsible for strategic and (selected) applied research on technology generation, nucleus seed production, and policy support, and the private sector carries out adaptive and (selected) applied research, commercial seed production (breeder, foundation, and truthfully labeled/certified hybrid seeds), processing, and marketing. The NGOs/farmers' cooperatives conduct on-farm demonstrations of hybrid seed production and technology transfer activities. The national government plays a catalytic role in the development and dissemination of the technology. The international agencies (FAO and ADB) help sensitize policymakers to various policy support needs, while APSA continues to identify issues related to commercialization of the technology through its special interest group on hybrid rice. IRRI continues to carry out strategic research to develop improved parental lines and hybrids, improved seed production technology and agronomic management guidelines, making these available freely to public and NGO institutions for evaluation, adaptation, and utilization.

In conclusion, public-private sector partnership is essential for a successful and faster development and dissemination of hybrid rice technology. The national governments should recognize the strength of each sector and carefully craft a mutually acceptable mode of partnership through a consultative process at an appropriate level of implementation in the country.

B. Mishra – India (a public sector research institution's perspective)

In India, the public sector is strong in generating hybrid rice technology because it has access to genetically diverse germplasm, well-developed research infrastructure, adequately trained human resources, and international institutions that develop this technology. The private seed industry has grown up in the last 4 decades, enabling it to handle large-scale production, processing, and marketing of hybrid seeds of various crops, including rice.

The government of India shares reasonably freely its hybrid rice germplasm with the private sector. The private hybrids are evaluated in the national network to identify those ready for accreditation (notification) and for use in frontline demonstrations, along with public hybrids.

The government also trains private-sector personnel on hybrid rice seed production, organizing meetings and workshops on hybrid rice jointly with the private sector.

The MAHYCO Research Foundation (a private, nonprofit NGO with interest on hybrid rice) has provided funds for the national hybrid rice program in its initial stage of development.

This partnership has resulted in accreditation of five private rice hybrids along with 15 public hybrids for promotion through government programs; production of 8,600 t of hybrid rice seeds in 2004, mostly by the private sector; conduct of about 9,500 frontline demonstrations during the last 5 yr to create public awareness of hybrid rice technology; training of 11,000 personnel (including many from the private sector); and putting 560,000 ha under hybrid rice during 2004.

To develop this partnership further in India, the public sector expects the following from the private sector:

- Sharing of information on seed quantity produced and sold on a regular basis
- Production and marketing of some public rice hybrids by the private sector on mutually acceptable terms
- Funding of some research projects on hybrid rice
- Participation and partial funding of hybrid rice promotion activities organized by the public sector
- Supply of private hybrid seed at reduced price for national frontline demonstration trials
- Retaining the original name of public-sector-developed rice

To strengthen public-private sector partnership for faster promotion of hybrid rice in India, the country needs policy support for sharing of public hybrids and parental lines with the private sector on an exclusive basis. Also, the country should have a policy that regulates the price of hybrid rice seed so that it does not go beyond the reach of small farmers.

N. Giao – Vietnam (public seed industry's perspective)

Vietnam is fast shifting from a centrally planned to a market economy. Consequently, the seed industry, which was in the public sector before, is moving toward privatization. In recent years, the Southern Seed Company in Ho Chi Minh City, which I have led for several years, has shifted from being a public sector entity to a joint (public-private) venture.

North Vietnam has benefited from rice hybrids developed in China. The seeds of these hybrids are available at a low price through the border trade. The government of Vietnam has a strong commitment to promote hybrid rice and is playing a catalytic role by i) supporting applied and adaptive research in breeding and seed production of hybrids; ii) training seed producers, extension workers, and farmers; and iii) conducting on-farm demonstrations to create public awareness. Consequently, hybrid rice area increased from 100 ha in 1990 to 600,000 ha in 2004. The Ministry of Agriculture and Rural Development has recently set a target of 1 million ha for hybrid rice by 2010.

Since 80% of the hybrid rice seeds are currently imported from China, the pace of dissemination of hybrid rice technology in Vietnam depends on the price and supply of seeds from China. Recently, the price of hybrid rice seed has risen and resulted in a "stagnation" of hybrid rice area. To increase the hybrid rice area further, locally developed rice hybrids and their seeds must be made available.

The Hybrid Rice Research Center in VASI has developed some local hybrids (HYT 57, HYT 83, HYT 100, VL 20, and TH3-3) derived from IRRI-bred and local parental lines. The Southern Seed Company has also found these hybrids as well as some other IRRI-bred hybrids (IR76708H and IR7521) useful. Some newly introduced CMS lines from IRRI (IR79156A and IR7521H) have given good outcrossing and seed yield in southern Vietnam. High seed yields (between 3 and 5 t ha^{-1}) have been obtained in this region, indicating its potential for hybrid rice production.

To improve hybrid rice production locally, the Vietnamese government is encouraging the private sector to join government seed companies so that these would do a better job under some joint undertaking. In the long term, the private sector will play an important role in the development and dissemination of hybrid rice in Vietnam and a good partnership is being established for that purpose.

From a public-sector viewpoint, the private sector in Vietnam should take the following responsibilities: 1) foundation seed production of parental lines; 2) F_1 seed production, processing and packaging, marketing and distribution; and 3) adaptive research to improve F_1 seed production techniques.

The public sector, on the other hand, can take responsibility for 1) developing commercial hybrids with appropriate duration, high yield, acceptable level of disease/insect resistance, and grain quality similar to those exported utilizing IRRI-bred and locally bred parental lines; 2) introducing promising hybrids from China and India under a license agreement and evaluating these national networks; 3) transferring elite hybrids and their parental lines to the private sector for seed production and marketing; 4) doing extension work to promote hybrid rice technology; and 5) continuing to support the private sector in seed production by providing them favorable credits and tax shelter and training their personnel in seed production and processing technologies.

This public-private partnership will be extremely helpful in the development and dissemination of hybrid rice.

K. Subba Rao – Pioneer, India (private seed industry's viewpoint)

An ideal public-private sector partnership should be stable and sustainable over the long term and mutually beneficial, generating significant benefits to both private companies and public institutions. The outputs and gains of this partnership should be time-bound.

Some barriers to an effective partnership are lack of a framework, lack of mutual trust and appreciation, lack of gains, and high risk and uncertainty.

The public sector has the following strengths: adequate resources (with regard to human, capital, germplasm, technology, expertise, and infrastructure); capability to mobilize resources and do research; access to funding for national priority programs; and established resources for technology dissemination. On the other hand, the private sector has the seed production and marketing skills (understanding markets, creating market and market networks, and mobilizing markets) and the flexibility to act.

The partnership should aim to have synergy by using the identified strengths in key areas to ensure hybrid rice adoption: i) breeding and biotechnology, ii) seed production, iii) technology transfer, and iv) farm practices.

To increase the pace of development and dissemination of hybrid rice technology, the partnership should aim to develop a policy framework for germplasm enhancement and technology transfer, product evaluation, farmer training for seed productivity improvement, leveraging extension system and public awareness for promotion of the technology, price support public procurement, and awareness campaign among trade partners to ensure marketability, and training and cross-country expertise to develop human resources. This policy framework should be facilitative rather than controlling.

The partnership can be enabled through collaborative projects with the built-in provision of licensing and profit sharing. Public-sector germplasm should be accessible to the private sector through material transfer agreement and licensing agreements. A similar access to any other technology should be available to the private sector through licensing or on purchase or sale basis. The public sector should enforce participatory varietal protection, farmer rights, and intellectual property rights so that the private sector can operate without fear of illegal use of their products/technology. The public sector should also provide clear guidelines as to how the private sector can use public infrastructure for developing their products. The government should facilitate trade for hybrid rice grain and provide incentives for public-private collaborative research projects. A certain percentage of such projects should have a private partner. A country should also harmonize policies between the central and provincial governments.

The above goals can be achieved if national governments establish a public-private sector partnership forum for the promotion of hybrid rice technology. Here, both partners meet regularly to develop a modus operandi that would help meet the mutually acceptable goals of developing and disseminating the technology.

Henry A. Lim – Philippines (farmer cooperative's viewpoint)

Farmer cooperatives have played an important role in promoting hybrid rice technology in the Philippines during the past 4 yr. The government-cooperative partnership was the result of an information dissemination campaign done through consultative meetings, farmers' training, and regular briefings by the Philippine Rice Research Institute (PhilRice) and the government's Department of Agriculture (DA).

A strong partnership was developed through clear program policy statements from well-informed stakeholders and commitment of both parties. The Davao Oriental Seed Producers Cooperative (DOSEPCO), located in Davao Province in the Philippines, committed itself to support hybrid rice production technology in 2000 after spending a couple of years practicing it on a small scale, in collaboration with PhilRice. The Philippine government also took initiatives to pursue this commitment by creating task forces with PhilRice, deputizing seed inspectors (PhilRice staff), closely monitoring hybrid rice seed production in the fields, and retooling stakeholders in hybrid rice. The experience helped identify certain weak areas in the implementation of the hybrid rice program. These included inadequate purity of parental lines seeds provided by PhilRice, unrealistic targets for hybrid rice area coverage, constantly changing implementation policies, inadequate seed quality control services on the national level to serve hybrid rice growers, inadequate storage facilities for leftover seed stocks, and non-standard and tedious documentation process required by government to make payment for hybrid rice seeds procured from farmers' cooperatives.

In the light of these experiences, the farmers' cooperative sector recommends the following:

1. National authorities should develop and implement a 5-yr action plan to promote hybrid rice, including the gradual reduction of subsidy on hybrid rice seeds.
2. Seed procurement procedures should be simplified.
3. Production of parental lines of public rice hybrids should be centralized and controlled.
4. Parental line seeds distributed to farmers' cooperatives should be effectively monitored.
5. Hybrid rice commercialization should be promoted only in areas where hybrids have a clear comparative advantage over inbreds.

It is rather too early to draw any final conclusions on the effectivity of this partnership. Both the Philippine government and the farmers' cooperatives need to work in a way that this partnership is mutually beneficial and helps the cause of farmers adopting hybrid rice technology to increase their income and contribute toward national self-sufficiency in rice.