Technologies for Improving Rural Livelihoods in Rainfed Systems in South Asia

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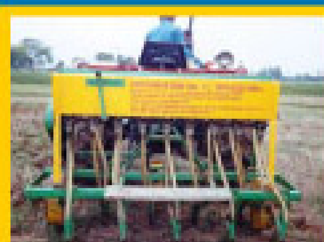

IRRI
International Rice Research Institute

IFAD
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CIMMYT

World Agroforestry Centre
Transforming Lives and Landscapes

ICRISAT

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

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

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

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Foreword

Hundreds of millions of rural poor in Bangladesh, India, and Nepal derive their food security and livelihoods from the 25 million hectares of the eastern Gangetic Plains devoted to farming systems based mainly on rainfed rice. The environments range from drought-prone bunded upland terrains in Jharkhand and Chhattisgarh states of India to flood-prone deltas in Bihar and West Bengal of India and Bangladesh. Because of high environmental fragility, high population density, and small landholdings, the majority of the farmers are resource-poor and live in poverty.

The International Fund for Agricultural Development (IFAD) supported IRRI by funding (through TAG 148 and TAG 263) research for the development of improved cultivars and agronomic practices useful to poor farmers in the eastern Gangetic Plains. IFAD also supported the IRRI-led project "Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" through TAG 634. The project was led by IRRI and jointly administered by three CGIAR centers, IRRI, CIMMYT, and ICRAF, while ICRISAT provided technical backstopping services on legume crops. This project started activities at the first planning meeting in February 2004 and the project terminated in June 2007. The project worked at 12 sites (nine in India, two in Bangladesh, and one in Nepal), of which IRRI administered seven rice-rice/legume system sites, CIMMYT four rice-wheat system sites, and ICRAF one site on hill-slope agriculture. While implementing the project, a general sequence of activities such as site selection in consultation with NARES partners, problem identification by using socioeconomic tools, selection of potential technologies, technology validation through farmer-managed field trials, and up-scaling was followed. Two to four potential technologies per site were validated and two per site finally selected for up-scaling. The three-year time frame of the project was inadequate for completing all the activities in the chain. In most cases, the last activity—technology up-scaling—began in the third year. In order to improve the livelihoods of landless and poor farmers, some supplementary livelihood support systems such as mushroom cultivation and vegetable seedling raising were also tested at a few sites.

This document, produced at the end of the project period, contains three major sections: (1) project implementation, (2) case stories, and (3) technical advisory notes. The first section briefly describes how the project was implemented and the benefits of adoption of the technologies selected for up-scaling. Stories recounting successful cases follow. Technical details of 14 technologies from seven IRRI-managed sites and one ICRAF-managed site are covered under the technical advisory notes (TANs). The TANs are prepared following the guidelines developed by IFAD. These TANs cover diverse categories of technologies, such as cropping systems, improved varieties, crop establishment methods, and nutrient management, and technologies for supplementary income for landless and marginal farmers. Resource conservation technologies (RCTs) such as zero-tillage wheat and rice were validated and efforts were made for up-scaling at the four CIMMYT-managed rice-wheat system sites. Technical aspects of these technologies are documented in the RCT Resource Book.

Thousands of farmers across 12 sites adopted these technologies and benefited. I hope that this document will be useful to the researchers, development workers, donors, and policymakers who are interested in improving the livelihoods of the rural poor of South Asia.

Robert S. Zeigler
Director General
International Rice Research Institute

Acknowledgments

This document is the outcome of three years of teamwork among farmers, national agricultural research and extension systems (NARES), and Consultative Group on International Agricultural Research (CGIAR) partners. We express our sincere gratitude to hundreds of farmers in the eastern Gangetic Plains across three countries—India, Bangladesh, and Nepal—for their positive attitude and courage in testing new technologies. Although most of the collaborating farmers are resource-poor, they are not poor in wisdom and are courageous enough to take the risk of testing new technologies, the failure of which might cause them starvation. We express our thanks to our NARES and CGIAR partner organizations for supporting this project's activities. Some high-level policymakers (e.g., the minister and secretary of agriculture), especially from Bangladesh and West Bengal and Chhattisgarh states in India, took keen interest in our technologies and supported our work. Some top policymakers came up with favorable policy support, which proved vital for paving the way for up-scaling. Media coverage, especially from Bangladeshi television, played a crucial role in promoting technologies such as direct wet-seeded rice and use of a plastic drum seeder. Many researchers and extension/development workers from GOs and NGOs of NARES partners worked at the front line of project implementation. Without their initiative and hard work, the project would have achieved little. We benefited from the advice and support of Shantanu Mathur of IFAD, Olaf Erenstein of CIMMYT-India, V. Pal Singh of ICRAF-India, Suresh Pande of ICRISAT-India, and Mike Jackson, Randolph Barker, Corinta Guerta, and Mirla Domingo of IRRI. We are grateful to the researchers/development workers who drafted and/or provided information on some of the technical advisory notes and case stories. We gratefully acknowledge editorial and printing assistance of Gene Hettel, Bill Hardy, and George Reyes of Communication and Publications Services.

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Project Implementation

Background

Hundreds of millions of rural poor in Bangladesh, India, and Nepal derive their food security and livelihoods from the 25 million hectares of the eastern Gangetic Plains devoted to farming systems based mainly on rainfed rice. Previous research on these farming systems has identified and developed improved cultivars and agronomic practices useful to poor farmers in the study areas in eastern India and in similar agroecologies in the region. IFAD supported these studies through grants TAG 148 and 263, which were carried out by a variety of research networks of international agricultural research centers (IARCs), national agricultural research and extension systems (NARES), nongovernmental organizations (NGOs), private enterprise, and farmer groups.

The International Rice Research Institute (IRRI) coordinates the Consortium for Unfavorable Rice Environments (CURE), which was formed by the merging of the Rainfed Lowland Rice Research Consortium and the Upland Rice Research Consortium. The International Maize and Wheat Improvement Center (CIMMYT) convenes the Rice-Wheat Consortium (RWC) for the Indo-Gangetic Plains. The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) coordinates the Cereal and Legumes Asia Network (CLAN) and the Global Grain Legumes Drought Research Network (GGLDRN). The consortia and networks have identified and developed a range of promising technologies that offer improved incomes for farmers of rainfed fields and ensure agroecosystem sustainability. A key to success has been the conversion from a commodity-centered approach to a systems-based one in which farmer participatory research generates location-specific recommendations. This approach has allowed better adaptation of improved practices to small-farm conditions and accelerated the pace of adoption around the field-testing sites.

More can be done to further accelerate adoption over a wider area, thereby addressing social issues (the needs and goals of the rural poor, including the landless), environmental issues (the sustainable use of soil and water resources), and economic issues (rising production costs and the advantages of crop diversification). It was also recognized that success in agricultural research for development depends on strong policy support from authorities, realistic marketing prospects for farmers, and diligent adherence to the principles of benefit and equity for all, including women and the disadvantaged. To tap into these opportunities for the resource-poor farmers of the rainfed eastern Gangetic Plains, IRRI took the lead in collaboration with other stakeholders to develop a concept note and negotiations with IFAD for funding. Stakeholders finalized a project outline, guiding principles, and objectives, and determined anticipated activities, impact assessment activities, and the phasing of implementation of the project in a meeting held in India in March 2003. After negotiations of more than two years, the "Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" (TAG 634) project was signed into being in August 2003. After the project launch in September 2003, project activities started through an inception and planning meeting held at New Delhi, India, on 16-17 February 2004. Senior research leaders and managers from the key sites, identified in the stakeholders' meeting held in 2003, participated.

Goal, objectives, and expected outputs

Goal:

The overall goal of the project is to reduce rural poverty by improving farmer livelihoods through sustainable gains in the productivity and diversity of rainfed environments in the eastern Gangetic Plains.

Objectives:

1) To identify policy and institutional changes that enable community-level participatory research and enhanced uptake of sustainable agricultural technologies for improving farmers' livelihoods.
2) To demonstrate and verify at the community level promising sustainable agricultural technologies and promote their accelerated adoption. To formulate and recommend new policies and strategies for accelerating the adoption of sustainable agricultural technologies in similar rainfed environments of the eastern Gangetic Plains.

Expected outputs:

1) An environment for validation of technologies through community-based decentralized farmer participatory research facilitated.
2) Farmers' demand for technologies at the systems level assessed for each site and a package of available technologies recommended for validation.
3) Uptake of improved technologies fast-tracked.
4) Capacity of selected stakeholders in ICT-based information management on improved agricultural technologies enhanced.

Project implementation

IRRI is responsible for the overall implementation of the project. However, IRRI manages the project in partnership with CIMMYT, ICRAF, and ICRISAT, and site-level activities are implemented in partnership with NARES and NGOs in India, Bangladesh, and Nepal, using a community participatory research approach. The sites managed by CIMMYT are basically those in the rice-wheat production system and the one in Manipur managed by ICRAF focuses on the agroforestry system on hill slopes. ICRISAT provides technical assistance to other centers and sites in planning and evaluating technologies related to pulses and oilseeds. CIMMYT has particular responsibility for the expected fourth output: "strengthening capacity of selected stakeholders in ICT-based information management." Table 1 provides a list of sites and Figure 1 shows the location of the project sites.

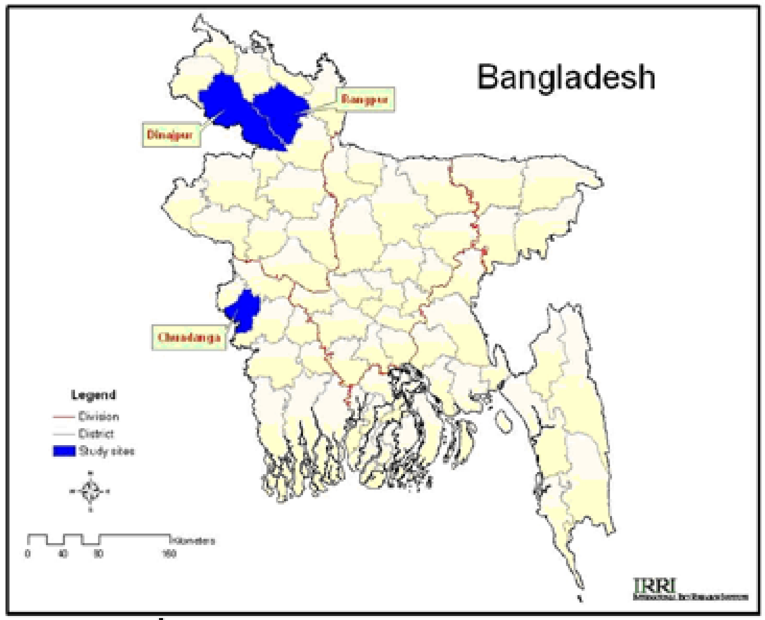
Implementation summary

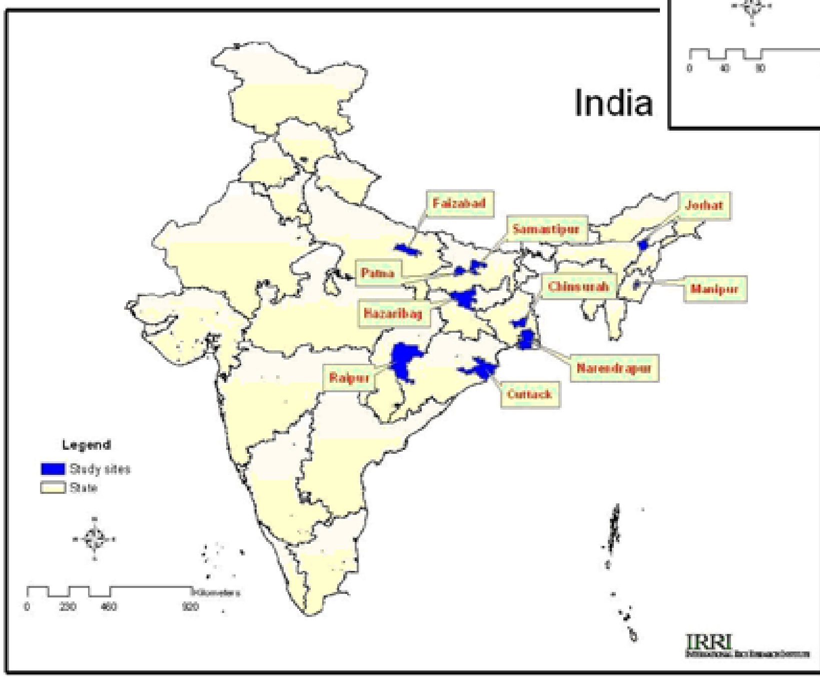
IFAD-supported research (TAGS 148 and 263) has identified a range of sustainable technologies that have the potential to improve the livelihoods of poor farmers of rainfed rice on the eastern Gangetic Plains. Findings of TAGs 148 and 263 inspired the development of the project "Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634)," which was also supported by IFAD. TAG 634 aimed to further realize these gains by focusing on facilitating farmers' adoption of these and other technologies. In the first year (2004), the project conducted socioeconomic studies to assess demand for technology, identified a large number of potential technologies to be validated for adoption, and mobilized support and developed protocols for community-level decentralized farmer participatory research. In year 2 (2005),

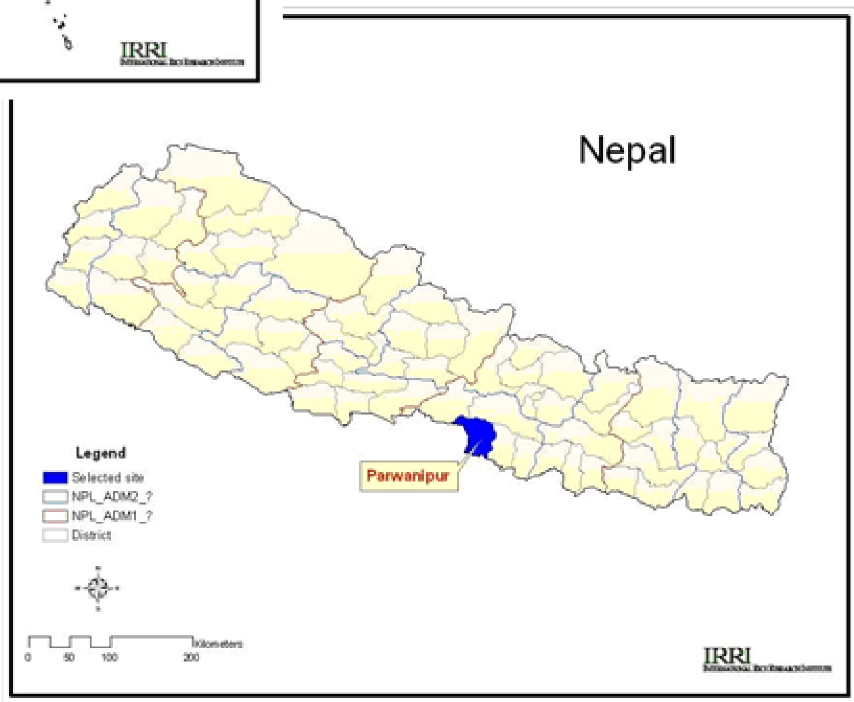
Table 1. List of project sites of the IFAD-funded project.

Site no.	Country	Project site	Production system	Principal partner
Sites managed by CIMMYT				
1	Bangladesh	Dinajpur-Rangpur	Rice-wheat	Wheat Research Center (WRC), BARI, BRRI Rangpur Station, RDRS
2	Bihar, India	Patna	Rice-wheat	Indian Council for Agricultural Research-Research Complex for Eastern Region, Patna
3	Eastern Uttar Pradesh, India	Mau	Rice-wheat	Narendra Deva University of Agriculture and Technology, Faizabad
4	Nepal	Parwanipur	Rice-wheat	Nepal Agricultural Research Council, Kathmandu sites managed by IRRI
5	Chhattisgarh, India	Raipur	Rice-fallow, rice-legumes	Indira Gandhi Agricultural University
6	Jharkhand, India	Hazaribag	Rice-fallow, rice-legumes	Central Rainfed Upland Rice Research Station; Holy Cross KVK; Birsa Agricultural University
7	Chuadanga, Bangladesh	Chuadanga, Pabna	Rice-rice, rice-legumes/ vegetables	Bangladesh Rice Research Institute, Department of Agriculture Extension, WAVE Foundation
8	North Bihar, India	Pusa	Rice-wheat	Rajendra Agricultural University; KVK, Jhargram
9	West Bengal, India	Chinsurah, Narendrapur, Ranaghat, and Nadia	Rice-rice, rice-vegetables	Department of Agriculture, Rice Research Station at Chinsurah, BCKV, NDZFDO, RKM-Asrama
10	Assam, India	Jorhat	Rice-rice	Assam Agricultural University
11	Orissa, India	Cuttack	Rice-pulses	Central Rice Research Institute
Site managed by ICRAF				
12	Manipur, India	Manipur	Agroforestry, rice-fallow	Central Agricultural University, Manipur

Fig. 1. Location of project sites in India, Bangladesh, and Nepal.







these technologies were validated at 12 key sites in the rainfed eastern Gangetic Plains across three countries—Nepal, India, and Bangladesh. Based on the performance of the validation trials, one to three star technologies were identified for each site and year 3 (2006) was dedicated for fine tuning, if needed, and up-scaling of these star technologies.

Site description

Chuadanga, Bangladesh

A vast area of Bangladesh belongs to the eastern Gangetic flood plains, which are also composed of the deltas of big rivers in the north and northeastern part of the country. Because of the prevalence of an unfavorable environment, the productivity of agricultural crops is poor. Therefore, poverty characterizes the livelihoods of the majority of the rural population. The toposequential distribution of land in the project areas shows that highlands constitute 25%, medium highlands 30%, medium lowlands 17%, and lowlands 28% of the total operational area. The low and medium lowlands (constituting 45%) are more prone to fragility and draw more attention for development in terms of technology adoption and up-scaling. At the study site, about 93% of the people primarily depend on agriculture and 54% of the household income comes from agriculture. The average holding size is 1.83 ha. Agricultural income is shared by rice farming (63%), nonrice farming (27%), and agricultural wages (10%). Out of the total land under cultivation, 87% is under own cultivation, 7% is leased, and 6% is shared. About 70% of the households have a full provision of rice, 10% have a provision of 6–9 months, 13% have a 3–5 months' provision, and 7% have less than 2 months' provision of rice.

Assam, India

Assam is one of the eastern-most states of India. Of the 27 million population, about 87% live in rural areas. The agroecosystem comprises plains, valleys, and hills, with fairly large areas under the valleys of the Brahmaputra River. Fragility of the ecosystem is primarily attributed to submergence, flash flood, as well as drought, all of which cause a high degree of uncertainty for crop production in the valleys. Rice as the main crop occupies about 2.54 million ha. *Sali* (wet season) rice grows on 67%, *ahu* (summer rice) on 20%, and *boro* (dry season) rice on 13% of the rice area. The low productivity of rice is the key constraint, caused by flash flood, terminal drought, poor socioeconomic conditions, poor nutrient management, predominance of local varieties, low temperature during early growth stages of boro (dry season) rice, and high incidence of insects, pests, and diseases. About 23% of the rice area is under irrigation and cropping intensity of the state is about 128%. Modern rice varieties are cropped on about 50% of the rice area. About 60% are small and marginal farmers, 29% medium farmers, and the rest large farmers. Male and female agricultural laborers constitute about 14% and 17% of the population, respectively. Among the three study villages, one is a tribal village having 83% scheduled tribe (ST) population. The second village is dominated by upper caste (94%) people while the third village is inhabited by a scheduled caste (SC) community (100%). The average size of operational holdings for rice culture is 0.91 ha. The farming households are 100% owned and leasing in or leasing out is nonexistent. Higher participation by women in various agricultural activities is observed in the ST-dominated village while participation is lower in the upper caste and SC-dominated villages.

Bihar, India

The state of Bihar is located in the mid-Gangetic Plains. The state is divided into South Bihar and North Bihar by the Ganges River. Of the total population of 83 million, 90% live in rural areas. The state is densely populated (>880/km^2). Only 30% of the women are literate vis-à-vis national rural literacy of 44%. The state is divided into three agroecological subzones within the alluvial plains. Nearly two-thirds of the gross cropped area is under irrigation, yet cropping intensity is only 135%. Excess moisture after harvest of rice delays establishment of a second crop. Cereals (rice, wheat, and maize) are cropped on about 79% of the area and pulses on about 11%, leaving very little for oilseeds, vegetables, and other crops. Some of the major causes of low productivity in agriculture are a lack of suitable varieties for the ecosystem, crop failure due to flood and submergence, high incidence of pests, zinc deficiency, and late establishment of the rabi crop, including wheat. In the project area, about 93% of the farmers are marginal and small, operating about 63% of the total cultivated area. About 5% are medium farmers and only 2% are large farmers. Agriculture is the major source of income, which accounts for 65% of the household income; 20% comes from business sources and 15% from services and other sources. Among the ethnic groups, the scheduled caste accounted for 25%, other backward classes accounted for 64%, and the general caste accounted for 11%. Expensive agricultural machinery such as pump sets, power tillers, tractors, and power threshers is owned by medium and large farmers. Women's active participation is visible in all kinds of agricultural activities.

Chhattisgarh, India

The state of Chhattisgarh is located at the eastern fringe of central India, at the heart of the tribal population of the country. It has a population of about 21 million (>150/km^2), with about 44% belonging to the SC and ST. Overall, rural literacy and female literacy are 61% and 47%, respectively. The state is divided into three agro-climatic zones—northern hills, Bastar plateau, and Chhattisgarh plains. Scanty and untimely rain and drought are responsible for crop failure and very low productivity. Only 36% of the total area is sown (4.8 million ha), with rice occupying about 3.5 million ha. About 24% of the cultivable area is irrigated through canals but basically it is also rain dependent. Cropping intensity of the state is 117%. In the project area, the average size of operational holdings is 1.53 ha. More than 82% of the households fully depend on agriculture. About 95% of the households have access to electricity. The average education is up to the sixth-seventh standard. There are 18% landless families, 66% marginal and small farmers, and 16% medium and large farmers. Women have either no or very little role in land preparation, application of agro-chemicals, seed broadcasting, and *biasi* (*beushening*) operations. In contrast, women's role is high in weeding, harvesting, threshing, drying, and other postharvest operations. About 6% of the households belong to the upper caste, 10% to the SC and ST, and the rest to backward classes. Low productivity, income, and price of produce; poor seed quality; and drought and crop failure are problems affecting livelihoods.

Jharkhand, India

Jharkhand, situated on the Chhatnagpur plain, is a plateau composed of diverse agroecological situations with plains, plateaus, and hills. The population is about 27 million, with 54% literacy. Jharkhand has highly unfavorable weather conditions that are attributed to a high degree of fragility of agricultural environment. Annual rainfall is about 1,000–1,400 mm, which occasionally drops to 600–700 mm. Poor soil conditions and a lack of water are mainly responsible for the very low agricultural productivity. As a result, about 60% of the population is below the poverty line. In the project villages, women's literacy rate is below the state average. About 4% of the farmers are landless, 75% marginal and small farmers, 20% medium farmers, and only 1% large farmers. Almost 99% of holdings are under ownership and only 1% belong to sharecroppers. Uplands are cropped with rice, maize, pulses, oilseeds, and vegetables, while midlands and lowlands are cropped mostly with rice and wheat. Rainfall occurs within 85 to 95 days from mid-June to mid-September, frequently causing water-stress conditions and drought. The major sources of income for all categories of farmers are basically off-farm sources, which account for about 75–80%. Agricultural income is limited to about 25% for the resource-rich, 20% for medium-resource farmers, and about 15% for resource-poor farmers. Women play a dominant role in transplanting of seedlings and postharvest processing, but they are not involved in land preparation, raising of seedlings, crop establishment, application of chemical fertilizer and pesticides, and threshing using tractors.

Manipur, India

Manipur is one of the eastern-most states of India, with a population of 2.17 million, of which about 34% are tribal folk. It has nine districts, with 90% of the area under hills. Altitude varies between 740 and 2,994 m. The monsoon is spread between May and October and 1,500 mm of precipitation fall annually. Soils in the hills are mostly red lateritic. In the valleys, soil varies from clay to clay-loam. Most soils are neutral to acidic (pH 4.5 to 6.5). The project area has rainfed hill slopes, with slopes ranging up to 30% or more. Altitude varies from 800 to 1,200 m and area is approximately 85,000 ha. Traditional *jhum* (slash-and-burn) cultivation is extensively practiced with pineapple as a sole crop on slopes and root crops and vegetables in small patches. Agriculture is the main occupation, followed by carpentry. Primary concerns are that *jhum* cycles are narrowing down and erosion of forest and soil is alarming. The soil moisture deficit is high in the dry season, while runoff is high in the rainy season because of flooding. Landholding is 1.28 ha. Women's participation in farming is higher than that of men. Farm families own on average 5 household animals, such as dairy cattle, draft animals, calves, heifers, pigs, and small ruminants. An average family consists of 5.65 members. The educational status of farmers in the study village is better than the average situation of the state, with about a 80% literacy rate. Agriculture is the primary occupation of all the households but agriculture with animal rearing is practiced by 53%, agriculture with selling labor is practiced by 41%, and agriculture with business is practiced by 6%. Landowners are all operators and, in addition, about 16% of the operational holdings are leased.

Cuttack, Orissa, India

Orissa is a coastal state of eastern India. Its seven districts are situated along the coast of the Bay of Bengal. The coastal plains receive about 1,700 mm of rainfall annually. The monsoon season experiences 6–7 depressions with cyclonic storms that occasionally cause tidal floods with the intrusion of brackish water in rice fields. The western-central area receives about 1,000 mm of rainfall and frequently suffers from waterlogging that affects rice crops. Most farmers are resource-poor, with limited sources of irrigation (about 15%). Low rice productivity is the main cause of high poverty. The project villages are located in three different districts whose farming communities are similar. On average, 79% are marginal farmers, 17% small farmers, and 4% large farmers. Rice-based cropping systems are mostly under rainfed conditions. Only about 8% of the rice lands are irrigated, 35% are rainfed lowlands, 9% are rainfed uplands, and the rest (48%) are flood-prone lowlands. More than three-fourths of the rice area is situated under unfavorable environments. Under the rainfed environment, the major cropping systems are rice-horsegram in uplands, rice-urad bean in midlands, and mung bean-rice in lowlands. Crops suffer from either excess rain or moisture stress. Low productivity of field crops and the low scope for alternative sources of income are the major reasons for poverty. Low crop productivity is due to the use of local varieties, poor-quality seeds, submergence, poor nutrient management, drought during the seedling stage, etc.

West Bengal, India

The West Bengal project sites are located in the Gangetic alluvial and coastal saline zone under the districts of Hooghly, 24-Parganas, Midnapore, and Burdwan. Rainfed submergence-prone and flood-prone lowlands occupy a greater part of it. Rice-rice, rice-potato, rice-rice-jute, rice-fallow, and rice-vegetables are the major cropping systems. Heavy rainfall in West Bengal and poor drainage frequently cause submergence and flood, which damage standing rice crops. Cultivation of traditional varieties and low technology adoption keep productivity low. On the other hand, very high population pressure on land (>900/km^2) and reductions in holding size led to a high concentration of small and marginal farmers (94%), which eventually led to high rural poverty. In the project area in 50–90% of the cases, men make most of the decisions on agricultural activities. Women belonging to medium and big farming households participate scarcely in agricultural operations. The study villages of South 24-Parganas had 20% landless families and the villages of Nadia had 10%. The concentration of marginal and small farmers' families is highest in Nadia (100%), followed by Hooghly (62%) and South 24-Parganas (49%). Irrigation coverage varies among districts, with the lowest in South 24-Parganas and highest in Nadia. About 31%, 34%, and 39% of the population of Hooghly, Nadia, and South 24-Parganas districts, respectively, is below the poverty line.

Star technologies and benefits of adoption

Site-wise star technologies with their expected benefits over current farmers' practices are listed in Table 2.

Table 2. Star technologies and their benefits over current practices.

Site	Star technology	Benefit over current practices
	IRRI-managed sites	
Chuadanga, Bangladesh	Direct wet seeding of rice using a plastic drum seeder	• Saves crop establishment labor by 95% and seeds by 50%. • Increases yields by 10–15% (0.5–1.0 t/ha).
	Rice variety BRRI dhan44 to replace BR11 in lowlands	• Produces 15–20% higher yields than the most popular aman variety, BR11. • Bold grains, taste of cooked rice, muri (pop rice), and cheera (flattened rice) are preferred in southwest region.
Raipur, Chhattisgarh, India	Line-sown short-duration rice-chickpea system for rainfed environment	• Line-sown rice using a seed drill saves seeds by 50% and laborers, and increases yields by 11% over the beushening method. • Rice-chickpea system can increase net income by 91% and 84% over rice-fallow and rice-lathyrus systems.
Hazaribag, Jharkhand, India	Short-duration rice Anjali for drought-prone rainfed bunded uplands	• Anjali yields > 4.0 t/ha and produces > 2.0 t/ha in drought when most other varieties fail or yield very little. • A variety of 95–100 days creates an opportunity for high-value chickpea after rice.
	Mushroom and elephant-foot yam for supplementary livelihood support for resource-poor families	• Cultivation of mushroom and elephant-foot yam provides supplementary income and improves household nutrition.
Jorhat, Assam, India	Modern boro (dry season) and improved bao (deepwater) rice varieties for flood-prone ecosystems	• Recent boro rice varieties Joymati, Joytiprasad, and Kanaklata (>5.0 t/ha) give >40% higher yields. • Improved bao (deepwater rice) varieties Basudev and Padmanath produce 25–30% higher yields than current varieties.
	Biofertilizer-based integrated nutrient management in boro rice	• Produces 0.90 t/ha higher yields than the farmers' practice in the boro (dry) season.
Cuttack, Orissa, India	Durga: a high-yielding rice variety for flood-prone ecosystems	• Durga can tolerate up to 100 cm flooding and produce >4.0 t/ha more than traditional varieties.
	Paddy straw mushroom for supplementary livelihood support for resource-poor families	• Cultivation of paddy straw mushroom improves household nutrition and provides supplementary income.
West Bengal, India	Direct wet seeding of rice using a plastic drum seeder	• Saves crop establishment labor by 90% and seeds by 50%. • Increases yields by 10–15%.
	Real-time N management in rice using a leaf color chart (LCC)	• Reduces N by 19% or 25 kg/ha (56 kg urea/ha) without affecting yield. • Reduces insecticide use by 50%.

continued on next page...

Table 2 continued.

Site	Star technology	Benefit over current practices
Pusa, North Bihar, India	Quality protein maize (QPM) hybrids as sole crop and intercropping with potato	• QPM hybrids produce >50% higher yields than farmers' varieties. • QPM hybrids intercropped with improved variety of potato produce >1.0 t/ha (27%) more maize and 1.3 t/ha (10%) more potato than farmers' practice.
	Zero-tillage wheat using tractor-drawn seed drill	• Enables timely planting of wheat after rice, leading to yield increase by 0.58 t/ha (18%).
	ICRAF-managed site	
Manipur, India	Integrated agro-horti-silvi culture on hill slopes	• Increases farm-level crop, biodiversity, and cropping intensity. • Provides regular income from different crops, fruits, and trees (timber). • Soil erosion decreases by >80%.
	CIMMYT-managed sites	
Rangpur-Dinajpur, Bangladesh; Patna, Bihar, India; Faizabad, eastern Utter Pradesh, India; and Parwanipur, Nepal	Direct-seeded zero-till rice and zero-till wheat	• Allows timely sowing of both rice and wheat due to 15 days' earlier harvest of rice. • Increases rice yields by about 10%. • Increases wheat yields by about 15–20%. • Saves water.
	Co-culture of *Sesbania* with rice	• Killing of *Sesbania* at 30 days after seeding by selective herbicide adds about 30 kg/ha equivalent of N and organic matter. • N savings increases to 55 kg/ha equivalent when combined with N management using LCC.
	Real-time nitrogen management in rice by the use of LCC	• Reduces N use by about 25% with slight increase in yields (6%).
	Alternative livelihood support system through mushroom cultivation, early vegetable seedling production in portable polyhouse, backyard poultry production, etc.	• Resource-poor women and youth having little or no farmland can generate some supplementary income for livelihoods.

Case Stories

Thousands of farmers across 12 sites validated and adopted the technologies dealt with under this project and benefited. Among these farmers, stories were written up for only 14. Our intention was to pick one or two farmers per site that had significantly improved their livelihoods through technology adoption or played a vital role in technology validation/up-scaling. These 14 stories are from eight out of 12 sites. There is no story from four sties. The absence of stories from four sites doesn't mean that no farmers had improved livelihoods by adopting technologies dealt with by this project; rather, it was due to a lack of initiative for writing stories. There seems to be a bias for stories on farmers adopting nonconventional technologies such as mushroom cultivation and vegetable seedling production. The number of farmers who adopted these alternative technologies is a small fraction of the farmers who adopted crop-based technologies. Yet, five out of 14 stories are based on these alternative technologies. This is mainly because improvement through crop-based technology adoption is generally taken for granted but nonconventional technologies such as mushroom cultivation are often overemphasized.

It was observed that, as most farmers are resource-poor, the benefit they derive by adopting a new technology on their limited lands is small. Income diversification is the key for improving livelihoods. But capital is needed for income diversification, and most resource-poor people lack capital. Evidence of the traditional perception that large or medium farmers are willing to test new technologies first followed by small and marginal farmers was not clear. Many small and marginal farmers are technology-hungry. These farmers look for new technology to lift some of the burden of poverty by increasing production through the adoption of improved technologies. To the subsistence farmers who produce rice for their own consumption, quality is not important to them because they seek quantity, and the opposite is true for wealthy farmers. As the majority of the farmers in the rainfed eastern Gangetic Plains are marginal and poor, the priority of future research and development should be given to yield maximization instead of profit through only quality and a higher price.

Rajib finds a better life by using dry-season (*boro*) rice technology: a case study in Jorhat District of the Indian state of Assam

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Ganakabari is a small village with 87 households in Jorhat District of the Indian state of Assam. Every year, the low-lying area is subject to deep flooding, due to monsoons that cause an overflow of the major rivers Brahmaputra and Bhogdai. For centuries, rice has been the major crop of the area, the staple for the local population. During the *kharif* (wet) season, farmers grow monocrop *sali* rice; their next crop consists of seasonal vegetables, oilseeds, and pulses. Most farmers in the village are either marginal, having less than 1 hectare of farmland, or small, with a farm size of 1–2 hectares. Most farmers have obtained a primary education.

The mighty rivers Brahmaputra and Bhogdai often cause flood damage to sali rice growing in the area. As a result, farmers experience food insecurity and poverty. The average yield of *sali* rice was only about 2.0 tons per hectare. As a result of the small farms and poor yields, most farmers in the area are poor. To improve livelihood opportunities in such areas, farmers found it necessary to grow rice during the dry (*boro*) season. Monsoons bring too much water; the dry season brings too little. Therefore, irrigation is a must for boro rice cropping. To encourage boro rice cropping, the state government started providing subsidies for low-lift pumps in 2000. State agriculture extension officials encouraged farmers in Ganakbari to use the pumps. Five of them started boro rice cropping for the first time during the 2002-03 season. They irrigated about 2.5 ha of land using low-lift pumps to get water from the Bhogdai River.

The farmers had water for irrigation, but they lacked the appropriate variety of boro rice. They had grown an unknown variety called No. 9 (possibly from Bangladesh) and two sali varieties, Luit and Lachit, in the boro season. The yield of No. 9 was about 5.0 tons per heactare and sali varieties yielded about 2.5 tons per hecatare.

The Bhogdai River is at its peak in the monsoon. Overflow of rivers regularly causes flooding in Assam. Flooding affects the sali (wet-season) rice crop. Farmers have adopted irrigated boro (dry-season) rice by using water from the river as an adaptation with nature. Adoption of boro rice cropping has improved farmers' livelihoods.

From 2003 to 2004, the Assam Agricultural University (AAU) at Jorhat initiated efforts to intensify boro cropping at Ganakbari, as part of the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains." The AAU research team organized farmers for boro rice cropping, using modern boro varieties developed by AAU—Kanaklata, Joymati, and Jyotiprasad. They gave seeds for these three varieties, as well as information and technical support.

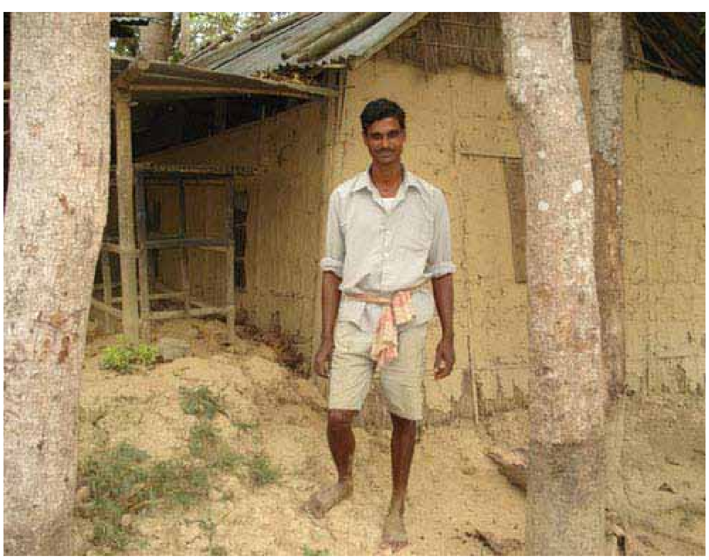
In the 2003-04 season, 24 farmers cropped boro rice in a 27.5-ha area. The AAU research team promoted biofertilizer-based integrated nutrient management (BINM), which reduces use of inorganic fertilizers and thus lowers production cost and water pollution.

In the 2004-05 and 2005-06 seasons, 33 and 25 farmers grew boro rice on 39 and 20 ha, respectively. In 2005-06, boro cropping decreased due to severe drought, which raised the cost of fuel and of boro cropping through irrigation. Most farmers who grew these modern varieties harvested more than 5.0 tons per hectare (instead of 2.0 tons per hectare of sali rice).

Most farmers have not abandoned sali rice; rather, they have adopted a boro–sali system. Boro rice is currently grown in about 30% of the rice land in Ganakabari. About 70% of boro land is now under a sali–boro system and the other 30% is planted to boro only. Of the three introduced boro varieties, Kanaklata became the most popular.

Rajib Neog is a young, educated farmer in Ganakabari village. With a secondary education, he has more schooling than many farmers. He is the youngest of five children. His eldest brother, a school teacher, settled with his family in the nearby suburban town of Dergaon. His three elder sisters all married and settled in other villages with their families.

Rajib remained at the family house in Ganakabari village to look after his parents and their 2-hectare farm. He used to cultivate mostly rice and seasonal vegetables. His family's life was difficult.



Rajib, a young, educated, and intelligent farmer, has just walked from the muddy rice field to his homestead.

Rajib stands proudly in front of his boro rice seed stock. He plans to sell Kanaklata seed just before the next boro season at the highest price.

Rajib, who is a receptive and technology-savvy farmer, saw the potential of boro cropping. In 2002-03, he was one of five farmers who cultivated boro rice for the first time in the village. In 2003-04, he adopted varieties Kanaklata and Joymati and BINM on 1.2 ha. Later, he increased the coverage to 1.5 ha, 75% of his land.

In the 2004-05 season, Rajib had a stunning success with his first attempt at growing Kanaklata. He reaped 6.25 tons per hectare, while yields of the sali varieties averaged 2.31 tons per hectare. Rajib's yield was the highest in his village. In the 2005-06 season, Rajib also harvested an excellent crop, yielding 6.31 tons per hectare. In 2004-05, his total harvest was 8.5 tons; in 2005-06, his total harvest was 9.95 tons.

In the 2006-07 boro season, Rajib's boro crop is very good and he expects another bumper crop. In addition to the higher yields of Kanaklata, Rajib grows the variety for its finer grain quality, good eating quality, and a high market price. Currently, he is growing mostly Kanaklata and No. 9.

Higher yields mean more profit. By adopting the new technology package, he was able to grow more than what he needs and has become a wealthy farmer. Occasionally, his elder brother collects rice from Rajib for his family's consumption. Higher yields also mean that Rajib has become a grower of Kanaklata seeds. He stores most of the seed just before the next planting season and he then sells it at the highest price.

In 2005, Rajib earned about Rs 24,000 (US$550) by selling 40 quintals of rice seeds. In 2006, he earned Rs 36,000 ($825) for 60 quintals. In addition to the income from rice farming, Rajib earns supplementary income by growing vegetables and raising goats and ducks.

As a result, people who know Rajib can see physical proof of his improved livelihood. In 2005, in preparation for starting his own family, Rajib used the additional income to construct an improved mud-walled tin roof house. In July 2006, he married a local girl, Pranita (Munu), who has become his constant companion. To his home Rajib has added a single-burner gas stove for cooking, which saves his family time and labor of finding firewood for cooking.

In the small village of Ganakabari and beyond, people quickly figure out who the prosperous farmers are. Successful boro cropping with record high yields has brought fame to Rajib. Many seek his counsel: neighbors in his farming community, scientists from development agencies and nongovernment organizations (NGOs), and agricultural extension specialists at the state government's Department of Agriculture.

In April 2006, Rajib received formal recognition as a successful farmer. He participated in a training course on seed selection and storage, presented at AAU by experts from IRRI and Bangladesh. During this training, the NGO Jeuti presented Rajib with a certificate of appreciation. "Jeuti" means "light," and the NGO dedicates itself to advocating the use of improved farming practices by poor farmers in Assam.

By presenting the certificate, representatives from Jeuti recognized Rajib's achievement with growing Kanaklata. Since the training course, as a way of sharing his knowledge with other farmers, Rajib has organized a self-help group (SHG) called Bhogdaiporia for resource-poor farmers in his village. In recognition of Rajib's accomplishments as a farmer, members of the local SHG have selected him as secretary. As a result, his social status has improved. Neighboring farmers ask him for seeds and seek his advice on modern cultivation practices.

Rajib; his new bride, Pranita; his father, Rameswar Neog; and his mother, Maloti Neog. Together, Rajib and Pranita share the responsibilities of farming and taking care of Rajib's elderly parents.

Mohammed Jabber Ali Mondal: how new varieties and crop diversification help one hardcore poor farmer reduce his poverty

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Living with a knee that won't bend, Jabber's approach to farming must be flexible. Mohammed Jabber Ali Mondal lives with a knee that is permanently stiff, as a result of contracting polio as a child. Unable to bend that knee, Jabber walks with a limp.

With a knee that won't bend, only 0.23 hectare of land for farming, and a four-member family to support, Jabber's challenge is to rise above seemingly insurmountable poverty. Working in rice paddies and other crop fields requires continuous bending and sitting; with a stiff knee, it is extremely difficult for Jabber to cultivate his land. However, as farming is his only option to make a living, Jabber persevered. In fact, he has become an efficient farmer, doing all the work in his fields.

Jabber's house is located in his parents' compound.

In West Bengal, where average farmholding is less than 1 ha, the notion of supporting four persons on only 0.23 hectare of farmland may sound ridiculous. But it is a reality for Jabber and for millions of others in South Asia.

Jabber finds ways to supplement the income from his farm

When he started his own family, Jabber knew his farm would be too small to support all four of them. He thought, "Farming is vital for the subsistence of my family. But I must find a supplementary source of income to improve our livelihood." Jabber cannot afford to hire labor; occasionally, he earns additional income working in other farmers' fields as a day laborer. Because of his stiff knee, the demand for his labor is low; a farmer hires him only when he cannot find an able-bodied worker. However, when Jabber does find work, he receives the same pay as the other workers. Finding very few additional sources of income in his neighborhood, Jabber has desperately sought a part-time job in the local towns—Birnagar and Ranaghat—and also in the district town of Krishnanagar. But who would give a job to someone who had no skills other than farming, an education only up to ninth grade, and a physical limitation as well?

The 1,500-km commute to Delhi

Despite the slim chances of finding work, Jabber followed a lead from a neighbor who worked as an electrical mechanic in Delhi, the capital of India. Jabber decided to go to Delhi to work during the lean farming period. Desperate, Jabber traveled more than 1,500 km from Birnagar to Delhi, leaving his wife and children at home. His parents and siblings assured Jabber that they would help look after his standing crop and his family in his absence.

Through a contact person, Jabber found a job toasting hand-made *roti* (bread) in a *dhaba* (roadside restaurant) in a busy commercial area. Over the past several years, Jabber has toasted several thousand roti per day, for a monthly salary of Rs 3,000 (less than US$70). He has worked for 2–3 months at a time, returning home before the peak farm activities began. He used to go to Delhi about two times a year, but he opted to stop going because he saves little money after paying for his lodging and food.

Despite the long travel and the long work hours, Jabber has ample motivation to keep on seeking additional income. Eight years ago, Jabber got married. He and his wife have two children: a 6-year-old son and a 3-year-old daughter. Until 2005, they lived with Jabber's parents, as members of the joint family. Jabber was engaged fulltime in farming along with his father, earning bread and butter for the whole family.

Jabber's father, Mohammed Masta Bari Mondal, is a small farmer, who for many years farmed on 1 ha of agricultural land at Khisma village, in the Ranaghat block of Nadia District in West Bengal, India. With eight children (four sons and four daughters) to support, he has always lived in poverty. However, he has managed to arrange marriages for his three eldest daughters. He has given Jabber a bit more than Jabber's share of the property: 0.23 ha of land out of his 1 ha, perhaps out of consideration for Jabber's stiff knee.

In addition to the help from his family and his own efforts, Jabber has received resources from the Nadia Zilla Farmers Development Organization (NZFDO), a local NGO that works to help farmers by introducing and validating suitable technologies from state, national, and international sources. NZFDO is a partner of IRRI, which is implementing the IRRI-led and International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" in Nadia.

Destitute and brave

Anyone who thinks that marginal farmers cannot afford the risk of trying new technologies probably has not met Jabber. He is a hardcore poor farmer, yet he is always seeking new technologies. Jabber maintains close contact with NZFDO in the town of Birnagar. NZFDO collaborates with Bidhan Chandra Agricultural University, the Department of Agriculture of the state government of West Bengal, IRRI, and the International Maize and Wheat Improvement Center (CIMMYT). With resources from NZFDO, Jabber is a leader farmer who tries new technologies. With assistance from NZFDO, Jabber grows at least three crops per year. He produces enough rice for his family's consumption and also cash crops such as pointed gourd (*patal—Trichosanthes dioica* Roxb.), spices such as chili, and vegetables such as cauliflower and cabbage in winter. Jabber regularly tests new rice varieties, has validated zero-tillage rice cropping and direct wet seeding of rice using a plastic drum seeder, and has adopted real-time nitrogen management in rice with a leaf color chart (LCC).

Jabber looks forward to the days when his *patal* (palwal) plants bear fruit and cover the trails.

Jabber has an LCC in his house. Since adopting this technology in 2004, he has saved some nitrogen fertilizer and has produced healthy crops. When he first tried another technology, direct wet seeding of rice by use of a drum seeder, he was puzzled by the aggressive growth of weeds, which took a while to keep under control. However, ultimately, he harvested about 15% more rice than from the transplanted crop.

As part of his technology validation process, Jabber grew rice variety GS-1, which gave him 6.8 tons per hectare with the drum seeder technology. This was also a test variety. Jabber said

Jabber smiles as he stands next to a good crop in his rice field.

that it was a very good variety, but it had low market demand. He has produced rice for subsistence, so he was not concerned with market value. He wanted high yield.

For the 2006-07 boro (dry) season, Jabber planted rice in a 0.13-hectare plot using a plastic drum seeder. He grew IET4786 (Satabdi) variety. The crop condition is excellent and he expects to produce about 6 tons per hectare.

After harvesting the standing boro rice, Jabber plans to grow a high-value crop—summer cabbage. Cultivation of this crop is new in the area. He has no experience in growing summer cabbage, but one of his uncles did grow the crop last year.

As a member of a hardcore poor farming community, Jabber is in a continuous struggle for subsistence to support his four-member family. His physical limitations have made his struggle more difficult. But has accepted this reality. Thus, he always smiles and he often sings. He probably uses smiles and songs to ease the mental pressure brought about by poverty. Jabber knows that his struggle may not be ending soon; thus, he tries technologies that promise to increase production and profit, and ease the pressure of poverty. His only hope for the future is that, one day, his children may be able to improve their quality of life. Deep down, Jabber knows that such a day will not come soon, not within the decade, perhaps not at all.

Patal, Palwal,
Pointed gourd…

By any name, this vegetable is in high demand.

Trichosanthes dioica Roxb., Cucurbitaceae, has several common names: *patal*, *palwal*, and pointed gourd.

- This tropical vegetable, originating in the Indian subcontinent, is one of the important vegetables in the region.
- *Patal* is rich in vitamins. Per 100 g edible part, it contains the following nutrients: 9.0 mg Mg, 2.6 mg Na, 83.0 mg K, 1.1 mg Cu, and 17.0 mg S.

Some practitioners of folk remedies claim that *patal* possesses medicinal properties—it can lower total cholesterol and blood sugar.

Modern technology for wheat cultivation has eased the poverty of Jogendranath's family: a case study in Bangladesh

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Unable to read and owning less than 1 ha of farmland, Jogendranath Roy is a marginal farmer by Bangladeshi standards. Jogendranath grows rice in the wet season and wheat in the dry season on 0.40 ha of cultivable land.

His illiteracy makes it difficult to seek and adopt new technologies to increase rice production. However, Jogendranath avails of other ways of learning:

- He joins training programs conducted by the Wheat Research Centre (WRC), which implements the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" at the site.
- He follows his neighbors around their fields.
- He experiments to determine how to increase his own farm production.

Jogendranath's farm, in B. Vita village, Birgonj Upazilla, in Dinajpur District of Bangladesh, provides food for Jogendranath, his wife, Praymada Rani Dabi, and their two sons and two daughters. Only the younger daughter, Moti Choitee, and the younger son, Depu Roy, go to a junior school run by the Bangladesh Rural Advancement Committee (BRAC), the internationally known NGO. The couple could not afford to send their elder son, Debesh Roy, and elder daughter, Moti Ale Bala, to school.

The six family members depend on less than 0.50 ha of farmland for their livelihood. Hardship is a constant companion. Until recently, Jogendranath's farm products could offer food security for 8–9 months only. That his family had managed to survive during the other 3–4 months of the year gives evidence of the family's resourcefulness and tenacity. Jogendranath and

Thanks to technical support from the IFAD-funded project, Jogendranath and Praymada were able to improve their living conditions. They stand with their two children at the doorway of their recently constructed room, made of bricks, which is the building material that prosperous people use.

Jogendranath and Praymada make bamboo baskets.

The new wheat variety, Shatabdi, produced a bumper crop in Jogendranath's field.

Praymada remember the times their children went to bed with empty or half-filled stomachs. To this day, the memories pain them.

To help their family cover essential expenses, Jogendranath and Praymada made, marketed, and sold simple but useful bamboo products: baskets for carrying and/or storing grains, winnowing fans for cleaning the grains, fishing traps, and other items that people bought at the weekly market. Income from this alternative livelihood was small, yet vital for purchasing oil, salt, fish, pulses, sugar, and garments. Somehow Jogendranath's family survived.

Like most farmers, Jogendranath had been using fairly old varieties of wheat (Kanchon) and rice (BR11) and traditional management practices. Yields had been low to moderate. Additionally, he did not know that the acidic soils in his region were limiting his production of wheat. In 2004, his opportunities to learn expanded when he got involved with IFAD-funded projects, and he participated in a training program that the WRC of the Bangladesh Agriculture Research Institute was conducting in his district. In the training, he learned about modern rice-wheat management practices, seed storage, and new varieties. He decided to replace his old wheat variety, Kanchon, with the most recent one, Shatabdi, and he planted wheat in lines, with the use of a power-tiller-operated seed drill, instead of broadcasting the seed. He also applied lime to the soil to neutralize the acidity.

At the end of the first dry season (2004-05), the outcome was a stunning surprise. He harvested about 1.6 t of wheat from his 0.4-ha farm (4 t/ha) instead of the 800 kg he used to harvest when he grew Kanchon using traditional management practices. His success stunned the farmers in the area and this created a demand for Shatabdi seeds.

Within one season, the adoption of new technologies has changed Jogendranath's circumstances. Food security is no longer his main concern. His success has convinced other farmers to adopt modern wheat cultivation technologies and to use Shatabdi seeds.

To meet the demand for seed, Jogendranath evolved into a wheat seed grower. He earned about Tk 14,000 (US$200) by selling wheat seed at Tk 25.00 (37 cents) per kilogram, and built a semi-*pucca* (permanent) room out of bricks. In 2006, he also took out a mortgage for 0.10 ha of land at a cost of Tk 20,000 ($300) by selling 400 kg of rice, 400 kg of wheat, and two head of cattle.

In addition, Jogendranath has stored more than half a ton of Shatabdi wheat seeds, which he plans to sell before the next season at a higher price. He is planning to use that money to take out a mortgage for more land. Additionally, Jogendranath is using land for sharecropping. In the 2006-07 season, he cultivat-

Praymada stands beside her family's stock of wheat seeds of the new variety, Shatabdi.

ed wheat on 0.75 ha. Adoption of new technologies has not only improved his food security and financial condition; it has also raised his social status. Jogendranath feels proud when neighboring farmers come to buy wheat seed from him. Now he is happy and hopeful for a better future for the family. Whenever he gets a chance, he expresses his gratitude to the IFAD project, which has played a key role in improving his livelihood.

Jogendranath and Praymada show a beam of satisfaction with their recently constructed room.

Kamal Hossain secures his own future and helps his neighbors secure theirs, by promoting BRRI dhan 44

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Kamal Hossain is a large farmer now, but he will become a small farmer when the 6 ha of family farmland is divided among Kamal and his four brothers. Eventually, the farm will be divided among the heirs of Din Mohammed, Kamal's father.

Crop diversification and income diversification: a way of life for Kamal

In Chuadanga District of Bangladesh, with 6 ha of farmland currently at his disposal, Kamal cultivates several varieties of rice: traditional, modern high-yielding, and hybrid. He has been able to play a significant role in the up-scaling of BRRI dhan 44, a rice variety that researchers have developed at the Bangladesh Rice Research Institute (BRRI). Kamal produces BRRI dhan 44 seed on his family's farmland in Aramdanga village, in Damurhuda upazilla, in Chuadanga District. Kamal grows crops on 2.5 ha; he has orchards on 1 ha: mango, jackfruit, and *shesu* (fast-growing timber plants). He leases out the remaining 2.5 ha.

"I produce everything that we need, except kerosene oil," says Kamal. "I need to buy only kerosene oil for my family." Kamal grows rice during three seasons: *boro* (dry), *aus* (summer), and *aman* (wet). In addition to rice, he grows vegetables, legumes (lentil, chickpea, and *khashari*), oil seeds (mustard and sesame), spices and condiments (onion, garlic, chili, turmeric, and coriander), jute (fiber), and other crops.

WAVE Foundation training: Khadija learns about production, processing, and storage of rice seeds

Kamal and his family have received training from the WAVE Foundation, a regional NGO that promotes microcredit, responsive governance, rights for women and children, and the improvement of livelihoods through the empowerment of farmers. By attending the training provided by the WAVE Foundation, Kamal's wife Khadija learned how to produce, process, and store healthy rice seeds. The training in 2005 was part of the WAVE Foundation's partnership with the DFID-funded project, PETRRA, to eliminate poverty through rice research assistance in Bangladesh. The partnership between the IFAD-funded project (TAG 634) and WAVE Foundation promoted the up-scaling of the recently released rice variety, BRRI dhan 44, in the southwest region of Bangladesh.

Din Mohammed's household: (clockwise, from left rear) Kamal; Kamal's wife, Khadija; their daughter, Shabiha; their son, Naimur; and Kamal's father, Din Mohammed.

WAVE Foundation training: promoting farmers' adoption of new rice variety BRRI dhan 44

In their work on BRRI dhan 44, researchers selected a variety that would grow in the tidal wetlands of Bangladesh and would produce a high yield. As a result of this work, the WAVE Foundation was able to collect 21 kg of BRRI dhan 44 rice seeds from the BRRI. Before the 2005 planting season, development personnel from the WAVE Foundation organized a training program on the cultivation of BRRI dhan 44. After the training, presenters gave 1 kg of seed to each farmer.

Kamal sets about cultivating new rice variety BRRI dhan 44

Kamal was one of 21 farmers who received the training. Impressed by what he learned about BRRI dhan 44, he decided to grow the new variety on at least one bigha (1 bigha = 33 decimals, or 0.13 ha) of land. Kamal had only 1 kg of seed—too little for sowing 0.13 ha of land—but he was able to persuade another farmer to give his seed to Kamal. The other farmer was reluctant to grow the new variety immediately and preferred to observe its performance in Kamal's field. Kamal carefully used the 2 kg of BRRI dhan 44 seed. He sowed in a plot covering an area of 16 decimals, using 1–2 seedlings per hill, instead of the 3–5 seedlings per hill that he normally used. In the rest of the plot, he planted BR11, the most popular wet-season rice variety. Kamal followed the instructions carefully and implemented good crop husbandry.

Excellent performance: innovation's reward

The performance of BRRI dhan 44 was excellent. Soon the difference between the two varieties, BRRI dhan 44 and BR11, became evident in the field. Farmers who were passing by stopped and asked about the new variety. Many requested seeds in advance of the harvest. BRRI dhan 44 delivered a stunning yield. Kamal harvested 10.5 maunds (1 maund = 37.5 kg), or 390 kg, from his 16-decimal plot—the equivalent of 6.02 t/ha, an outstanding yield for the wet season. This was more than 20% higher than that of BR11.

Milestones in the up-scaling of BRRI dhan 44

Kamal's efforts are part of a larger effort to promote the use of BRRI dhan 44 in Bangladesh. Over the past 3 years, TAG 634, the International Fund for Agricultural Development (IFAD)-funded project supporting the up-scaling of BRRI dhan 44, has reached several milestones:

- In 2005, with marketing support from a local NGO, the WAVE Foundation, and through seed exchange with relatives and neighbors, Kamal's first growing season produced seeds that more than 35 farmers were able to use.
- In 2006, Kamal produced seeds that reached more than 100 farmers and covered an even larger area of Chuadanga District.
- In 2007, the workshop "Up-scaling BRRI dhan 44," conducted on 7 May in Chuadanga, revealed that this rice variety had reached more than 1,000 farmers in nine districts in 1 year.

Kamal stands amidst a bountiful crop in his field.

Kamal, a prosperous farmer, avails of a variety of resources

Kamal now has almost 10 times the amount of farmland that a Bangladeshi farmer has on average (0.6 ha). Thus, unlike most farmers, he uses a variety of resources to generate income. For example, Kamal owns a power tiller (hand tractor) and a shallow tube well. He operates this equipment himself, tilling and irrigating his own plots. He neither rents out this equipment nor provides services to other farmers.

An entrepreneur as well as a farmer: Kamal's beef-fattening business

In addition to farming, Kamal owns a beef-fattening business. He buys 4–5 young bulls each year, fattens them with a special diet, and sells them, in preparation for the Muslim celebration *Eid-ul-Azha*, the Festival of Sacrifice, in which millions of people sacrifice cattle and goats. Kamal pays about Tk 7,000–8,000 (US$100–115) per head. After 10–11 months, he sells each head at about Tk 30,000–35,000 ($430–500). Unlike other farmers, Kamal grows fodder in one of his plots. The other farmers cannot afford to grow fodder because they need their land for subsistence food production. Kamal earns more than Tk 100,000 ($1,500) per year from his beef-fattening business. Such an in-

Kamal pets a young bull he is rearing for his side business: beef fattening.

come is beyond the dream of most Bangladeshi farmers. Kamal's beef-fattening business produces tons of cow dung, which he uses to enrich the soil.

Kamal's bumper crop: success speaks for itself

Seeking a crop yield comparable with Kamal's bumper crop of BRRI dhan 44, many neighbors and relatives have asked Kamal for seeds. However, because of a verbal agreement between the WAVE Foundation and the farmers, he sold five maunds (190 kg), about half of his 2005 product, to the NGO. The WAVE Foundation had promised to buy back the grains at a price that was slightly higher than the market price. Kamal also sold or exchanged seed with other farmers. He exchanged 10 kg of seed with each of his two uncles, and he sold 10 kg each of seed to another 10 farmers. In the next wet season, Kamal was also able to sell seedlings. He grew excess seedlings of BRRI dhan 44 in a nursery and sold them to five farmers. He also continued to enjoy high yields of BRRI dhan 44. In the 2006 wet season, Kamal grew BRRI dhan 44 in a 63-decimal (0.26-ha) plot, from which he harvested 33 maunds (1.24 t) of paddy, the equivalent of 4.85 t/ha, about 15% higher than the yield of BR11.

After the second harvest, thanks to the training they received from the WAVE Foundation, Kamal and Khadija had properly cleaned, dried, and stored the BRRI dhan 44 rice seed they produced in 2006. Kamal's plan was to sell them at a higher price, as seeds, and consume the rest.

Although Kamal no longer had an agreement to sell seeds to the organization, it helped him market his BRRI dhan 44 seeds to three seed dealers, who traveled 25 km from Chuadanga to Aramdanga to buy them. Kamal got a good bargain: the seed dealers bought 25 maunds (940 kg) of seed, paying Tk 500 per maund, even though the current market price for paddies was less than Tk 400 per maund. Kamal also sold seeds to more than 15 farmers, kept some for planting in the next season, and consumed the rest.

Success tastes great

Although urban people like fine-grained rice, people in the southwest region of Bangladesh like the bold transparent grains of BRRI dhan 44 because they taste good. Kamal also likes the eating quality of BRRI dhan 44. "Cooked BRRI dhan 44 rice tastes as soft and as sweet as the traditional wet-season varieties," said Kamal. "Its *panta* (rice left over from dinner and soaked overnight in water) is also tasty and good for breakfast. And its quality as *muri* (puffed rice) and *chera* (flattened rice) is as good as that of traditional varieties."

Legacy of TAG 634

With assistance from the WAVE Foundation and other organizations, Kamal has helped other farmers adopt BRRI dhan 44, a high-yielding variety that has good eating quality. Kamal is now in a strong position to support his family, even after that day when the family will divide the 6 ha of farmland among Din Mohammed's heirs.

People in the southwest region of the country like BRRI dhan 44 because its size (bold), texture (soft), and taste (sweet) are similar to those of popular traditional tidal wetland rice varieties.

Up-scaling of rice variety BRRI dhan 44

In 2005, the Bangladesh Rice Research Institute (BRRI) released rice variety BRRI dhan 44, mainly for use in the nonsaline subecosystem of the tidal wetlands of Bangladesh. This variety offers several advantages over Bangladeshi mega variety BR11:

- BRRI dhan 44 plants are taller.
- BRRI dhan 44 performs better in the lowlands, producing a grain yield 15–20% higher than the yield of BR11 in tidal wetlands as well as lowlands in other areas of the country.

The IFAD-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" has followed a nontraditional approach for up-scaling BRRI dhan 44, through NGOs instead of government agencies.

In 2005, BRRI gave 21 kg of BRRI dhan 44 seeds to a regional NGO called the WAVE Foundation, which works mostly in the southwest region of Bangladesh. Before the planting season, WAVE trained 21 farmers from six villages in Chuadanga District, and gave 1.0 kg of seed to each farmer. These 21 contract farmers cultivated BRRI dhan 44 and obtained an average yield of 5.3 t/ha, about 20% higher than the yield of BR11.

After harvest, the WAVE Foundation bought 2.5 t of seed from the contract farmers and stored it. Contract farmers also sold or exchanged seeds with more than 100 interested farmers. Before the next wet season, WAVE sold 1.5 t of seed to 127 farmers and about 1 t to Action Aid Bangladesh and Practical Action, partner NGOs of the EU-funded project Food Security for Sustainable Household Livelihoods (FoSHoL).

During the 2006 wet season, more than 1,000 farmers in nine districts cultivated BRRI dhan 44. Their yield averaged 5.5–6.5 t/ha, about 15–20% higher than that of BR11. The WAVE Foundation collected about 7 t of seed, and farmer-members of NGO partners for the FoSHoL project also stored a similar amount. There were more seed exchange activities after the 2006 season than had been in 2005. Project participants expect that, in the 2007 wet season, several thousand farmers will grow BRRI dhan 44 in many different regions of Bangladesh.

Efficient use of limited resources and family manpower through adoption of RCTs is sustainable

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Sudama Piyush, a 56-year-old resident of Srivar Gopalpur village (Naubatpur block), lives in a region inhabited by members of a high social caste. He owns a unit of land that is smaller than what most of his peers have. Tradition prevents Sudama from doing agricultural labor. His farm, located 16 km away from Patna, consists of only 0.25 ha of land, which supports three adults.

Sudama and his family are completely dependent on rice–wheat farming. Because his farm can support a subsistence crop only, Sudama lacks the money to buy inputs such as fertilizers and pesticides. He seeks to increase yield by other means: improved practices. Since 2004, Sudama has grown zero-till direct-seeded rice (ZTDSR), followed by zero-till (ZT) wheat. He made these changes in the rice–wheat system on his farm with the guidance of researchers from the Indian Council of Agricultural Research (ICAR) for the Eastern Region stationed at Patna. Support has come from the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains."

Sudama Piyush stands in his field, where he grows zero-till direct-seeded rice and *Sesbania*.

In May 2004, a team of ICAR scientists went to Sudama's village and taught resource-conserving technologies (RCTs) to farmers. They explained the benefits of using ZTDSR cultivation. Farmers were skeptical about the scheme at first because, for generations, they had grown rice seedlings in a nursery and then transplanted these to a puddled field.

The other RCTs included in this system are use of optimum seed rate, use of herbicides for weed control in ZTDS, balanced use of fertilizer, and co-cultivation of *Sesbania* with rice, to increase the soil's N content. Since 2004, Sudama has continued double zero-tilling in his rice–wheat system for several reasons:

(i) The system enables timely crop establishment, leading to a yield increase—more than 20% in wheat and about 10% in rice.

(ii) Seed saving in rice (40 kg/ha) as well as in wheat (25 kg/ha) is significant.

(iii) Nitrogen fertilizer is saved (up to 70 kg urea per ha) in rice because of atmospheric N_2 fixation by *Sesbania*.

(iv) These resource savings amount to about Rs 4,000 (US$100) per ha for rice and Rs 2,000 ($50) per ha for wheat.

Sudama was the first farmer who agreed to grow ZTDSR on his farm, and he also agreed to implement the second-generation RCTs. These emphasize simultaneous cropping of *Sesbania* and rice, and killing the *Sesbania* 30 d after maturity by applying the herbicide 2,4-D. Researchers suggested the use of green manure to save on inorganic fertilizers, especially urea, and adding organic matter to the soil.

In the past, farmers grew *Sesbania* for green manure as a solo crop. This is then cut and plowed under for decomposition. Over time, farmers no longer practice green manuring because there is a shortage of labor, water, and other resources. Besides, inorganic fertilizers are readily available. As a result, farmers became concerned about soil health because other practices had been less effective.

The idea of growing *Sesbania* and rice together and then knocking down the *Sesbania* after 30 d with a herbicide was unacceptable to most farmers. When Sudama agreed to adopt the practice of green manuring, he became the laughingstock in his village. Children teased him and picked *Sesbania* from his fields.

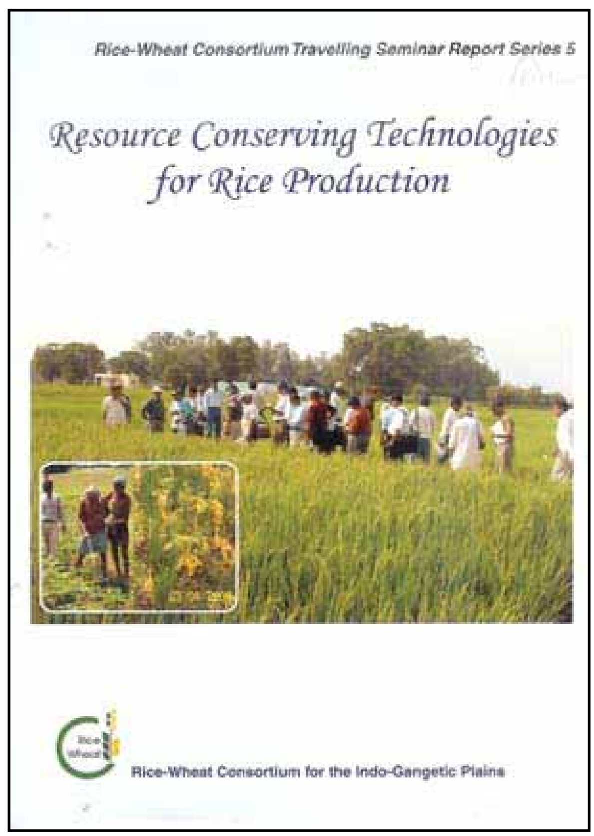
However, after Sudama had successfully demonstrated the effectiveness of this practice, his critics were astounded. In the next season, most villagers and residents of a nearby area adopted this practice. A photograph of Sudama using the herbicide to kill *Sesbania* also appeared on the cover page of a Rice-Wheat Consortium (RWC)–International Maize and Wheat Improvement Center (CIMMYT) bulletin.

Farmers who grow ZTDSR face more weed problems than those who grow transplanted rice. Rice farmers use herbicides before sowing, as well as preemergence herbicides. Weed management in ZTDSR is more expensive than in paddy rice because farmers need to hire laborers to remove the weeds. Although Sudama is considered a very small farmer, his relatively higher social status means that he can use his own physical labor only in his fields but not in others.

ZTDSR gives Sudama an advantage over farmers who grow paddy rice; farming of paddy rice requires uprooting and transplanting of nursery-grown rice seedlings, which causes another labor crisis. Because Sudama is a poor farmer, he cannot afford to hire laborers. By growing ZTDSR, he is able to overcome the labor constraint and, by using his own physical labor in his field, he can best manage his rice production.

The herbicide 2,4-D kills *Sesbania.* The rice plants remain unaffected; they derive benefits from the N_2 fixed by *Sesbania* plants.

Sudama Piyush is spraying selective herbicide to kill *Sesbania* but not rice.



Sudama's picture while applying herbicide to knock down *Sesbania* appeared on the cover page of a resource conservation book.

Sudama said that he will continue to grow ZTDSR. Not only has it given him independence from the labor crisis, it has also kept him healthy with the physical exercise he gets by working in his own field. In conventional rice farming, standing water recedes, the result of cracking during long dry spells; however, in ZTDSR farming, the soil stays moist for a longer period.

Sudama uses the same practice for growing wheat. He is able to sow ZT wheat by the last week of November. Because of the timely sowing, his crop is healthy, the grains are heavy, and he gets a higher yield. In canal-irrigated fields, conventional wheat gets waterlogged, causing yellowness because of restricted aeration. In many fields, crops die. ZT wheat has no such problems; it also offers the benefits of resource savings and higher yield.

Sudama says that with his limited resources, he gets a better yield by using his own labor and by using his resources more efficiently. With his increased earnings through RCTs, he has been able to buy a cow; the earnings from the sale of milk are enough to cover his daily expenses.

Sudama stands in his double-zero-tillage field. The wheat crop is ready for harvest.

How a drum seeder transformed Jamal Sheikh from an average farmer into a leader

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Jamal Sheikh of Sreepur village is a small farmer by Bangladeshi standards. His farm is slightly larger than 1.5 ha, a composite of several scattered fields. Farming is bread and butter to his seven-member family. Jamal Sheikh had little formal education, yet he is a technology-hungry farmer. He believes that his struggle for a decent living must embrace modern technologies and must ensure education for his children.

In keeping with this belief, Jamal Sheikh is one of the pioneers who introduced shallow tube-well-based irrigation schemes in the mid-1970s, adopting modern varieties of *boro* rice in the dry season. Since then, he has always been keen to try new and improved crop varieties as well as their associated production technologies.

Jamal Sheikh explains to media personnel and policymakers, including the state agriculture minister, how he adopted direct wet-seeding technology.

Jamal Sheikh speaks about his experience with direct wet seeding of rice using a plastic drum seeder to fellow farmers, extension agents, researchers, policymakers, and members of the media.

Jamal Sheikh's home village, Sreepur, is a remote settlement in the Sujanagar *upazilla* (subdistrict), in Pabna District of Bangladesh. Sreepur nestles in a low-lying area, prone to deep flooding. It is known locally as *Gaznar beel*. It used to be subjected to annual flooding by two mighty rivers of the world—the Padma (Ganges) and the Jamuna (Brahmaputra). These two great rivers flow into one in Bangladesh, and their junction is a few kilometers east of Sreepur village. The Padma is only about 5 km west of the village. During the monsoon season, the entire area, except for man-made village islands, remains under high floodwater for several months. These river systems have profoundly influenced farming, as well as the livelihood of the people in and around Sreepur.

During the past three decades, dramatic changes in farming systems and farming practices have taken place in and around Sreepur. As in most other areas of Bangladesh, a rapidly increasing population demands larger quantities of rice. To make the area favorable for cultivating high-yielding varieties of rice during the dry season, the government has constructed flood-control embankments and sluice gates.

To take advantage of the higher yield brought by the Green Revolution, farmers have installed shallow tube wells and started growing high-yielding modern rice varieties in the dry (boro) season using inorganic fertilizers and, occasionally, pesticides too. In the past, boro rice was a very minor crop, occupying less than 5% of the rice land. Now, it occupies about 40% of the total rice area, replacing most dry-season nonrice crops and deepwater rice crops.

Human and animal muscle has been partly replaced by mechanical power—power tillers, threshers, and low-lift water pumps. Currently, high-yielding modern boro rice and cash crops (onions) dominate in the dry season, substantially reducing crop genetic diversity.

Among 462 *upazillas* in Bangladesh, Sujanagar currently has the widest area devoted to onion cropping. Most fields remain fallow during the monsoon season, except for a few areas where farmers grow deepwater rice and jute, but to a lesser extent than they did half a century ago. In terms of cultivated area, over the past 50 years, the amount of land used for growing deepwater rice has decreased by 76%—from 2.06 million ha to 0.50 million ha. The area where jute is grown has also decreased, by about 50%.

In the past, the monsoon season was the main season for staple food (rice) production. The environment was ideal for growing deepwater rice and jute (a fiber crop). Deepwater rice was the dominant crop, but jute also grew in abundance as a cash crop.

In fact, at one time, Bangladesh (formerly East Pakistan) was the top jute fiber producer and exporter in the world. And jute was the most important foreign currency earner of the former East Pakistan. Many industries in Dundee, UK, and elsewhere in the world were dependent on jute fiber from Bangladesh.

In the mid-20th century, the increased use of synthetic fiber and polyethylene pushed down the demand for jute fiber in the world market. Jute cropping thus diminished in the delta too.

In contrast, in the dry season, farmers had a greater choice of nonrice (*rabi*) crops, which were dependent on residual soil moisture. These crops included a variety of legumes (lentil, chickpea, green pea, *kheshari*), oilseeds (mustard, sesame), spices and condiments (chili, onion, garlic), and millet.

In small pockets here and there, local varieties of boro (dry-season) rice used to be grown using traditional irrigation. Crop and genetic diversity was high, and agriculture was organic—traditional varieties and practices were used. Farmers were entirely at the mercy of nature and depended on human and bullock power. As a result, production was low and most farmers were poor, except for a few families that owned large farms.

Despite the financial difficulties that come with being a poor farmer, Jamal Sheikh has managed to provide some schooling for all his children. His eldest son, 21-year-old Suzon, dropped out of school when he was in grade 10. With this level of education, he can find only intermittent employment, which generates too little income to improve the livelihood of his family. The young man lives at home with his parents. From time to time, he helps his father with the farm and, after the harvest of the onion crop, he engages in petty trading. For instance, during the onion harvesting period, he buys onions from farmers and sells them to larger traders in the market. Sometimes he waits until the price is right.

Suzon wants to go abroad to earn a higher income. So far, he has not found the right contact to make it happen, even though he has paid money (Tk 15,000) to a manpower broker. The second son, 19-year-old Shobuj, has gotten a bit further in his studies. A grade 12 student, Shobuj is exploring employment opportunities but so far has found nothing. Jamal Sheikh's three other children are currently in school.

In addition to the help from his eldest son Suzon, Jamal Sheikh has partially mechanized his farm. He bought a power tiller and used a shallow tube well for irrigation of his boro rice.

He grows boro rice in several fields, which are near each other, slightly smaller than half a hectare. He grows onions on another half hectare and other nonrice (rabi) crops on the rest of his land. He grows boro rice variety BRRI dhan 29, developed by the Bangladesh Rice Research Institute (BRRI). Scientists, extension workers, and farmers consider it the best variety to grow in that area. Farmers who can grow only one crop like this variety for its high yield, though its crop cycle is longer.

Technology-hungry Jamal Sheikh has not hesitated to try the new technology of direct wet seeding of rice. He began using a plastic drum seeder when his elder brother, Dr. Zainul Abedin, a well-known farming systems specialist, asked him to organize a few farmers to try the new idea. Jamal Sheikh convinced two more farmers and, in early December of 2003, one of them joined him in attending an experience-sharing-cum-training course on direct wet seeding at BRRI headquarters.

BRRI scientists, the local collaborators of the IRRI-led, IFAD-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains," facilitated this session. Farmers and scientists from BRRI and IRRI claimed that the technology would save on labor and

This plastic drum seeder, made in Vietnam, works better with four cylinders than with six.

seeds and would increase production over conventional transplanted rice crops.

The new drum seeder technology promised to save on labor and increase yields in a region where labor-intensive transplanting of rice seedlings had been the norm. The area suffers from labor scarcity, especially when boro rice crop establishment coincides with onion transplanting. Onion is a high-input cash crop that gets priority over boro rice. Jamal Sheikh and his neighbors Osman Pramanik and Gofur Sheikh decided to take a risk and try the plastic drum seeders in their fields. They direct-seeded BR29 on small plots of land during the boro season of 2003-04.

During the first few weeks, the uncertainty of the new venture created terrible anxiety. Initially, fields looked barren. Then they became fields of weeds. Farmers who did not try DWS laughed behind their back, as if the adopters were stupid. Jamal Sheikh and Osman Pramanik persevered; however, from time to time, they also became suspicious of their crops. Even so, they had confidence in Dr. Abedin and in the BRRI scientists.

Their patience soon paid off. After a few weeks, the trials began showing great promise. Rice canopies filled the field, plants showed more vigor, and the canopies grew taller than those of transplanted crops in adjacent fields. The difference became more pronounced in the late reproductive phase, with taller and denser canopies and more panicles. At this stage, passersby would stop at the fields where rice was planted by a drum seeder and wonder what those farmers had done differently. Even visitors to the village did not forget to have a look at the new "fun." The crop matured earlier than the transplanted ones, and the yield was higher.

Later in 2004, BRRI researchers and residents of Sreepur village organized a meeting for local farmers from Sreepur and neighboring villages, and for agriculture extension and research officials from the national, district, and upazilla levels. Jamal Sheikh and Osman Pramanik both told of their experiences of planting, for the first time in their lives, sprouted rice in lines, using drum seeders during the 2003-04 boro season.

As a result, six groups of interested farmers received six drum seeders. In the next boro season (2004-05), 30 farmers planted rice using drum seeders, on about 40 bighas (5.3 ha) of land. Some farmers ran trials in which they seeded without tillage to save on the cost of irrigation and land preparation. They could do this because the soil remained muddy enough for planting after the floodwater receded.

The experience this time was similar to that of the first year. Most other farmers, who used drum seeders, were confused when the condition of the crop was poor during the early growth stage, mainly due to cold injury. Some farmers wanted to plow the crop under and reestablish it with transplanted seedlings. Jamal Sheikh visited them, encouraged them to keep weeds under control, and wait and see. Most of them listened and carefully managed the weeds that emerged soon after seeding. Eventually, crop growth became vigorous as in the first year, under either normal tillage or no tillage.

Jamal Sheikh not only organized the farmers of his own village, he also spread the news among farmers in neighboring villages. Whether such farmers received a drum seeder or not, many showed interest, and Jamal Sheikh traveled to several of these neighboring villages to help farmers establish rice crops in the new way. Soon, he became the source of new knowledge about rice production. He was considered a leader.

Aware that drum-seeding technology was beginning to catch on in the region, researchers at BRRI and IRRI, with as-

Boro (dry-season) rice grows in the low-lying areas of Sujanagar, Pabna, Bangladesh.

Osman Pramanik answers questions from a television reporter.

sistance from the Department of Agricultural Extension and a local NGO named Society of Progressive Action for the Needy, organized a farmers' field day. Among the attendees were farmers from neighboring villages, agriculture extension personnel, researchers from BRRI and IRRI, policymakers, and members of media (television).

Additionally, about 500 farmers and the state minister for agriculture attended. Jamal Sheikh and Osman Pramanik made all the arrangements. Participating farmers told of their experiences, and everybody was impressed with the standing crop. Attendees had been certain that grain yield would be higher than for the transplanted crop, but they could not carry out the crop cut or measure yield because the crop was not yet ready for harvest. Chanel i TV covered the farmers' field day with a nationwide broadcast of an interview with Jamal Sheikh and Osman Pramanik.

Later, Jamal Sheikh and Osman Pramanik harvested 8.8 t/ha and 8.7 t/ha from the fields where they used drum seeders for planting; their transplanted fields yielded 6.0 t/ha and 7.6 t/ha, respectively. Both farmers had planted the same variety, BRRI dhan 29, in both DWS and transplanted fields.

In June 2005, Jamal Sheikh and Osman Pramanik discussed this technology at an international workshop at BRRI. Again, they described their experiences to farmers from all over the country, as well as to scientists, policymakers, and media personnel. Their success in the 2004-05 boro season, as well as their exposure to dignitaries and members of the media, boosted their morale. Jamal Sheikh volunteered to promote DWS technology to other farmers. He encouraged farmers in his own village and in several adjacent villages to adopt DWS with a plastic drum seeder.

As a result, farmers used this technology to plant about 200 bighas (27 ha) of land during the 2005-06 boro season. Jamal Sheikh and Osman Pramanik adopted the technology in all of their boro fields. They are happy with the performance of the drum seeder. In addition to higher yield, the technology reduced the demand for labor during a critical time, when there is a shortage of labor during the planting and nursing of onions and boro rice.

However, weed control at the early stage is difficult, demanding some labor. Better strategies for weed management would greatly improve the technology of drum seeders. Additionally, Jamal Sheikh has modified the seeder to stop the central axle from bending. He has detached two of the six terminal drums, so that the seeder bears the weight of four drums instead of six. The seeder performed much better bearing the weight of only four drums.

In the last 2 years, Jamal Sheikh has become a popular figure in the region. He has transformed himself from an average farmer into a community leader, finding unprecedented success as a farmer, through the adoption and promotion of DWS technology that uses a drum seeder. His ability to help other farmers, by sharing a useful technology, has helped him gain respect.

How Kangali Charan of West Bengal, India, used the leaf color chart to reduce the use of nitrogen and insecticides in rice farming

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Marginal farmer Kangali Charan has shared his hard work and wisdom with other participants in a project funded by the International Fund for Agricultural Development (IFAD). Called "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains," this was implemented by the Philippine-based International Rice Research Institute (IRRI) and the Nadia Zilla Farmers Development Organization (NZFDO, a local NGO). This project validates the effectiveness of farming technologies in Nadia District, West Bengal, India.

Kangali Charan stands in his field where rice was planted using a plastic drum seeder.

Kangali Charan's life: hardship and perseverance

A journey of many years and many kilometers has brought Kangali Charan to this project and to this community in West Bengal, India. With his gray hair, lean figure, and protruding cheekbones, Kangali Charan seems a decade older than his actual age of early-to-mid-50s. A look at Kangali Charan's family history does much to explain his premature aging.

Born and brought up in a village in Rajbari subdivision, in Faridpur District, Bangladesh (formerly East Pakistan), Kangali Charan remembers neither of his parents. His parents owned, by Bangladeshi standards, a large farm, more than 6 ha of land. Then tragedy struck. His father passed away 4 months before Kangali Charan was born. His mother passed away when Kangali Charan was still a baby, leaving behind three orphans.

Kangali Charan's two elder brothers were too young to take care of themselves or to farm. Their elderly grandmother raised them, with great difficulty. They lived through hard times, with no able-bodied adults to cultivate the fields or to give the children the affection that parents give. The eldest son grew up detesting farming. As a teenager, he joined a rural group of folk singers and seldom lived in his family's house.

Meanwhile, Kangali Charan pursued an education at a rural school up to grade 10. In 1969, he passed the national secondary school certificate examinations. In addition to his formal education, Kangali Charan began farming when he was a teenager.

Adulthood: new responsibilities and successes

By the early 1970s, Kangali Charan was taking on the many responsibilities of adulthood. He got married to Maya, started his own family, and then made the decision to flee with his family to what he hoped was a safer place. In April 1971, in the early stages of the liberation war in Bangladesh, Pakistani soldiers were on a killing spree, and Hindu communities were an easy target. Fearing for their lives, Kangali Charan, his family, and the others walked through villages and across fields to the Indian border.

In December 1971, after the liberation of Bangladesh, Kangali Charan and his family returned to Bangladesh. Meanwhile, Kangali Charan's eldest brother settled in Shibpur village of Barashat Panchayat, in Nadia District of West Bengal, India. As was common practice, Kangali Charan sometimes crossed the Indian border to meet his brother.

By the 1980s, Kangali Charan again thought of moving to India. Not only was he frustrated by the intimidation from the youths in the adjacent villages; he also found it unacceptable that the leaders in his community seemed unable or unwilling to protect the interests of religious minorities or to control the people who were perpetrating the violence.

Fleeing persecution: migration to India

In 1991, Kangali Charan initiated his family's second migration to India by sending his elder son, Mangal Bhaduri, to live with Kangali Charan's brother in India. In 1999, Kangali Charan sent his younger son, Nilkamal Bhaduri. In India, Mangal and Nilkamal both pursued their education, while living at their uncle's house in Shibpur, near the town of Birnagar. Eventually, Kangali Charan sold his farm and sent money to his sons. They bought land near their uncle's house. Finally, in 2000, Kangali Charan migrated to India with his wife and daughter, leaving his second brother in Bangladesh.

Greater prosperity through income diversification

Having achieved the goal of relocating his immediate family to India, Kangali Charan has taken on the challenge of providing a better life for his family. Although he owns farmland smaller than what he had in Bangladesh (about one-third of a hectare) as well as a small piece of land on which he built his house, Kangali Charan has generated additional income by investing in a shallow tube well. This provided enough water for him to irrigate his crops and to sell water to farmers who grow crops nearby.

Investing in a better life for his children

Kangali Charan has earmarked the income from the shallow tube well to send his second son to school. During the wet season, Kangali Charan was charging Rs 600 per bigha (US$15 per 0.13 ha) for rice cropping. During the dry season, he was charging Rs 1,000 per bigha ($24).

Kangali Charan and his neighbor Atul Mondal hold a banner during a farmers' field day in a field where rice was planted using a drum seeder.

The recent installation by the government of an electric meter has made Kangali Charan unsure of how much money he will be able to earn in the future from his shallow tube well. He used to pay a fixed amount per year, Rs 10,000 ($240), for the electricity to operate the tube well. Until he knows how much he will be paying, he may charge the farmers on an hourly basis.

Hard work and the ability to learn from experience enabled Kangali Charan to diversify his crops and sources of income. He does the work in the field himself and seldom hires laborers.

Prosperity through crop diversification

Kangali Charan has also expanded his crop area. Adding to the 0.33 ha of farmland that he owns, he leased 0.27 ha and sharecropped another 0.27 ha.

Although he grows cereals (rice and some wheat) for home consumption, he dedicates most of his farmland to cash crops. In the wet season, Kangali Charan grows rice and jute; in the dry season, he grows rice, wheat, sunflower, onion, *Rajanigandha* (tuberose) flowers, and vegetables. Tuberose, onion, and jute generate the most income.

In addition to discovering what to grow, Kangali Charan knows what not to grow. He once experimented with *Gadha* (marigold) flowers, but gave up after one season because growing the crop was labor-intensive.

Sharing what he has learned: TAG 634

In addition to his solo projects, Kangali Charan is an active collaborator with IRRI and NZFDO. He has worked with them to validate technologies through the IFAD-funded project "TAG

634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains."

Results of collaboration

For instance, since 2004, Kangali Charan has validated and adopted real-time nitrogen management in rice by the use of a leaf color chart (LCC), which has reduced his use of nitrogen fertilizer and reduced pressure from insect pests. As a result, he stopped spraying insecticides onto his rice plants because the adoption of LCC technology has reduced the pest load.

Now that Kangali Charan is proficient with real-time nitrogen management, he no longer needs to compare the rice leaf color to the LCC panel. By looking at the color of the rice leaves with the naked eye, he can determine when plants need an application of nitrogenous fertilizer.

During the 2005-06 wet seasons, Kangali Charan worked to validate another technology: the labor-saving efficacy of direct wet seeding of rice through the use of a plastic drum seeder. During the most recent dry season, he adopted direct wet seeding in one plot, and he plans to use this technology again in the future.

Moreover, he also tried planting one to two seedlings per hill, a seed-conserving technology promoted by IRRI and NZFDO. As a result of using the two technologies (line seeding by drum seeder and LCC), Kangali Charan got a higher yield, about 20% more than his transplanted rice crop.

Fulfillment of a dream: two weddings and an honor student

In addition to these entrepreneurial activities, Kangali Charan has begun fulfilling the dream of a better life for his children. Having brought a substantial amount of money from Bangladesh, Kangali Charan was able to pay for two weddings—one for his daughter in 2003 and one for his eldest son in 2004. His daughter, the youngest of three children, has an eighth-grade education. Her husband is from a large farming family that owns 3 ha of farmland. The family also owns mango orchards, their main source of income. The family's financial condition is strong, and Kangali Charan is happy for his daughter, who is now the mother of a baby girl.

Kangali Charan's other son, Mangal, has also started a family. Mangal dropped out of school after completing one year of a B.S. degree in commerce. He then found success in his personal life. In 2004, Mangal married a beautiful girl and they now have a 1-year-old daughter, Riya. In the village, Mangal manages a small grocery store, a pay-phone booth for public use, and prepaid cell phone cards. This income provides spending money for his wife, his daughter, and himself, and he even takes food to his parents.

Exhausted, Kangali Charan takes a respite with his wife, Maya Bhaduri, and second son, Nilkamal.

Kangali Charan's younger son, Nilkamal, has gone the furthest in getting an education; he is currently in his final year as a B.S. honor student in mathematics. His dream is to become a mathematics teacher.

Better life means no one to farm with Kangali Charan

Kangali Charan has learned that, by achieving his dream of educating all three children and marrying off two of them so far, he may be giving up another aspiration: increasing the size of his farm. As has been the case in other families, for Kangali Charan's children, a better life does not include farming. Of the three children, only Nilkamal helps his father on the farm from time to time.

Greater prosperity may be just ahead

Despite any frustration Kangali Charan may feel with the limitations of farming on a small amount of land, his family is enjoying a much better livelihood than most other marginal farming families. Kangali Charan has been able to succeed mainly because he had cash from selling his property in Bangladesh, part of which he used to diversify his income. He is also a hardworking farmer who farms twice as much land as he owns. He grows mostly cash crops and provides irrigation services.

Kangali Charan looks forward to the day when Nilkamal becomes a mathematics teacher; a steady income from a teaching job would further improve the quality of life of his family members.

For Sirajul, a farmer in West Bengal, India, validation of new agricultural technologies is a hobby

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Sirajul Islam is a prosperous farmer in Bangaljhi village of Chapra block under Nadia District of West Bengal, India. This low-lying area is about 14 km west of the border with Bangladesh. Sirajul is a happy person and he looks much younger than his actual age of 60.

Sirajul's grandfather was a large farmer with more than 15 ha of farmland. He had four sons. Sirajul's father inherited about 3 ha and became a medium-size farmer. Sirajul has two brothers and he inherited less than 1 ha from his father, becoming a marginal farmer by definition, but not in reality.

Sirajul has changed his economic status through nonagricultural activities as well as investments in agriculture. Now, he owns a farm of more than 2 ha; milling facilities for rice, wheat, spices, and oil; a warehouse for storing agricultural products; and several plots in the highland that are suitable for commercial ventures or housing construction. He lives in a complex with a fairly large two-story brick building. He has a small pond for fish farming, a plot for growing vegetables for household use, and bamboo groves. Let's learn how Sirajul has changed his fate.

Sirajul and Dr. B. Bagchi (a former university professor currently involved with NZFDO) look over the pond that Sirajul uses for fish farming.

Sirajul attended school through grade 10 and he studied agriculture during his last two grades. In grades 9 and 10, he became interested in farming. However, he did not want to depend on marginal farming for his livelihood, and so he sought alternatives.

After completing grade 10, Sirajul completed a 2-year course in mechanics at a vocational training center in the district town of Krishanagar. Then he sought employment in shipping and completed a 4-month training course in ship mechanics in the city of Kolkata. He was interested in traveling and in earning better wages so that he could change his fate. In the meantime, he also attended a 2½-month premilitary training course offered by the national voluntary force. This training opened up employment opportunities in security and the defense forces. In fact, Sirajul got an offer to join the police force as a sub-inspector. He turned down the offer and interviewed for a position as a ship mechanic with a British shipping line called Texaco. In 1970, he was offered a job, and he boarded ship at Bombay port.

That was the beginning of his 34-year career in shipping. Sirajul worked for a number of shipping lines from different countries. During his 34 years in shipping, he visited most countries of the world that have seaports. He has circumnavigated the globe many times, crossed the Panama Canal at least six times, and crossed the Suez Canal six to eight times. In 2002, he retired from shipping and settled in Bangaljhi village with his own family.

In 1975, Sirajul got involved with agriculture on his family's farm during his home visits. He got married in 1977. In 1981, he left his extended family and started his own family. In 1983, he established his own separate farm while still working as a sailor. Once a year, he came home to visit for a few months and to organize the farm. When Sirajul went back to the sea, his wife managed the farm the rest of the year with the help of hired laborers. His father and brothers also helped Sirajul's family while he was away. Sirajul later bought more than 2 ha of land. In 2002, after retiring from the shipping business, he concentrated on farming and used the money he had saved during his employment with shipping lines to open several new income-generating ventures: a mill for rice, wheat, and spices; a warehouse; and other businesses.

Sirajul has two sons and no daughters. His elder son, Karimul Hoque, dropped out of school while he was in his first year of a BA program. He is now involved in the commodity business of nonperishable agricultural products. He buys commodities from farmers at harvest when the price is low, stores them in his warehouse, and sells them when the price is high. He mainly stores jute fiber, mustard, coriander, dried chili, sesame, and other commodities. Next to rice, jute is the most popular crop in the area and jute fiber trading is a lucrative business. Sirajul has given the warehouse and more than 100,000 rupees to his elder son, who is married and has a 3-year-old daughter. His family lives with his parents.

Sirajul's younger son, Talimul Islam, enrolled in a BS program in hotel management in the Salt Lake area, a posh part of the city of Kolkata. As a private institution, it is expensive—the annual tuition fee is Rs 120,000. Supporting such an expensive education is only possible because, unlike most Indian farmers, Sirajul has a secure financial footing.

Sirajul now cultivates about 1.5 ha of his land in a compact block in front of his house. The other plots are scattered throughout the village and rented out or given to poor farmers for sharecropping. In the wet season, he grows rice and jute. In the dry (winter) season, he grows rice and a variety of nonrice crops: wheat, black gram, chili, onion, potato, sesame, garlic, and various vegetables.

Now that Sirajul has attained financial security, testing and adoption of new agricultural technologies are his hobby. Sirajul has contacts with the Nadia Zilla Farmers Development Organization (NZFDO) at Birnagar, which is more than 35 km away, and also with the Department of Agriculture in India's state government network. Sirajul took part in the validation of International Rice Research Institute (IRRI)–International Fund for Agricultural Development (IFAD) project technologies implemented by NZFDO, which includes direct wet seeding of rice by the use of a plastic drum seeder and real-time nitrogen management by the use of a leaf color chart (LCC).

Sirajul stands in his rice field planted to BRRI dhan 28. His farm and bamboo groves are in the background.

Sirajul has adopted real-time nitrogen management in rice farming by the use of an LCC, which has reduced the use of nitrogen fertilizer on his farm by more than 20%. The adoption of LCC technology has also substantially reduced insecticide use on his farm—from three to four sprays to one.

Reduction in pesticide use is a supplementary benefit of real-time nitrogen management in rice. Sirajul has an LCC in his house and he also encourages his neighbor farmers to adopt the technology. He has validated the direct wet-seeded rice technology by the use of a plastic drum seeder in two seasons. He has saved money on crop establishment labor and had yields about 15% higher than for transplanted rice. Sirajul considers weeds to be the major constraint of the drum seeder technology, and so he is practicing this technology in one or two of his plots, but not in all of them.

When the need arises for validation of a new agricultural technology, both the Department of Agriculture and the NZFDO always approach Sirajul. A few years ago, Sirajul got information that farmers were growing a very good rice variety called BRRI dhan 28 on the other side of the border in Bangladesh. In 2005, he collected 10 kg of BRRI dhan 28 seeds from the border area.

BRRI dhan 28 is one of the best and most popular rice varieties developed by the Bangladesh Rice Research Institute (BRRI) for dry-season cropping. In the 2005-06 dry season, Sirajul cultivated this variety in a 0.13-ha plot and got very good yields. He also likes the finer, slender grains of BRRI dhan 28.

In the following wet season, Sirajul cultivated BRRI dhan 28 on a 0.13-ha plot and had a good harvest, though this variety is not meant for growing in the wet season. He has given seeds to

Sirajul grows eggplants of a special variety. Under processing for seeds at Sirajul's yard (drying outdoors under partial shade), several slits are made on the eggplant so that moisture can escape without rotting the pulp.

several interested farmers in his village, and 30 kg of seeds to a farmer who came from a place 7 km away. In the current 2006-07 dry (*boro*) season, he is growing BRRI dhan 28 on about 1 ha of land. In Bangaljhi village, the total area under cultivation for this variety is more than 2 ha. He has now become a promoter of BRRI dhan 28 in the area. Once he collected seeds of a hybrid rice variety of Chinese origin (Shonar Bangla) from the Bangladesh border. It was good, but it had no market demand because of its very coarse grains.

In 2005 and 2006, Sirajul pioneered the use of zero-tillage jute-cropping technology in his village. Many of his fellow villagers followed suit. He irrigates the dry-season rice field about 7–8 d before the harvest. He then broadcasts jute seeds in the standing rice crop 2 d after irrigation. After the rice is harvested, he provides irrigation, applies fertilizer, and manages weeds as needed. Recently, Sirajul started cultivating turmeric, a new high-yielding variety of garlic, and corn.

Thirty-five years of employment in the shipping industry as a mechanic created a strong financial base for Sirajul. After retirement, he invested some of his wealth in rural areas and diversified his sources of income. The training he received in agriculture at school during his teen years cultivated an interest in agriculture in his heart. His world travel as a sailor has broadened his outlook and enriched his vision and perception of life.

Unlike most other wealthy persons, Sirajul has settled in a rural area, rather than in a town or city. He has found happiness in the remote rural area where he was born and raised. To him, a rural area is a good place to live. Now, Sirajul is a happy and wealthy person, and farming has become his hobby.

Providing service in tillage and seed drilling has boosted Abdul Wahab's livelihood: a case study

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With 2.83 ha of cultivable land, Mohammed Abdul Wahab is a medium farmer by Bangladeshi standards. He is a literate farmer with 12 years of schooling. He lives in South Mominpur village of Sadar Upazilla in Rangpur District with his wife, two sons, and two daughters. His elder son, Mohammed Mahbub Rana, has dropped out of secondary school. The young unmarried Rana is currently helping his father on the farm and in his new venture as a service provider.

Wahab's three other children are attending school. Although Wahab is a medium farmer, he has faced financial difficulties because his income has depended on farming only. Sometimes, he had to borrow money from family members, friends, or even moneylenders. As a result, he has not been able to hold on to his crops to wait for better prices. He had to sell most of his crop right after the harvest, when prices were at the lowest level, in order to pay debts and meet living expenses, and to buy inputs for the following season's crop.

When Wahab cultivated his land in the traditional way, he got lower yields. In 2004, after participating in International Fund for Agricultural Development (IFAD) project activities, he learned more about crop management and new varieties from scientists at the Wheat Research Centre (WRC) of the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Rice Research Institute (BRRI).

Wahab boosted his wheat production by adopting a recently developed variety, Shatabdi, using better management practices. However, he did not stop there. With encouragement and technical guidance from the IFAD project collaborators, Wahab decided to become a service provider as well as a farmer.

Wheat variety Shatabdi at flowering—this was line-sown by a power-tiller-operated seed drill.

In 2005, Wahab bought a power tiller on installment with a 50% down payment and a power-tiller-operated minimum-tillage seeder (PTOS)* from the Rice-Wheat Consortium (RWC)/International Maize and Wheat Improvement Center (CIMMYT) on installment with a 33% down payment.

Soon after he bought the equipment, Wahab started to provide services to other farmers: tillage and line seeding of wheat.

*Its price is Tk 40,000. This machine will help sow wheat in lines, reduce turnaround time (by 10–15 d), reduce planting cost (by 30–50%), reduce weeding cost (by 20–30% compared with the cost of weeding a broadcast wheat field), and maximize wheat yield (by 15–25%) as well as profit.

Abdul Wahab stands next to his elder son Rana, who helps out in farming and in his new venture as a service provider.

The power tiller and the seed drill in action. Farmers walk behind the drill to monitor the wheat-planting activity.

He began earning money on a regular basis by renting out his PTOS and power tiller. Initially, his son Rana operated the equipment, but, to keep up with the demand, they soon needed to recruit one person to work as the dedicated operator. In 2005-06, Wahab earned about Tk 52,000 (US$800) for renting out the PTOS and Tk 98,500 ($1,500) for renting out the power tiller.

Now, with additional income, Wahab can cover his daily expenses, buy agricultural inputs for crop production, and pay for labor wages. He also can store his crops and sell them during lean periods at much higher prices than at the time of harvest. In the meantime, he has completed his mortgage payments and has become the full owner of the power tiller and the PTOS.

Farmers have a very high demand for line seeding of their wheat crop. During the 2006-07 dry season, Wahab's machines were very busy; he thus needed to employ another operator at that time.

In 2006, Wahab bought 25 decimals of land using the funds he earned from selling wheat and rice and from renting out the power tiller and PTOS. He also mortgaged another 25 decimals of land from a farmer by using the income he had earned by selling some rice and some Shatabdi seeds.

Wahab has improved his living conditions by building two semi-*pucca* (permanent) rooms out of bricks. He has stored 1 t of Shatabdi wheat seed for the next season, for his own use and for selling.

Wahab is now a food-surplus farmer, enjoying a happy life and a higher social status. In an interview, he reflected on his recent past and said, "The life of a Bangladeshi medium farmer is very difficult. Changing my occupation from farmer to farmer-cum-service provider has given a boost to my livelihood."

New technology, entrepreneurship, hard work, and cooperation have helped Vinod and Sabita earn a livelihood for their family

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In the undulating, terraced lands of the Indian state of Jharkhand, on the Chhotanagpur Plateau, agriculture depends on erratic rainfall, and so productivity is low. Bahari, home to a farmer named Vinod Prasad, is a remote village in Hazaribag District of Jharkhand. Vinod's family is resource-poor. They own only 480 m^2 of land for growing vegetables, and another 1,520 m^2 of land for growing rice only during the wet season. In this fragile rainfed ecosystem, on a small farm, Vinod's parents have struggled hard for subsistence.

In 1978, Vinod's father, Kheman Mahato, took a low-paying job at the Holy Cross Convert Dairy Farm near Hazaribag, which is almost 10 km away from their home. The job ensured some regular (though low) income, but the farm struggled in the absence of adult male labor.

Years later, as a child, Vinod started to help on the farm besides attending a local primary school. When he got to high school, it became clear to him that his family could not afford to give him a higher education. In 1997, after completing grade 10, he left school to help his parents support the family.

Chhotanagpur

Chhotanagpur is a region that encompasses the tribal communities in the Indian states of Jharkhand, Madhya Pradesh, Orissa, and West Bengal. Many residents of the area identify with the name, even though the area has no political recognition. Nagpuri, a local dialect of Hindi, is common in the area. SOURCE: http://en.wikipedia.org/wiki/Chhotanagpur.

Sabita and her daughters tend the family's general store.

With the knowledge he had gained in school, Vinod was ready to take on greater responsibility and find new activities. He revitalized the farm by adopting better varieties of rice and vegetables and by improving management practices. In 1998, he opened a small general shop at their house. In the same year, the family started rearing poultry for commercial purposes.

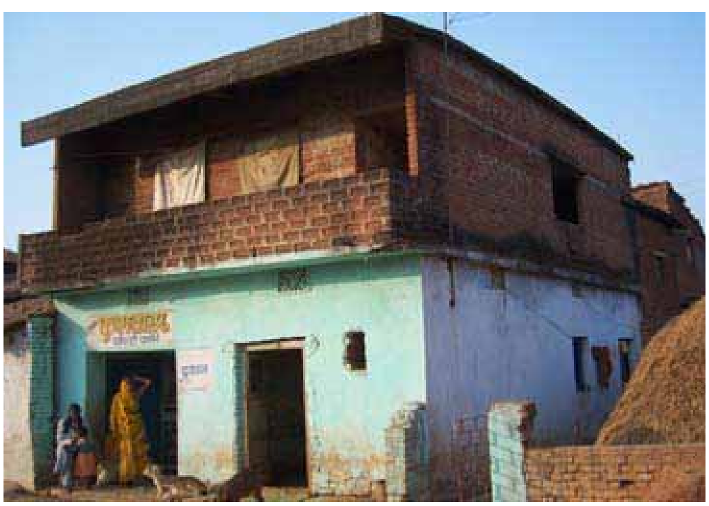
In 2000, Vinod married Sabita Devi. When she came to Vinod's five-member family, its members represented three generations. Within 6 years, Vinod and Sabita added a fourth generation by becoming the parents of three children: one son, Pakaj Prasad, and two daughters, Shobha and Rekha. The number of family members had increased to nine, and Sabita faced a tremendous workload. However, her mother-in-law and grandmother-in-law helped Sabita with childcare and household chores.

In addition to household work, the young bride helped her husband manage the shop, maintain the poultry unit, and tend the vegetable garden. They grew vegetables such as amaranth, Indian spinach (*palak*), cabbage, cauliflower, and herbs and spices such as coriander leaf and fenugreek (*methi*). They sold some crops and kept others for home consumption.

The hardworking couple faced several challenges. Rice production in their other plots provided subsistence for a few months only and, in 2004, they closed the poultry unit because of a disease outbreak. Also, wildcats preyed on the birds at night. Vinod and Sabita persevered and, through improved farming practices and profits from the shop, the family's finances improved. But Vinod and Sabita did not stop there; they sought additional opportunities.

In 2004, Sabita underwent 3 months of training to become a dressmaker. After the training, she accepted orders from other villagers when she had time. Meanwhile, Vinod became a focal person for the technology validation program for the Krishi Vigyan Kendra (KVK–Agricultural Science Center). Sabita organized a women's self-help group (WSHG) in the village under KVK's supervision.

In 2005, as a way of introducing supplementary livelihood support systems for resource-poor farmers, KVK trained farmers to cultivate mushrooms and encouraged them to get technical support from the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains." Vinod's father learned about these opportunities for earning income and discussed them with his family members.



Nine family members—four generations of Vinod's family—live in this house. Downstairs is a general store; upstairs is space for cultivating mushrooms.

Sabita with her mushroom product.

The momentum toward prosperity continued. In 2005, Vinod attended 2 days of training. And, 1 month later, Sabita attended training as a leading member of her WSHG. Subsequently, she and two other members of her training group offered training to the other members of her WSHG.

A few years ago, in addition to growing mushrooms, Vinod and Sabita started to grow elephant-foot yam, which the KVK staff had introduced to them. With this venture, they again found success. In the last season, they produced 7 quintals of elephant-foot yam, worth Rs 8,000 (US$182).

After years of saving money, Vinod's family has extended their six-room house by adding two more rooms on the roof. The nine family members share four rooms, the shop occupies one room, and cattle occupy another on the ground floor. The family used the two rooms on the upper floor for business ventures such as poultry rearing and mushroom cultivation.

In 2005-06, during the dry seasons, Vinod and his family tried for the first time to cultivate mushrooms in 20 bags in the rooms on the rooftop. They did very well as beginners—a harvest of 16 kg at 80% efficiency. Sabita has sold some to her neighbors, but most of her buyers came from officers' colonies in Hazaribag town.

To help support the couple's efforts, Vinod's mother has taken on marketing responsibilities. She sold mushrooms mostly in Hazaribag, at Rs 50–60 per kg. Even with family consumption, on the first try, they made a profit: an income of Rs 800 ($18) and expenses of only Rs 280 ($6).

During the second dry season (2006-07), Vinod and his family increased the batch to 70 bags and harvested 60 kg of mushrooms. Their gross income was Rs 3,600 ($82). From this, they spent Rs 950 ($22) to buy a sprayer to water the bags and maintain the high humidity that is vital for mushroom cultivation. (In the previous two seasons, they had used their hands to sprinkle water onto the bags.)

Vinod and his family wanted to increase production by increasing the number of bags, but space is small. KVK resource persons Sister Sajita and Sister Mary, who helped coordinate the WSHG and gave training and follow-up supervision, suggested making racks to increase the capacity for mushroom cultivation. They increased the second batch to 70 bags; they are now harvesting nearly 100 kg per batch. So far, they have easily sold their mushrooms.

For Vinod and his family, hard work and a willingness to take risks have resulted in benefits for every family member. Four generations of Vinod's family are living harmoniously under the same roof, from the oldest (71) to the youngest (<1). By sharing responsibilities and supporting each other in the struggle for livelihood improvement, the members of Vinod's extended family set an example for all of us.

The adults are heavily engaged in activities that generate income and maintain the household. Yet, they do not hesitate to explore new opportunities. Sabita, a mother of three young children, has an immense appetite for work. Considered to be among the hardcore poor, Sabita's family members have very little access to education, as boys are always given preference.

Still, Sabita and her family members created opportunities for themselves. Although lacking in formal schooling, Sabita has mastered several activities, including nontraditional ones: leading WSHG, cultivating mushrooms and elephant-foot yams, tailoring, and managing the shop, in addition to household work and taking care of the children.

Sister Mary visits Sabita and Vinod's mushroom production facility.

Currently, the family's annual earnings have grown to more than Rs 60,000 ($1,370). This level of income is helping Vinod's family members to make their dreams come true. Vinod's younger brother, Jitender, is in grade 11 and Vinod's son, Pakaj, is in grade 1. The family would like both children to pursue higher education, the one that Vinod himself could not have because of resource limitations.

Their dream is for Jitender and Pakaj to find high-paying employment with their higher education. Their more immediate wishes include constructing a toilet (which the house currently lacks), plastering the rooms on the rooftop, and adding another room where they can sell slippers and shoes.

Jitender Kumar improves his family's well-being by efficient labor use on the farm

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Not only is Jitender Kumar a hardcore-poor Indian farmer; he also is heir to a legacy filled with adversity. Jitender's family belongs to the other backward class (OBC), a caste that the *Constitution of India* recognizes as having been traditionally excluded from certain jobs and activities.

In Azadnagar village, Phulwari Sharif, in the Indian state of Bihar, Jitender and his family live 10 km away from Patna City, the capital of Bihar. Jitender's extended family has 14 members. Seven are adults (three males, four females) and seven are children whose ages range from 3 to 14 years.

The family owns only 0.15 ha of farmland; too little land on which to support 14 people. To survive, Jitender's family members sell their labor to other farmers. Also, they have leased 0.88 ha of land for sharecropping, with the understanding that, every year, they will give the landowners 25.6 quintals of paddy rice per ha and 3.2 quintals of wheat per ha, or the cash equivalent. The landowners receive this income simply because they own the land; they do not give any input.

Most of the 1.03-ha farmland is used to grow rice and wheat. On 0.78 ha, rice alternates with wheat. On the other 0.25 ha, during *kharif* (wet) and winter (dry) seasons, Jitender grows vegetables such as Cucurbitaceae (gourds), tomato, *brinjal* (eggplant), Colocasiae (taro), and others for family consumption and for cash.

To keep expenses as low as possible, Jitender's family makes efficient use of its most plentiful resource: the labor of its members. Rather than hire a tractor for tillage or use laborers for farm operations, Jitender uses the labor of male and female family members for all farming operations, save one, tillage. He and his neighbors have a mutual agreement to borrow each other's bulls at no cost because their families need two bulls for tilling but they own only one animal each.

Every year, Jitender's 14-member family needs about 15 quintals of rice and 7 quintals of wheat. On the 0.78 ha of farmland that his family uses to grow these crops, annual production varies—from 39 to 43 quintals of rice and 15 to 17 quintals of wheat.

After giving 22.5 quintals of rice and 2.8 quintals of wheat to the landowner in exchange for the use of 0.88 ha of farmland, Jitender's family usually has 17–21 quintals of rice and 12–14 quintals of wheat left. After meeting the family's needs, Jitender seldom has any rice to sell, but he can sell a few quintals of wheat.

Rice and wheat production provided the staple foods that ensured the family members' caloric intake. But there are nutritional needs for protein, fats, vitamins, and other nutrients. Moreover, they also need nonfood items such as clothing, medicine, education, and supplies for household maintenance. The sale of vegetables and wages earned from working as farm labor play a key role in meeting these needs. Annual gross income from vegetable crops, grown in two seasons on a 0.25-ha area, is about Rs 30,000 (US$710), which gives a net income of about Rs 20,000 ($480).

Because the growing children in his family have increasing appetite for food and other items and as commodities become more expensive, Jitender needs additional sources of income. Jitender's income depends on the availability of family labor for farm operations, so he thinks that using additional land for sharecropping would not be profitable.

In 2004, while Jitender was seeking supplementary income in exchange for minimal capital and labor, a research team from the Indian Council of Agricultural Research (ICAR) for the Eastern Region, stationed at Patna, approached Azadnagar village to test the feasibility of low-cost technologies that require less farmland: mushroom production, raising vegetable seedlings, honeybee husbandry, backyard duck raising, and other activities. The researchers believed that resource-poor farmers could have a supplementary livelihood by adopting these activities.

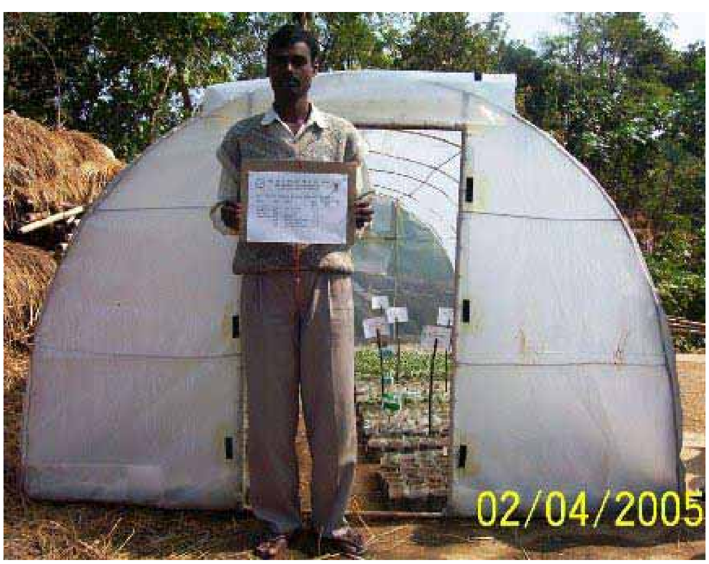
The research team coordinated this effort as part of the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains." Jitender was one of the pioneers who experimented by adopting three activities: raising winter vegetable seedlings in a polyhouse for early planting, cultivating mushroom, and rearing honeybees. None of these activities require much farmland, only a bit of space at home. Coordinators of the TAG 634 project provided Jitender with a 5 × 2.5-m polyhouse, a few polybags with substrate and mushroom spawn, two boxes full of honeybees, and technical support.

The early planting of winter vegetables meant early marketing and selling these at a higher price. But early planting is restricted by rains when seedlings rise ahead of normal time. The polyhouse has removed that barrier.

To benefit from this improved practice, Jitender placed a polyhouse on his homestead. In the first trial, he raised 3,500 Cucurbitaceae (bottle gourd, bitter gourd, cucumber, sponge gourd, ridge gourd, and pumpkin) seedlings in polybags. After only 3 wk, Jitender sold the seedlings at a high price, Rs 1.00 (2.4 cents) per seedling per polybag. His gross income from the first batch was Rs 3,500 ($80), a solid return on an investment of only Rs 500 ($12) for seeds, polybags, and fertilizer.

Cucurbit seedlings are grown in polybags inside Jitender's polyhouse.

Polybags containing substrate and mushroom spawn hang in a corner of Jitender's house, as part of the mushroom production cycle.



Jitender stands in front of his polyhouse, holding a list of Cucurbitaceae seedlings that grow inside.

Jitender planted all the seedlings of the second batch in his own field, at a time of the year when early marketing would ensure him a higher price. Because the demand for Cucurbitaceae seedlings is lower when a third batch would be ready, Jitender stopped growing seedlings after the second batch.

Gradually, Jitender and his family members learned the skills of mushroom cultivation, in both winter and summer. It takes very little labor and costs are low because Jitender is using a corner in his mud-walled house rather than farmland for mushroom cultivation.

Currently, Jitender is producing about 30–40 kg of mushrooms in the winter and about 50–60 kg in the summer. In the

Jitender checks a bee box for honey.

local market, he sells the mushrooms at Rs 60 ($1.40) per kg during winter; it is Rs 80 ($1.90) per kg in the summer. His annual income from mushrooms totals about Rs 6,000 ($140). Jitender is continuing his experiment with honeybee rearing. So far, he makes no profit from this venture because he needs to buy sugar to feed the bees during the off-season, when flowers, the natural source of sugar, do not grow in abundance.

For the past three years, Jitender engaged in these low-cost, nonfarmland activities. Currently, he generates at least Rs 12,000–13,000 ($290–310) per annum from raising vegetable seedlings in the polyhouse, cultivating mushrooms indoors, and planting vegetables early in his field with very little input and labor. Income from these supplementary livelihood support systems is vital in meeting some of his family's needs. Jitender's success is an example to inspire other poor farm youths to look for supplementary livelihood opportunities to improve their quality of life.

One day laborer finds a way out of poverty and inspires others

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Until the mushrooms came along, 52-year-old Lal Muni Devi led a life full of drudgery. Her husband had been sick and unable to work, so Lal Muni and her younger son worked as day laborers. They earned enough to provide a dowry of jewelry to marry off Lal Muni's youngest daughter.

Lal Muni is not a farmer. Rather, she and her family members are among the landless poor, who, because they own no land, cannot directly benefit from the new resource-conserving practices that are starting to make a difference in the lives of small farmers in her community.

For many years, what little income Lal Muni and her family earned had come from selling their labor to local farmers. They prepared the land for cultivating rice and transplanted rice seedlings from nurseries to paddies. They also weeded rice and wheat fields and harvested the crops, all by hand.

Lal Muni and her family live in a dark, windowless, thatched-roof, single-room house. At night, they keep their cow in one corner of the room to protect themselves from thieves. Their house is located in the village of Azadnagar, a half-hour drive from Patna, the capital city of Bihar State in India, in the impoverished eastern section of the vast Indo-Gangetic Plains. Most farms here are small, less than 2 ha. Almost all farmers grow two crops every year.

Until 4 years ago, Lal Muni's only source of income was the work she did for other farmers, as a day laborer. Since then, her life has changed for the better. Scientists from the Indian Council for Agricultural Research (ICAR) for the Eastern Region stationed in Patna brought together 25 women from her village to form a self-help group (SHG) called *Mahila Utthan Samiti*. The women were taught how to grow oyster mushrooms, with technical support from the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains."

Lal Muni Devi inspects the mushrooms that grow in her thatched house.

After a long day in the field, Lal Muni and her family members used to return to a home where small kerosene lamps provided the only light. Now, those lamps help family members with a new source of income: growing mushrooms. Inside, balls of wheat straw hang on twine from the roof. Oyster mushrooms grow on each ball, thriving in the dark, damp interior of the house.

The economic prospects are good and the mushrooms do not require much labor. Mushroom spawn are readily available and affordable, at Rs 50 (US$1.20) per bag, and wheat straw, the material on which the mushrooms grow, costs nothing. Packed in plastic bags, balls of wheat straw hang in rows under Lal Muni's thatched roof, nourishing the oyster mushroom shoots in the humid setting. ICAR scientists have also taught Lal Muni and SHG members to grow the milky white summer mushroom too, so they have year-round income.

Lal Muni Devi and other villagers talk with Dr. Thelma Paris (center) from the Philippines-based International Rice Research Institute (IRRI).

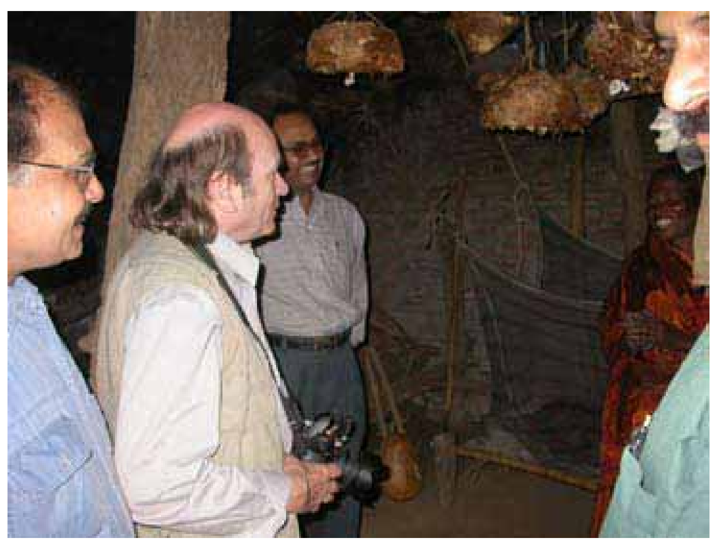
Lal Muni thinks back with gratitude for the people who helped her change her life for the better. "The method taught by ICAR instructors appealed to me as it did not require any land," she said. "Prior to this, I had never even heard of mushrooms. Then I learned to grow them in my house and found that they brought good profits.

"Since childhood, I had worked as a farm laborer in other people's fields—under scorching sun, heat, rain, and cold—to make ends meet," she said. "I am grateful to the scientists of ICAR who taught me to earn my livelihood respectably and independently, in the shade and comfort of my house, without any boss," Lal Muni added with a broad smile. "It also helped that the market was easily available in nearby Patna City."

For the first 2 years, ICAR provided free spawn until the participants were able to generate income. This year, women buy spawn at Rs 50 per kg and ICAR matches that purchase with an equal quantity of free spawn. "One kilogram of seed yields 10–14 kg of mushrooms. The winter variety sells at Rs 50–60 ($1.20–1.43) per kg; the summer variety sells at Rs 80–120 ($1.90–2.86) per kg.

But, of the 25 women, at least half quit the program after ICAR stopped providing free mushroom seeds. "I had left mushroom growing, but I will now start again and become like Lal Muni," says Nirmala Devi of the same village. Many men from the village are also taking up mushroom farming after knowing the price that mushrooms fetch.

Villagers talk with representatives of the Rice-Wheat Consortium (RWC)–International Maize and Wheat Improvement Center (CIMMYT) team, led by Dr. E. Olaf and K. Paudyal.



Mr. David Mowbray from CIMMYT visits Lal Muni's house and takes photos of her mushroom crop.

Lal Muni welcomes a team of experts from the USA-based Bill & Melinda Gates Foundation to her thatched house.

Lal Muni harvests her mushrooms.

Urmila Devi, a resident of the village, has thrown her support behind these enterprising women by granting them interest-free loans of her salary. She has also received training by ICAR at its Research Center at Ranchi (Jharkhand).

Lal Muni is grateful for the support that the Indian government has given to the IFAD project, in the form of approval and provision for ICAR scientists who are government staff. Her village has received many visitors from different parts of the world—delegates from foreign agencies and members of the electronic and print media. However, Lal Muni and other villagers are anxious about what will happen when project activities end in June 2007. "What will happen when the ICAR people leave?" she asks. "Who can help us in our future endeavors, when the project ends?" ICAR scientists have promised to provide technical help in the future; still, the villagers are looking for a more clearly outlined plan for assistance, which can help them achieve complete self-sufficiency.

Lal Muni and members of her local SHG display their bags of mushrooms.

How Kameshwar Singh found prosperity as a mushroom grower: a success story

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Kameshwar Singh has traveled a long, difficult path to arrive at the current stage of his life: not only supporting his six-member family but also sending all four of his children to school. Kameshwar remembers how, after several years of working as a teacher, he thought of going back to his home village to take up farming.

He calculated the likely outcome. "Survival of six persons on 8 bigha (1 ha) of land through farming would be extremely difficult," said Kameshwar. "My life would be more difficult than my parents'. They had only me to support; I had four children. My parents sent me to college and university, but I could not afford to do that for my children."

Kameshwar Singh, successful mushroom farmer.

Having earned a master's degree in geography from Bihar University in 1987, Kameshwar has always valued education. From a small farming family, Kameshwar is the only son of parents who dreamed that their son would complete a higher education, find good employment, and bring prosperity and happiness to the family and to his own life. They had spent their hard-earned money to pay for his years of higher studies.

Upon graduation, Kameshwar learned that attaining knowledge was one thing and earning a living with that knowledge was quite another. He had struggled hard to find employment in his field of study, but *Lakshmi*, the Hindu goddess of good fortune, would not smile upon him. A well-paying job proved elusive, but he found success in his personal life: he found someone whom he married in 1989.

Eventually, Kameshwar found employment as a geography teacher in a rural private college. The financial condition of the college was poor; his salary was low and irregular. By then, Kameshwar and his wife already had several children.

In 1998, frustrated after 7 years of financial struggle, Kameshwar left his teaching job and started a private school of his own, in the town of Siwan. He rented a 10-room house for this purpose; to his great disappointment, fortune was not yet ready to turn her face to him. In 2002, after a 4-year effort to make a living from this unsuccessful private school, Kameshwar finally gave up.

Disappointed but never defeated, Kameshwar desperately sought income-generating activities. He knew that the job market had no demand for a person with a master's degree in geography. He had already wasted years searching for decent employment. He asked himself, "What else can I do? What options do I have?"

Soon, Kameshwar had his answer. His parents had passed away, and he inherited 8 bigha (1 ha) of farmland in a rural area.

Kameshwar decided not to give up yet on the dream of prosperity for him and his family. He would try again, but at what? At that time, a salesman from a private firm based in Lucknow, a city in Uttar Pradesh, visited Siwan. He wanted to motivate people to cultivate mushrooms. He provided mushroom spawn (seeds), described some techniques for getting started, and sold a kit in exchange for Rs 4,000.

A new owner of farmland, and desperate yet hopeful, Kameshwar decided to take a chance on cultivating mushrooms. He converted one of his classrooms into a facility for mushroom production. In addition to the uncertainty that is integral to any kind of farming, Kameshwar was taking a risk in his choice of crop. Over the years, NGOs and missionaries had encouraged poor people to grow mushrooms, but they are a nontraditional food item. With the exception of some tribal people, people in South Asia hardly ever eat mushrooms as part of their day-to-day meal, and shoppers have difficulty locating mushrooms in the market. In the big cities, mushrooms are a delicacy, and mushroom producers who live near cities tend to target restaurants. Kameshwar is an exception; he is working to create a demand in his district.

First, however, Kameshwar needed to produce a crop. To his disappointment, the first attempt failed because it was the month of April, and the approaching season was too hot for the mushroom species that Kameshwar had attempted to cultivate. All other would-be mushroom farmers also failed, and the salesperson did not return to deliver the follow-up services he had promised when he sold the spawn and the kit.

Although other farmers gave up, Kameshwar persevered. He started exploring how he could produce mushrooms successfully. He discovered that Rajendra Agricultural University (RAU) in Samastipur District had a unit that deals with spawn production and provides technical assistance to interested growers. RAU was more than 200 km from Siwan and the journey was difficult, but nothing could deter Kameshwar from visiting the mushroom unit at RAU.

As a result, the visit to the Mushroom, Compost, and Spawn Production Centre at RAU became the turning point for Kameshwar. He returned home to Siwan with technical know-how, and a supply of quality spawn for a second attempt. This time it worked; Kameshwar successfully produced lots of mushrooms. The most challenging part was done; he did not face much difficulty in marketing his product. Kameshwar returned

Mushrooms are ready for harvest.

to the university for more spawn and to get answers to the many questions he had thought of while growing mushrooms for the first time. Since then, he has become a regular visitor at RAU and has received full technical support from the centre.

In February 2004, Kameshwar attended a 1-wk formal training on mushroom production at RAU. During this learning and exploration stage, Kameshwar came into contact with members of the IRRI-IFAD project team at RAU. By that time, the IRRI-IFAD project had started experimenting with mushroom cultivation as an alternate source of livelihood for resource-poor farmers in the Indian states of Bihar, Orissa, and Jharkhand. The team at RAU identified Kameshwar as an innovator and assisted him with technical input, encouragement, and guidance.

Kameshwar's dream is to put Siwan District on the map for mushroom production in the state. He has made significant efforts to promote mushroom as food and to create a demand for it in Siwan. He knew that market demand plays a deciding role in maximizing his earnings from mushroom production. He has regularly participated in exhibitions with his product, explained the goodness of mushroom as food, and demonstrated how to prepare various food items from it. The local newspapers supported him by writing about the benefits of eating mushrooms and covering Kameshwar's tireless efforts to produce and market his crops. Additionally, Kameshwar developed and printed a two-page leaflet in the local language (Hindi), introducing mushroom as a source of good nutrition.

So far, the marketing of his product is going smoothly. Kameshwar sells fresh mushrooms at the counter in his house-cum-production unit, for Rs 80 per kg, and supplies vendors and shop owners, at Rs 50 per kg. He dries and packs leftovers into 100-g packets, which he usually sells at Rs 400 per kg. One kilogram of fresh mushrooms becomes 100 g when dried properly.

Kameshwar dries unsold fresh mushrooms and packs them into 100-g packets for selling later.

Kameshwar provides hands-on training on mushroom growing to the women self-help group members.

His wife and children help in the production and sale of mushrooms. Their participation has become easier because production, sales, and residence all take place in the same compound.

In the meantime, other people have started growing mushrooms in Siwan. Kameshwar does not see them as competitors but rather as partners in developing the demand and market for mushrooms. Kameshwar assists them with technical knowledge and supplies them with the quality spawn he has collected from RAU.

The efficiency of mushroom production per kilogram of spawn has increased dramatically. Hot summer days are considered detrimental to mushroom production, yet Kameshwar's technical know-how has overcome this problem. Now, he is producing mushrooms year-round.

Kameshwar produces oyster mushrooms from September to April, milky white mushrooms from April to August, and button mushrooms from October to March. Kameshwar is planning to increase his mushroom production capacity, with inoculation of 200 bags with spawn every 14 d. He is also planning to produce quality spawn for himself and for other local growers. He is coordinating with an NGO named Krishi Sansadhan Vikas Kendra, which deals mainly with local mushroom growers. The NGO is organizing self-help groups in the district to promote mushroom cultivation among resource-poor youth and women farmers.

So far, Kameshwar's productivity is growing strong from year to year. In 2003, Kameshwar collected 50 kg of mushroom spawn from RAU; in 2004, he collected 100 kg; in 2005, he collected 145 kg; and by May 2006, he collected 72 kg. In 2003, Kameshwar produced 250 kg of mushrooms; in 2004, he produced 815 kg; in 2005, he produced 1,171 kg; and, by the end of May 2006, he produced 727 kg.

Kameshwar produces good button mushrooms.

In 2003, Kameshwar spent Rs 12,500 for mushroom production and his sales income was Rs 9,800: a negative balance of Rs 2,700. However, in 2004, he made a profit of about Rs 16,000. In 2004, his profit was Rs 33,000, and, in the first 5 mo of 2006, his profit was Rs 28,000. Currently, more than 60% of Kameshwar's household expenditure comes from mushroom cultivation; the rest comes from milk taken from his four new Jersey cows and from his rural land.

After a long struggle, Kameshwar has begun earning his livelihood as a mushroom grower. *Lakshmi* has now turned her face to him. He is happy with his wife and four children. However, he nurtures some pain in his heart. His parents were not here to see his success, for which they sacrificed so much. His only satisfaction is the thought that, from the heavens, they probably see his success and feel happy.

Lakshmi is the Hindu goddess of prosperity, wealth, purity, and generosity, the embodiment of beauty, grace, and charm. Most Hindu families worship her daily. The Lakshmi Puja (festival) is celebrated on Kojagari Purnima, the night of the full moon in October.

LAKSHMI

Lakshmi is depicted as a beautiful woman with four hands, sitting or standing on a full-bloomed lotus and holding a lotus bud, which stands for beauty, purity, and fertility. Her four hands represent the four goals of human life: righteousness, desires, wealth, and liberation from the cycle of birth and death. Cascades of gold coins flow from her hands, suggesting that those who worship her gain wealth. Lakshmi is a mother goddess; followers address her as *mata* (mother) instead of just *devi* (goddess). Laskhmi is present in each and every Hindu household. Householders worship Lakshmi, asking her to bring well-being and prosperity to the family. Businesspeople and homemakers alike offer her their daily prayers.
SOURCE: http://hinduism.about.com/library/weekly/extra/bl-lakshmi1.htm.

How mushrooms paved the way to success for Jayant Kumar Rout of Orissa, India

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Jayant Kumar Rout is an innovative farmer who lives in Bhatpada village in Cuttack District in the Indian state of Orissa. The village is about 50 km away from Bhubaneswar City, the capital of Orissa. The local ecology is suitable for rice production, especially during the wet season, when all farmers grow rice. In fact, during the wet season, environmental conditions offer very limited alternatives to growing rice.

Rice production provides seasonal employment and an essential staple for the year. After the wet season, most farmers grow legumes.

Jayant owns several small plots that add up to a 1.18-ha farm. Innovation is a necessity for Jayant: his six-member family, including his elderly mother, is entirely dependent on his small farm. Previously, the farm had produced too little food to meet the day-to-day needs of Jayant and his family; they had food security, but they were unable to manage other expenses comfortably. They did not starve, but they lacked nutritious food, proper clothing, education, housing, and medical care.

As an innovative farmer, Jayant is always looking for new technologies that bring higher yields and more profit. After being introduced to staff members at the Krishi Vigyan Kendra (KVK) Agricultural Science Center at the Central Rice Research Institute (CRRI) in Cuttack, Jayant began cultivating modern rice varieties and using improved management practices. Yet, his household income was still too low to improve the livelihood of his family.

Despite his never-ending struggle to improve, the barrier of subsistence remained. He realized that dependence on crop production alone, on his small farm, would keep him at the subsistence level forever.

Jayant asked himself, “How can I lift my family out of this trap? Farming is vital, but I need to find ways to earn additional income.” He was determined to provide a decent life and a better future for his two sons and daughter. He was also looking for employment opportunities for his eldest son, Satyajit, who had recently dropped out of grade 10 at the age of 15. At this stage, KVK personnel encouraged him to try mushroom cultivation. KVK also provided training on how to cultivate mushrooms.

In 1998, Jayant began a serious effort at mushroom cultivation to create a source of steady additional income for his family. But mushrooms need to grow in the shade, and his house had only two small rooms, where six of them were living. Jayant constructed a temporary small shade out of inexpensive rice straw, polythene sheets, and bamboo on less than 400 square feet of land adjacent to his house. Since then, Jayant’s eldest son, Satyajit, has joined the activity on a full-time basis. Jayant and Satyajit started producing paddy straw mushrooms (*Volvariella volvacea*) in the wet season and dhingri mushrooms (*Pleurotus sajorcasu*) in the dry season. They used locally available, inexpensive paddy straw as a substrate for mushroom production.

To find buyers for his product, which many Indians think of as a delicacy rather than a daily staple, Jayant established contact with the marketing network that sells mushrooms in Cuttack and Bhubaneswar. As a result, vendors started coming regularly to buy his mushrooms and, in 1998 and 1999, Jayant earned an average yearly profit of Rs 10,000–15,000 (US$225–350) from mushroom cultivation.

By 2000, confident of his capabilities and of the potential of mushroom production, Jayant increased his capacity for mushroom production. He constructed another temporary but much

Jayant is inside his mushroom cultivation shade, which he made out of rice straw (roof), bamboo (pole and roof support), and polythene sheets (fence). Many polybags with substrate and spawn (seeds) are on the floor.

A contact farmer harvests mushrooms that she produced inside her house.

bigger shade (3,500 square feet) on a plot about 100 m away from his house.

To Jayant's joy, the increased capacity led to a steady increase in production. In 2000, his profit from mushroom cultivation was Rs 40,000 ($900); in 2001, it was Rs 50,000 ($1,150). The following year, disappointment tempered Jayant's joy. In 2002, his efforts at dhingri mushroom cultivation led to a loss of Rs 25,000 ($570), mainly due to bad-quality spawn (seed). This prompted him to investigate whether he could produce quality spawn for his own use. He approached the KVK-CRRI personnel, presented his idea, and requested assistance.

In 2003, KVK-CRRI personnel arranged with the Agricultural University at Bhubaneswar to train Jayant one-on-one to produce mushroom spawn. He also worked in a laboratory at the university to gain experience. Jayant learned that the development of a spawn production facility would cost more than he could afford. So, to generate additional funds that would eventually finance a spawn production facility, he intensified his efforts at mushroom cultivation. In 2003 and 2004, Jayant earned annual net profits of Rs 80,000 ($1,800), and Rs 110,000 ($2,500), respectively, from mushroom cultivation.

In 2004, the International Fund for Agricultural Development (IFAD)-funded project "TAG 634: Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains" started a collaboration with CRRI at Cuttack. The project at Cuttack expanded its activities beyond field crops. It introduced mushroom cultivation to resource-poor farm women, as a way to develop a supplementary source of income and to improve family nutrition.

As had been the case for Jayant's mushroom crop in 2002, the lack of quality spawn was a major constraint to the expansion of mushroom cultivation by poor farm women. Realizing that he would be helping the entire community by constructing a mushroom spawn production unit, Jayant approached CRRI again and requested technical and financial assistance to create the unit.

Meanwhile, loan officers at the local banks refused to extend a loan to Jayant. They turned down his loan application because he did not have enough assets to secure the loan. On the other hand, CRRI personnel understood that, by collaborating with Jayant to build a spawn production unit, they could solve the constraints of the TAG 634 project activities at their site.

With the community benefit in mind, CRRI extended technical and financial assistance to Jayant, in the form of equipment such as a laminar flow and an autoclave, which are vital to a spawn production unit. The equipment was worth Rs 70,000 ($1,600). Encouraged by this assistance, Jayant set about raising money for the construction of the unit. He used his entire savings from mushroom farming (Rs 110,000, or $2,500), and borrowed about Rs 100,000 ($2,300) from friends and family members.

In December 2006, Jayant's dream came true. A simple inaugural ceremony launched his spawn production unit. Attendees included the director of CRRI, the IFAD project leader from the Philippines-based International Rice Research Institute (IRRI), a group of mushroom farmers from the IFAD project villages, and his fellow villagers.

Jayant Kumar Rout speaks at the inaugural ceremony of his mushroom spawn production unit. The ceremony was attended by dignitaries from IRRI and CRRI and fellow farmers.

Although his entrepreneurial spawn production unit is now commanding a fair amount of his time and effort, Jayant has not given up mushroom farming. He and his eldest son, with assistance from three hired workers and other family members, are running both facilities: one for producing spawn and another for cultivating mushrooms. They use their own mushroom spawn and sell spawn to other farmers.

In the first 3 months, Jayant sold about 3,000 bottles of spawn, at Rs 10 per bottle. Currently, he earns a net profit of about Rs 1,500 per week or Rs 78,000 ($1,800) per annum from the spawn unit, and about Rs 120,000 ($2,700) per year from the mushroom farm.

Since 1998, because of improved financial circumstances, Jayant has been able to send his two younger children to college. His second son, Biswajit, and his daughter, Renubala, are working to complete their bachelor's degrees. Jayant and his family members were very happy about their achievements during this short time span.

In addition to the satisfaction he feels from helping his own family, Jayant is happy because not only does he produce his own mushroom spawn, he also supplies spawn to nearby villages and provides employment to three people, in addition to the family members he employs.

By word of mouth, Jayant has become widely respected in his village and in nearby villages. His success in cultivating mushrooms and quality mushroom spawn has triggered his dream of a mushroom dehydration plant where he can dry and pack his products, as well as the products of other small mushroom growers for added value.

With the right approach and determination, Jayant is confident that he can do it. With a limited formal education, he has demonstrated his entrepreneurial skill as a mushroom grower and as a producer of quality mushroom spawn. Will his third dream materialize? Only time will tell; his experience to date indicates a positive outcome.

Jayant's wife and daughter and IRRI social scientist Thelma Paris inspect the spawn bottles inside the mushroom spawn production unit.

Technical Advisory Notes

Fourteen technical advisory notes (TANs) are included in this document. Thirteen of these are from seven IRRI-managed sites and one from an ICRAF-managed site. These TANs are prepared following the guidelines developed by IFAD. The TANs cover diverse categories of technologies: cropping systems, improved varieties, crop establishment methods, nutrient management, and technologies for supplementary income for landless and marginal farmers. Resource conservation technologies (RCTs) such as zero-till wheat and zero-till rice, *Sesbania* co-culture with rice as a green-manuring crop, and real-time nitrogen management in rice by using a leaf color chart, and alternative income generation technologies such as mushroom cultivation were validated and promoted at four CIMMYT-managed rice-wheat system sites. Technical details of these RCTs were documented in the RCT Resource Book. However, RCTs such as zero-till rice, real-time nitrogen management using a leaf color chart, and mushroom and elephant-foot yam cultivation were also validated and adopted at some of the IRRI-managed sites included in this document.

Cropping Systems

Line-sown short-duration rice followed by chickpea for rainfed environments of Chhattisgarh, India

A. Introductory Section

Technology source:	Indira Gandhi Agricultural University (IGAU) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Increase rice and pulse production, and improve farmers' income and livelihoods
Crops and enterprises:	Rice and pulses
Agroecological zones:	Rainfed environments of Chhattisgarh State of India
Domain of potential application:	Rainfed environments of Chhattisgarh, Jharkhand, and part of Orissa State of India
Key words:	Rice, kharif (wet season), line sown, seed drill, drought, chickpea, yield, household food security, and profit

B. Main Text

Summary

The state of Chhattisgarh is located at the eastern fringe of central India, at the heart of the tribal population of the country. Most of the households are resource poor, with 18% landless, 66% marginal and small farmers, and only 16% medium and large farmers. More than 82% of the households fully depend on agriculture but the environment is very fragile (Fig. 1). Uneven and untimely rain and drought are responsible for frequent crop failure and low productivity. About 24% of the cultivable area is irrigated, mostly through canals, but basically it is also rain dependent, and 76% is rainfed. Cropping intensity is low (121%), with rice grown in the kharif season and pulses or oilseed crops in the rabi (dry) season. Monocropping of rice is the dominant system and, among the double-cropping systems, rice-*Lathyrus* is important in the plains under rainfed conditions. Rice is grown in the kharif (wet) season and 80% of the rice is direct seeded. In the rainfed system, most rice crops are established following a traditional system called *biasi* or *beushening*. The *biasi* or *beushening* operation is not possible when drought occurs 30–45 days after seeding, which results in unmanageable

Fig. 1. Fragile rainfed environments in the dry season in the Chhattisgarh plains, India.

weeds in rice fields. As a result, rice yields are generally low and therefore poverty is widespread. Technologies for improvement such as a seed drill for line seeding for escaping the adverse effect of early drought, good stand and proper weed control, and a short-duration rice variety to escape terminal drought and to accommodate an additional postrice crop were available but adoption was very low. The impact of line-sown short-duration rice followed by chickpea in the rainfed environment on production as well as farmers' income was validated at two villages in the Chhattisgarh plains through community-based compact block trials. Trials revealed that the rice-chickpea system has great potential for increasing production and profit.

Technical details

Rice in rainfed fragile environments suffers from drought and thus yields are low. Double cropping in this environment is limited because of a lack of residual moisture for the establishment of a second crop after medium to late rice, as well as free raising of livestock, particularly in the dry season. In addition to drought, low rice yields are also caused by the traditional *biasi* or *beushening* system of rice crop establishment, which is broadcasting of 100–125 kg of seeds per ha on pretilled friable wet soil after the onset of monsoon rain. About 30–45 days after seeding, when sufficient rain water has accumulated on the rice field, it is then plowed to manage weeds and redistribute seedlings manually (Fig. 2). In the rainfed system, in most cases, low-yielding traditional varieties of rice and other crops are grown. The rice crop also suffers severe competition from weeds, which are difficult and expensive to control if rain doesn't occur during *beushening* operations. In the double-cropping system, rice-*Lathyrus* is common but the yield (<0.5 t/ha) and market price of *Lathyrus* are low (Rs 7/kg). Chickpea, another pulse, is popular and can produce higher yields as well as offer a much higher price (Rs 20/kg) than *Lathyrus*. Individual efforts for double cropping face severe problems in protecting dry-season crops from free-grazing livestock. Such efforts of early rice followed by chickpea are also subject to damage by field-to-field transportation of harvested rice and draining out of water from medium to late rice fields. Considering these biophysical and socioeconomic constraints, a system technology ("line-sown short-duration rice followed by chickpea") was designed from the available technologies on the shelf and its performance validated at Kapsada and Akoli villages in the Chhattisgarh plains using a community approach.

Community-based validation:

The IGAU research team attempted community-wide validation

Fig. 2. ***Beushening*** **operations in rice fields at Kapsada, Raipur, Chhattisgarh.**

Fig. 3. Group discussions among stakeholders for line-sown rice-chickpea technology.

of the line-sown short-duration rice followed by chickpea system technology. A series of farmers' discussion sessions (Fig. 3) were held on how to change the traditional *biasi* or *beushening* system of rice crop establishment for managing weeds in early drought conditions and for better yield, how farmers can use line-sowing technology although they cannot afford the machinery, what modern varieties can replace existing ones for higher yields as well as to escape terminal drought and to accommodate a second crop, and which second crop will give higher profit, etc. Although there were tractors in both intervention villages, farmers did not have a seed drill. As there was no demand for the seed-drilling service, tractor owners were reluctant to invest. They were also unaware of the source and process for obtaining a tractor-drawn seed drill. The research team brought both stakeholders together and helped tractor owners obtain a seed drill from IGAU and other agencies. They also helped the communities to establish rules of business for tractor owners as service providers for tillage and seeding, determined rental arrangements, and trained interested farmers on the technologies. The community developed a system of protecting its dry-season crop from free-raised livestock by arranging guards and imposing a fine in cases of crop grazing. In the kharif season of 2004, line-sown rice adoption rose up from the base of 79 ha in 2003 (base year) to 267 ha (Fig. 4). Adoption of the rice-chickpea system (Fig. 5) steadily increased from 83 ha in the base years (2003-04) to 226 ha within two years. However, the traditional rice-*Lathyrus* system decreased from the baseline of 185 ha to 153 ha in two years.

In the first year, farmers used the varieties they used to grow, of which four—MTU-1010, Mahamaya, Swarna, and ISD-

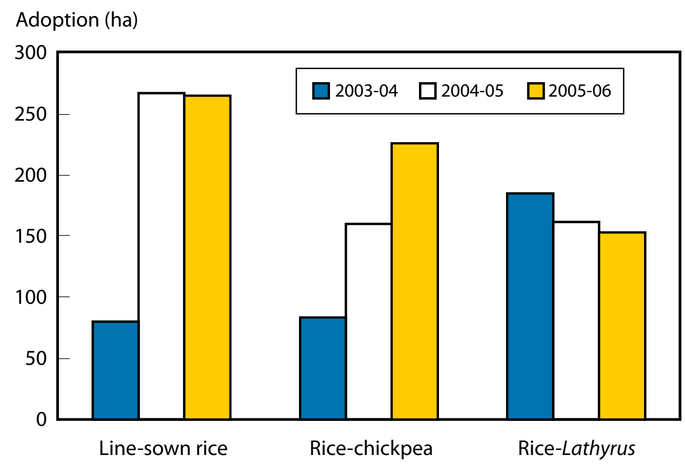

Fig. 4. Adoption pattern of technologies in the intervention villages (2003-04 is baseline year) in Raipur, Chhattisgarh, India.

1—were common. Among these four varieties, Swarna (145 days) performed best (4.4 t/ha) (Fig. 6). However, most farmers preferred MTU-1010 (with 3.75 t/ha yield) mainly due to its short duration (110 days) for accommodating the second crop, chickpea. In the 2005 and 2006 rice seasons, most farmers grew MTU-1010 under the double-cropping system.

Alternatives

Line sowing is adopted for efficient weed management and to withstand early drought for improving yields over those of the broadcast *beushening* system. Adoption of a mechanical weeder reduces the cost of weeding in rainfed environments. Cur-

Fig. 5. Line-sown rice and chickpea in Kapsada village, Chhattisgarh.

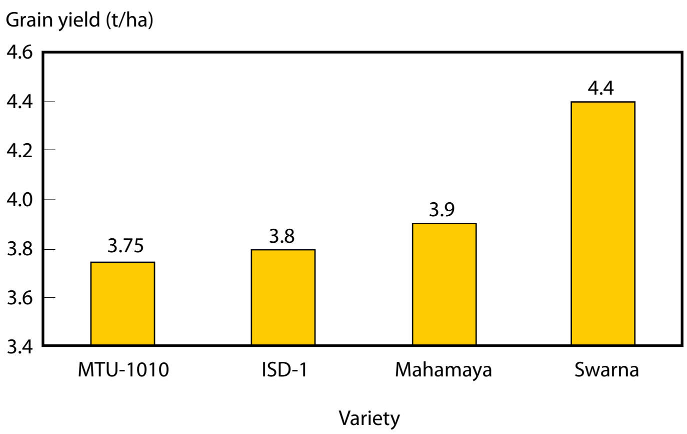

Fig. 6. Average yield of different rice varieties in Akoli and Kapsada villages in the 2004 kharif season.

rently, rice variety MTU-1010 is used, which could be replaced by drought-tolerant and pest-tolerant/-resistant short-duration modern varieties, if available, provided they are suitable and produce at least 4 t/ha in the kharif (wet) season. Short-duration (95–100 days) variety Anajali introduced in the rainfed undulated terraces in Jharkhand is a potential candidate. Other pulse and oilseed crops such as lentil, linseed, safflower, coriander, etc., can also be grown after rice in the dry season as a second crop if profit is on a par with or more than that of chickpea or if problems of pests and diseases occur owing to the continuous cropping of chickpea.

Expected impact

The line-sown rice crop (Fig. 7) produced on average 4.0 t/ha of grain, which was 0.4 t/ha or 11% higher than that of the *biasi* or *beushening* system of traditional crop establishment. Line-sown rice can tolerate drought during the early vegetative phase, 30–45 days after seeding. Farmers saved 25–50 kg of rice seeds per ha by adopting line-sowing technology and also saved some labor, mainly from *beushening* operations and weed control. Line sowing saved Rs 1,100 per ha on variable cost coupled with 11% higher yield than *biasi* or *beushening*. System productivity (rice equivalent yield) averaged 3.8 t/ha for rice-fallow, 4.2 t/ha for rice-*Lathyrus*, and 6.1 t/ha for rice-chickpea. Average net returns of the rice-chickpea system were Rs 17,100 per ha, which were almost double (91% higher) those of the rice-fallow system and 84% higher than those of the rice-*Lathyrus* system mainly because of higher production and a higher price of chickpea (Rs 20/kg) than *Lathyrus* (Rs 7/kg) (Fig. 8). A line-sown improved short-duration rice variety followed by an improved chickpea variety or other pulse and oilseed crop suitable for a particular area can substantially increase production and household food security and improve livelihoods of rice-growing farmers in rainfed environments of Chhattisgarh. Adoption of this technology on about half of the rainfed rice lands of the state would bring billions of rupees in benefits per annum to the state and to the nation.

Constraints to adoption

Community-managed compact block cropping is essential for successful adoption and an increase in pattern-based technology such as line-sown short-duration rice followed by chickpea. However, organizing communities for such agricultural technology adoption is often difficult and requires dynamic and

Fig. 7. Line-sown rice at reproductive stage at Kapsada village, Raipur, in 2005.

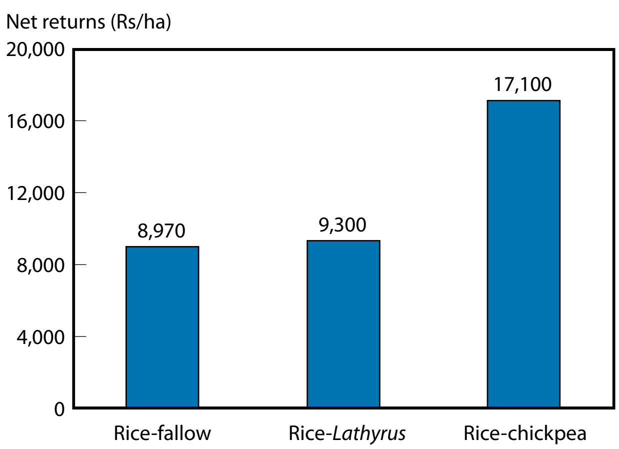

Fig. 8. Net returns of different cropping systems at Raipur, Chhattisgarh, India.

knowledgeable leadership. There are many dynamic leaders in the farming communities but most lack knowledge on and confidence in the recently developed technologies. Experienced and dedicated catalysts are needed, as demonstrated by the IGAU research team in two villages, in order to stimulate, use, and guide local potential and dynamic farming community leaders. Researchers can perform such a catalyst role at a few pilot sites but the department of agriculture and department of local government of the state and/or nonprofit organizations need to come forward to replicate the success in the state.

Validation status

The line-sown short-duration rice followed by chickpea system technology was successfully validated through community-based farmer-managed research in two villages (Kapsada and Akoli) in the Chhattisgarh plains over two successive cropping years (2004-06). However, the service providers developed in the intervention villages for line seeding using a tractor-drawn seed drill started to extend their services to the adjoining villages from the second year (2005-06). Many farmers in nonintervention villages adopted the technology using local devices such as a bullock-drawn seed drill and planting seeds in furrows made by the plow. By the third year (2006-07), the line-sown rice covered 482 ha in two intervention villages and approximately 385 ha in nonintervention villages.

Conclusions

Compact block validation through community-managed experiments revealed that direct dry seeding of rice using a tractor-drawn seed drill can manage weeds, tolerate early drought, save seeds (25–50 kg/ha) and labor, and increase rice yield by about 11% over the traditional establishment method of *biasi* or *beushening*. The rice-chickpea system can increase net income by 91% and 84% over rice-fallow and rice-*Lathyrus* systems in the fragile rainfed environments of Chhattisgarh. This double-crop system has a significant positive impact on household food security and livelihood. The research team has demonstrated that a boost in production, farmers' income, and livelihood is possible in fragile rainfed environments by adopting appropriate system-based technologies. However, the community approach is a must for successful implementation, which requires dynamic local leadership and effective technical backstopping and guidance from public-sector organizations. Research organizations are not equipped with manpower nor do they have a mandate for implementation throughout the state; therefore, public-sector departments such as the department of agriculture and department of local government and/or nongovernment organizations should come forward for state-wide technology dissemination.

C. Additional Information:

Date of release

February 2007

Sources of useful additional information

IGAU and IRRI (Indira Gandhi Agricultural University and International Rice Research Institute). 2006. Rice-based chickpea production technology. (In Hindi.) Indira Gandhi Agricultural University, Raipur (India): IGAU, and Los Baños (Philippines): IRRI. 6 p.

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Short-duration rice variety Anjali and the Anjali-chickpea system for fragile rainfed uplands of Jharkhand, India

A. Introductory Section

Technology source:	Central Rainfed Upland Rice Research Station at Hazaribag, Jharkhand, and International Crop Research Institute for the Semi-Arid Tropics, Hyderabad, India
Funding source:	"Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG634)" project
Expected benefits:	Reducing farmers' vulnerability to drought and increasing household food security and farmers' income
Crops and enterprises:	Rice and chickpea
Agroecological zones:	Rainfed uplands of Jharkhand (agro-climatic zone 7)
Domain of potential application:	Rainfed uplands of eastern India
Key words:	Rice, short-duration variety, chickpea, rice-chickpea system, cropping intensity, grain yield, profit

B. Main Text

Summary

Rice in the fragile undulated terrain of Jharkhand often suffers from severe terminal drought, causing a moderate to severe yield reduction or even crop failure. To escape or minimize yield losses from drought, the Central Rainfed Upland Rice Research Station (CRURRS) at Hazaribag, Jharkhand, developed a short-duration (95–100 days) modern rice variety. Development of this variety created an opportunity for escaping terminal drought and cultivating another short-duration crop following Anjali using residual moisture. The performance of Anjali and Anjali followed by chickpea was validated by farmers at three sites in Jharkhand over three years.

Technical details

In the kharif (wet) season, rice is grown on the terraces of undulating lands of Jharkhand. The uppermost toposequences of terraced land are known as Don III. They have shallow top-soil depth and poor water-holding capacity and are drought prone. These lands are predominantly monocropped under rainfed conditions. Farmers traditionally grow either long-duration

(115–140 days) photosensitive local landraces such as Kalamdani, Dudhiras, and Jonga or improved varieties such as IR36, Sarjoo 52, and Suruchi. With the advent of improved varieties, farmers are gradually adopting the transplanting method of crop establishment instead of traditional direct seeding followed by *beushening*. Drought is common, and occurs mostly either at the seedling or reproductive stage. In recent years, farmers were compelled to either transplant very old seedlings or abandon nurseries due to a delay in rainfall. CRURRS validated short-duration rice variety Anjali and a cropping system whose components are Anjali and chickpea as a sequence crop using residual moisture. In on-farm trials and front-line demonstrations, grain yield of Anjali ranged from 3.0 to 3.5 t/ha. Adoption of this short-duration variety allows early harvesting of rice and growing of chickpea as a sequence crop. This cropping system substantially increases cropping intensity and income and thereby improves livelihoods.

Rice

The appropriate sowing time of wet-season rice is between the third week of June and first week of July. After the premonsoon rain, plow the field once with a tractor- or bullock-drawn disc harrow followed by one plowing with a moldboard plow to make fine tilth and level the field by laddering. One summer plowing will drastically reduce the weed population. Make 6–8-cm deep furrows by using a country plow and broadcast 100 kg of seed per ha and level the field by laddering (Fig. 1). Apply NPK at 60-40-20 kg/ha. Apply 20 kg N and the entire amount of P in the form of DAP and K as basal. Apply the rest of the N in the form of urea in two equal splits at tillering (25–30 days after seeding) and at booting.

Weeds can be controlled by spraying butachlor (1.5 kg a.i./ha), anilophos (0.5 kg a.i./ha), or pendimethalin (1.0 kg a.i./ha) at 1–2 days after rice emergence on moist soil, followed by one need-based hand weeding at 25–30 days after seeding. Need-


Furrow opening


Seed broadcasting


Line-sown rice

A field with Anjali at ripening stage

Fig. 1. Land preparation and rice crop establishment by broadcasting of dry seeds on a field with furrows, which gives rise to a line-sown crop, and Anjali at ripening stage.

based application of Tilt at 1.0 mL/L of water at 8–10% brown spot infection, Hinosan 50 EC at 0.1% once at flowering and at 8–10% neck blast infection, and endosulphan 35 EC at 1.2 mL/L of water at milk stage against rice bug is important. Harvest the mature crop 28–30 days after flowering. After threshing and proper cleaning, sun-dry grains to 12% moisture content for seed purposes and to 14% for milling.

Chickpea

Immediately after the harvest of rice, plow the field two times with a moldboard plow (bullock- or tractor-drawn). Treat seeds with *Trichoderma viride* 4 g + Vitavax 2 g with a small amount of gur per kg of seed and *Rhizobium* culture at 5 g/kg. The seed rate is 75–80 kg/ha for small chickpea and 85–95 kg/ha for large chickpea. Sowing should be done behind the plow at 30–45-cm row-to-row and 7–10-cm plant-to-plant spacing, and at 5–6 cm depth (Fig. 2).

Improved varieties KAK 2, Bharati (ICCV 10), and P.G.114 maturing in 90–95 days, 115–120 days, and 120–125 days, respectively, are identified for this system. Apply DAP at 100 kg/ha, which will provide 18-46-20 kg NPK per ha at the time of sowing as basal application. Weeds are not a serious problem in chickpea in Jharkhand. However, one hand weeding at 25–30 days can be done, if needed. Pruning once between 40 and 60 days can be done to induce branching.

Spray neem seed extract or endosulphan at 1.2 L/ha at the time of pod formation just after flowering to control pod borer. Prepare the neem seed extract by soaking 12–13 kg of neem seed powder in 25 L of water overnight and filter through muslin cloth. Add 500 g of soap powder to the filtrate and mix well. Dilute the mixture with 300 L of water and spray on 1 hectare. Perches (T-shaped bamboo sticks) can be placed in the field to attract birds that prey on pest caterpillars. However, perches should be removed before crop maturity.

Harvesting should be done when pods turn light brown. Dry pods to 8–9% moisture content. Store dried seeds with some naphthalene balls in an air-tight container. Farmers can adopt this cropping system continuously for two years in the same field but then need to rotate with rice-oilseeds (toria or linseed) for at least once in three years to avoid problems of wilt disease.

Fig. 2. Sowing of chickpea behind the plow.

Fig. 3. ICCV-10 and KAK-2 chickpea varieties on terraced lands of Jharkhand in the rice-chickpea system.

Alternatives

The short-duration modern rice variety Vandana can be grown as an alternative to Anjali as both a sole crop and component of the rice-chickpea system.

Expected impact

Under favorable rainfall patterns, Anjali can produce about 4 t/ha. In the 2006 wet season, Anjali produced on average 4.49 t/ha (n=5) in similar fragile environments in Purulia District of West Bengal. In extreme terminal drought conditions in 2005 in Jharkhand, Anjali produced on average 2.15 (1.72–2.51) t/ha, while Vandana (another short-duration modern variety) produced 1.50 t/ha. Traditional variety Pansala produced 0.8 t/ha, whereas traditional variety Garibsail and modern variety IR36 failed to produce any yield (Fig. 4). In a favorable rainfall year, Anjali can produce as much as other modern varieties, but, if drought occurs, its yields are much higher than those of other varieties. Thus, adoption of Anjali will reduce farmers' vulnerability to drought and improve household food security. Adoption of the rice (Anjali)-chickpea system in potential areas could boost farmers' income, but its niches are yet to be identified and this needs further validation.

Constraints to adoption

The major constraint to scaling up of Anjali is the unavailability of seeds at the grass-roots level. Seed production and distribution through the state government network are needed. Unpredictable extreme drought is the major constraint of short-duration rice (Anjali)-chickpea technology. As chickpea depends on residual soil moisture, terminal drought in the preceding rice season affects the success of the following chickpea crop. In years of terminal drought, it is wise not to plant chickpea. Grazing on winter crops is a common phenomenon in Jharkhand, which can be overcome by a community-based approach.

Validation status

The performance of short-duration modern rice variety Anjali in Jharkhand under rainfed conditions was validated in farmers' fields at three sites over three years involving several hundred farmers. Under favorable rainfall patterns, Anjali can produce yields as good as those produced by other modern rice varieties grown in the state. However, under terminal drought conditions, which are common in Jharkhand, it can produce more than 2 t/ha when most other varieties fail or produce low yields. Adequate validation of Anjali was done. In 2006, 5.6 tons of its seeds were sold or distributed to more than 400 farmers. In the 2004, 2005, and 2006 dry seasons, about 70 farmers in three villages tried the short-duration rice (Anjali)-chickpea system. Chickpea cropping was successful in 2004 and farmers harvested

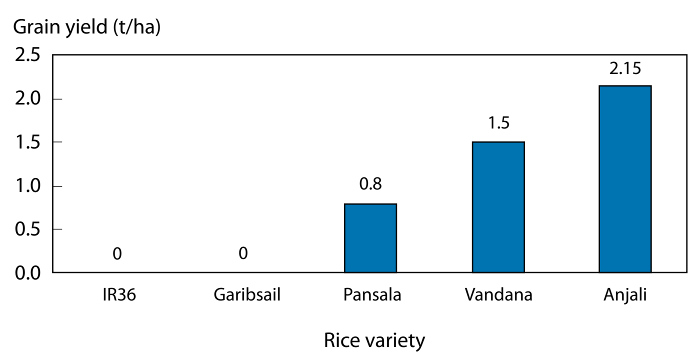

Fig. 4. Performance of Anjali and other rice varieties under drought stress in farmers' fields in Jharkhand in 2005.

satisfactory yields, close to 1 t/ha. But, extreme terminal drought in the 2005 dry season affected the rice crop and chickpea failed to germinate. Success in 2006 was mixed, fairly good in one village (harvested chickpea yielded close to 1 t/ha), poor in another village, and the crop was grazed by cattle in the third village at the vegetative stage because farmers anticipated that the crop would fail because of drought. Further validation of the rice (Anjali)-chickpea system is necessary. The system may not be suitable across Jharkhand but could be adopted in certain niches, which are yet to be identified.

Conclusions

Rice crops in the wet season in rainfed undulated terrains of Jharkhand often suffer from terminal drought. Under favorable rainfall patterns, short-duration (90–100 days) modern rice variety Anjali is as good as other modern varieties, and it can yield well under terminal drought conditions. Wide-scale adoption of Anjali in Jharkhand and similar fragile environments will reduce farmers' vulnerability, this improving household food security. So far, validation of the rice-chickpea system is inadequate. Adoption of such a system could boost farmers' income and livelihood.

C. Additional Information

Date of release

March 2007

Resource persons for the technology

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Agro-horti-silviculture in hill slopes for enhanced sustained production and hill conservation

A. Introductory Section

Technology source:	Central Agricultural University, Manipur, India
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Enhancing productivity, farm-level biodiversity, cropping intensity, and employment; generating regular and stable income; and reducing soil erosion
Crops and enterprises:	*Jhum*/agro-horti-silviculture
Agroecological zones:	Rainfed uplands/hills (slope land)
Domain of potential application:	India, Bhutan, Nepal, Bangladesh
Key words:	Agro-horti-silviculture, hill-slope agriculture

B. Main Text

Summary

About 85,000 hectares of cultivated area of Manipur State under the rainfed upland/hill (slope land) ecosystem have shown a continuous depletion of soil, forest/vegetation, and productivity due to surface soil erosion and narrowing of the *jhum* (slash-and-burn) cycle. In the dry season, germination and growth of crops are often severely affected due to moisture scarcity. Excessive runoff during rains causes flooding and damages whatever crops were grown in the foothills (flat land). An agro-horti-silvicultural farming system with several crop combinations selected by the faming community was introduced in Kairembikhok village, Waithu Hill District, of Manipur. The intervention site was about 36 ha and every household in the village participated in this endeavor. Farmers provided all the needed inputs and managed all farming operations. The project supplied only the seedlings of tree crops, which was seen as critical and was beyond the reach of individual farmers, and provided technical support for the efforts. The entire operation was designed and managed by the village community, beginning from the needs assessment to the evaluation of progress and results. The results

Project field area with participant farmers at Kairembikhok village.

so far indicated that the allocation of land resources to trees, tree + field crops, and field crops alone by landscape position is a preferred way of designing the agro-horti-silviculture farming system. The inclusion of crops with which farmers are familiar, needed for domestic consumption and local market demand, is a good indicator in the design. Likewise, the selection of crops providing income at different time frames, for example in 4–5 months, after 1 year, in 2 years, and so on, and land allocation to these crops according to family needs were other important criteria preferred by the community.

The results indicated that a 25–30% land allocation in upper slopes to timber trees, about 40% to intercropping of field crops (e.g., pineapple with pigeon pea, turmeric/ginger, groundnut along with lemon) on mid and side slopes, and the rest of the lands in the valley bottoms to cereals is a good choice and remunerative for the community. This system was evaluated as the best alternative to *jhum* cultivation and has resulted in a significant reduction in soil loss through erosion.

Technical details

Agro-horti-silviculture involving teak, champa, and wang tree crops; citrus, pineapple, jackfruit, and passion fruit as fruits; and pigeon pea, rice-bean, groundnut, soybean, ginger/turmeric, and rice as field crops was introduced from the monsoon season of 2004. Critical inputs such as seedlings of tree crops were supplied by the project, whereas all other inputs were supplied by the farmers, who also managed all operations.

Timber species were planted from the top to mid hill area and fruit crops from the mid to lower hill portion. Field crops were intercropped with fruit crops on mid hill slopes (mid to lower hill position) and also grown as pure crops on flat lands and in valley bottoms. About two-thirds of the tree plantings survived with no significant difference between species (Table 1). Tree seedlings attained an average height of 75 cm in two years. Among the fruit crops, survival rate was highest for pineapple (92%) and lowest for citrus (68%). Citrus attained an average plant height of 90 cm, whereas jackfruit attained 150 cm in two years.

Two crops of pulses (pigeon pea and rice-bean) and oilseeds (groundnut and soybean) were introduced as an intercrop in between the rows of pineapple during the rainy season in order to reduce soil erosion and improve soil fertility (Table 2). Among these intercrops, rice-bean performed best, followed by pigeon pea, but shading of rice-bean affected growth of the pineapple crop. So, farmers preferred pigeon pea over rice-bean. Some farmers have also preferred ginger/turmeric instead of pigeon pea, groundnut, or rice-bean.

Table 1. Survival rate of timber tree and fruit crops during 2005.

Crop species	Planted (no.)	Survived (no.)	Survival (%)
Tree crops			
Teak (*Tectoria grandis*)	1,000	676	67.6
Champa (*Michelia champaka*)	1,000	689	68.9
Wang (*Gmelina arboria*)	1,000	634	63.4
Total/average	3,000	1,999	66.6
Fruit crops			
Citrus spp.	3,690	2,527	68.5
Pineapple	120,000	110,274	91.9
Jackfruit	300	242	81.1
Passion fruit	570	422	74.0
Total/average	124,560	113,465	91.1

Table 2. Performance of intercrops grown with pineapple.

Intercrop	Total area planted (ha)	Production (kg)	Productivity (kg/ha)
Pigeon pea (*Cajanus cajan*)	1.0	1,450	1,450
Rice-bean (*Vigna umbellata*)	2.0	3,270	1,635
Groundnut (*Arachis hypogaea*)	2.0	2,110	1,055
Soybean (*Glycine max*)	2.5	1,708	683

Pineapple intercropped with pigeon pea in lower hills.

Teak-wang-pineapple intercropping.

Locally fabricated equipment for measuring soil erosion.

To record soil loss during the monsoon season (June to September), several sediment-measuring recorders were fabricated locally out of 24-gauge metal sheets and installed on different slopes. Estimates of soil loss from the *jhum* land averaged 140–170 t/ha/year, which was only 15–27 t/ha/year on the introduced agro-horti-silviculture land. Agro-horti-silviculture on hill slopes reduced soil erosion by about 84%.

Alternatives

The technology introduced through this effort is an alternative to the *jhum* system of farming. The other alternatives available are within the selection of crops in each category, for example, trees, field crops, fruit crops, etc.

Expected impact

The introduced agro-horti-silviculture system chosen, modified, and adopted by farmers is increasingly contributing to the livelihoods of participating households. The area covered by the adopted technologies is expanding and the productivity of introduced crops, farm-level biodiversity, and cropping intensity are increasing and soil erosion is decreasing. This system is providing regular income (seasonal, yearly, after two years, and so on). Over time, farm income has been increasing and generating employment opportunities, particularly for women and rural youth. It is expected that this will significantly help enhance rural livelihood and empower the rural poor. Demand for supporting such initiatives will increase from surrounding communities having similar situations.

Pineapple-soybean intercropping in the old tree system.

Pineapple-turmeric intercropping.

Constraints to adoption

Seedlings and quality planting material of desired species are not readily available and efforts are needed to produce them locally. Farmers' new interventions within this system are providing a bigger basket of options to choose from, but at the same time are making comparisons difficult because all the interventions are designed and compared with the *jhum* cultivation system.

Validation status

New crops are continuously introduced by the farmers themselves. Passion fruit has been planted on eroded lands. Ginger, turmeric, and colocassia are intercropped with pineapple. Mustard and peas are grown in foothills after rice. This is a welcome opportunity and indicates that the basic (genuine) technology has been found to be very suitable and, when validated over the years, is gaining popularity and expanding. However, support for tree seedlings and technical aspects will enhance up-scaling.

Conclusions

Community-designed and -managed agro-horti-silviculture technology is one of the best livelihood options for hilly and undulating areas. Greater participation by the farm community as a whole and joint planning initiatives involving multistakeholders would make implementation of the agro-horti-silviculture system easier and would accelerate technology adoption. Farmers have shown interest in mixed planting rather than pure crop block planting and are bringing new crops and varieties into the system. This also helps in minimizing risk from failure of a particular crop. The benefits of the adoption of this agro-horti-silviculture system in wider areas for the improvement of livelihoods and biodiversity and hill slope protection will be enormous.

C. Additional Information

Date of TAN release

January 2007

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Varieties

BRRI dhan44: a transplanted aman rice variety for tidal nonsaline areas of Bangladesh

A. Introductory Section

Technology source:	Bangladesh Rice Research Institute
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Increase rice yield and income, and improve household food security
Crops and enterprises:	Rice
Agroecological zones:	Tidal nonsaline and adjacent northern areas of Barisal and Khulna regions of Bangladesh
Domain of potential application:	Coastal region of Bangladesh and similar environments in West Bengal State of India
Key words:	Rice, aman (wet season), nonsaline tidal wetlands, variety, grain yield, validation, farmer preference

B. Main Text

Summary

The Bangladesh Rice Research Institute (BRRI) released several high-yielding modern rice varieties (MVs) for the transplanted aman (wet) season such as BR10, BR11, BRRI dhan30, BRRI dhan31, BRRI dhan32, etc. Although BR11 and BRRI dhan31 were adopted on a limited scale in the tidal nonsaline subecosystem of Bangladesh, neither was suitable, producing less than 4 t/ha. Single transplanted aman (T. aman) rice is grown in a major portion of this subecosystem. Traditional varieties (TVs) are often grown but their yields are generally low. To increase the productivity of this subecosystem, a new rice variety, BRRI dhan44, was released in 2005. Before its release, BRRI conducted multilocation trials mainly in the tidal nonsaline subecosystem. After the release, the WAVE Foundation, an NGO, made an effort to validate the variety in adjacent nontidal northern areas. Validation experiments revealed that BRRI dhan44 was a promising variety with a yield potential of 5–6 t/ha, which is significantly higher than the yields of popular TVs and MVs currently grown in the region. In addition, the taller (130 cm) nonlodging plant type of BRRI dhan44 is suitable for adoption over ranges of

tidal flooding depths. Its bold grains are preferred in the region; thus, its market price is on a par with that of popular TVs but about 10% higher than that of MVs. Its bold grain type is also good for value addition by making quality *cheera* (flat rice) and *muri* (pop rice).

Technical details

The tidal nonsaline area covers about 1.9 million ha in the southern districts of Bangladesh. The area is characterized by inundation, with tidal surge up to 100 cm twice daily from April to October. T. aman rice is the main crop in this area. Farmers mostly follow traditional practices in the absence of appropriate modern technologies. Currently, MVs cover about 27% of the rice area in this region but their yield performance is not satisfactory, less than 4 t/ha. The major reasons for limited adoption of MVs are semidwarf plant type, lack of submergence tolerance, finer rice grains, and low market price. So far, MVs released in Bangladesh have not fit well in the diverse agroecological conditions of tidal flood-prone areas. A tall, nonlodging or submergence-tolerant plant type is needed for this area. Farmers in the coastal areas prefer bold grains. Considering agroecological conditions and preference of local communities, BRRI developed BRRI dhan44 by crossing BRRI dhan30 and BRRI dhan31.

Characteristics of the genotype

The plant height of BRRI dhan44 can reach 130 cm (Fig. 1), which may vary with water depth. Growth duration during the T. aman season is about 135–140 days. Grains are bold, with 1,000-grain weight of 29–30 g, length of 5.6 mm, and width of 2.6 mm. Its yield potential in farmers' fields is 5–6 t/ha. Farming communities in the Barisal region and northern part of the Khulna region where validation experiments were conducted preferred this variety for its taller but nonlodging plant type, higher yield, and bold and shiny golden grains. BRRI dhan44 is also moderately resistant to rice tungro virus disease. Its grains contain 10.1% protein and 26.6% amylose. Positive characters of BRRI dhan44 compared with locally grown other MVs reported by farmers from tidal nonsaline areas of the Barisal region and nontidal areas of the northern Khulna region (Chuadanga District) of Bangladesh are

- High vigor—vigorous growth, high tillering
- Vigorous and rapid recovery from insect damage
- Long, wide, and deep green flag leaf
- Very late or no senescence of leaves at maturity
- Tall, nonlodging plant type suitable for a wide range of tidal depths

Fig. 1. Partial view of a field with BRRI dhan44 in the Barisal region.

- Submergence tolerance in seedbed as well as in field
- Less nitrogen required
- Large panicles with more filled grains
- Higher yield
- Shiny golden bold grains
- Good eating quality and higher market price

Seeding and transplanting

Follow standard management practices in raising good-quality seedlings. Good-quality seeds and nutrient management in the seedbed are critical for raising good-quality seedlings. Mid-June to the end of June is the appropriate seeding time of BRRI dhan44. Transplant 35- to 40-day-old seedlings during July to mid-August. Transplant 2–3 seedlings per hill at 20 × 15-cm spacing between rows and hills.

Nutrient management

Apply fertilizers at the recommended rate of 70-20-35-10-4 kg N, P, K, S, and Zn per ha. Apply all the fertilizers except nitrogen as basal. Nitrogen management may be difficult because of tides. Nitrogen is recommended to be topdressed in three equal splits at around 15, 30, and 45 DAT (days after transplanting), preferably during the low-tide period when water does not overflow the bunds.

Weed and insect pest management

Manual weeding two times is necessary to keep crops weed-free till 30–40 DAT. Use an integrated pest management approach for insect pest and disease management. Do not use pesticides unless this is absolutely necessary.

Table 1. Grain yield and growth duration of different transplanted aman rice varieties in tidal nonsaline and adjacent nontidal northern areas of Barisal and Khulna regions of Bangladesh.

Environment/region	Variety	Grain yield (t/ha)	Growth duration (days)
Tidal nonsaline and nontidal adjacent districts of Barisal and Khulna regions (n = 18)	TVs (Moulata, Sadamota)	2.31	161
	BR11	3.56	144
	BRRI dhan31	3.47	138
	BRRI dhan44	5.11	143
Nontidal northern areas of Khulna region; Chuadanga District (n = 32)	BR11	4.20	–
	Lal Swarna	4.50	–
	BRRI dhan44	5.28	–

Irrigation

Irrigation is not required for this variety when grown in the T. aman season in tidal nonsaline areas. However, in highland conditions and in the nontidal adjacent northern area, supplementary irrigation may be needed, especially during panicle initiation and grain-filling stages.

Yield performance

Grain yields of BRRI dhan44 are significantly higher than those of popular TVs and adopted MVs in both regions—tidal nonsaline areas and nontidal adjacent northern areas (Table 1). In the tidal nonsaline areas of the Barisal region, BRRI dhan44 can outyield BR11 and BRRI dhan31 by more than 40%, and more than double the yield of popular TVs such as Moulata and Sadamota. Growth duration of BRRI dhan44 is about 3 weeks less than that of the most popular TVs but similar to that of BR11 and BRRI dhan31. In nontidal northern areas of the Khulna region (Chuadanga District), BRRI dhan44 can outyield the most commonly grown varieties such as BR11 and Lal Swarna (an Indian variety) by about 20–25% in grain.

An on-farm trial at Bakergonj in the Barisal region also revealed that BRRI dhan44 can substantially increase (1.3 t/ha or 20%) annual rice production of the transplanted *aus* (pre-wet-season rice)–T. aman system if adopted in the aman season.

Alternatives

So far, there is no better alternative to BRRI dhan44 for increasing rice production in the tidal nonsaline subecosystem and adjacent northern area of Bangladesh.

Expected impact

Household level

The grain quality of BRRI dhan44 is similar to that of local popular varieties such as Moulata, Sadamota, Lalmota, etc. Thus, its market price is also similar to that of local varieties but about 10% higher than that of other MVs grown in the region (Fig. 2). Adoption of BRRI dhan44 will improve farmers' household food security due to additional production, and also increase farmers' income due to a higher market price.

An economic analysis based on similar and standard management practices and cost of production for all varieties indicated that adoption of BRRI dhan44 will have a significant economic advantage over BR11 and BRRI dhan31 as well as TVs. Net

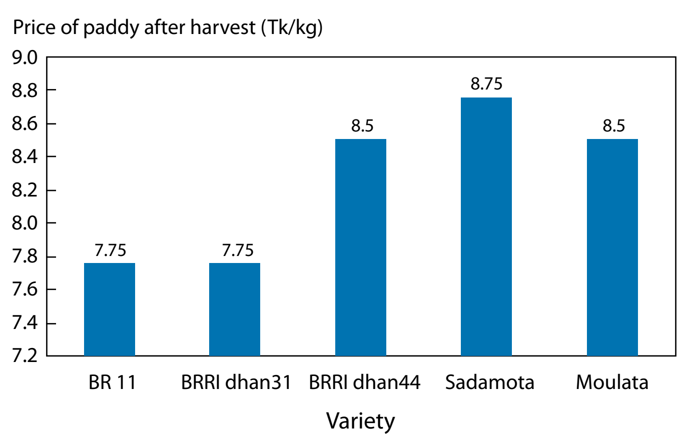

Fig. 2. Average price of T. aman paddy after the harvest in the Barisal region.

Table 2. Comparative economic analysis of BRRI dhan44, BR11, BRRI dhan31, and popular traditional varieties in the tidal nonsaline ecosystem of the Barisal region, Bangladesh.

Attribute	BRRI dhan44	BR11	BRRI dhan31	Traditional varieties
Paddy yield (t/ha)	5.11	3.56	3.47	2.31
Price (Tk/t)	8,500	7,750	7,750	8,625
Gross return (Tk/ha)	44,780	29,390	28,940	22,630
Gross cost (Tk/ha)	15,750	15,750	15,750	14,300
Net return (Tk/ha)	29,000	13,600	13,100	8,300
BC ratio[a]	1.84	0.86	0.83	0.58

[a]BC = benefit-cost.

Table 3. Potential area for cultivation of BRRI dhan44 in the Barisal region of Bangladesh.

District	Area (ha)			
	HL[a]	MHL-1	MHL-2	Total
Barisal	2,000	26,000	7,093	35,093
Bhola	14,988	42,768	20,000	77,756
Patuakhali	232	77,300	40,000	117,532
Barguna	33,400	35,000	35,000	103,400
Jhalkathi	1,600	17,710	14,000	33,310
Porojpur	–	24,850	15,000	39,850
Total	**52,220**	**223,628**	**131,093**	**406,941**

[a]HL = highlands, MHL = medium highlands.

returns were estimated at Tk 29,000/ha ($410) for BRRI dhan44, Tk 13,600 ($190) for BR11 and BRRI dhan31, and Tk 8,300 ($120) per ha for popular TVs (Table 2). On average, BRRI dhan44 will have an additional benefit of Tk 16,000 ($230) per ha over MVs and Tk 21,000 ($300) per ha over TVs.

National level

The greater Barisal region has about 407,000 ha suitable for BRRI dhan44 cultivation (Table 3), of which 27% or 110,000 ha are under MVs such as BR11 and BRRI dhan31 and the rest, 297,000 ha, under TVs. A shift from these MVs to BRRI dhan44 would result in 175,000 tons of additional paddy production worth Tk 1.5 billon or $21.3 million (Tk 8.5/kg paddy, $1 = Tk 70). In addition, if BRRI dhan44 were adopted on about 50% of the suitable area currently under TVs, the additional production would be 415,800 tons, worth Tk 3.53 billion ($50.5 million). The combined benefits of the adoption of BRRI dhan44 in tidal nonsaline areas and adjacent nontidal northern districts of the Barisal and Khulna regions would be enormous.

Constraints to adoption

Availability of BRRI dhan44 seeds and side-by-side weak promotion efforts are the major constraints to its rapid adoption in the target areas, the Barisal and Khulna regions.

Validation status

BRRI validated the performance of BRRI dhan44 along with a standard check at 12 locations in the Barisal region, at four locations in the Dhaka region, and at one location in both Khulna and Rajshahi regions involving 99 farmers in 2001 and 101 farmers in 2002. In 2005, the WAVE Foundation attempted validation and up-scaling of the variety in Chuadanga District in the Khulna region by providing farmers with training on quality seed production and storage, and 1.0 kg of each kind of seed to 32

Fig. 3. A farmer of Chauadanga District of Bangladesh is receiving 1 kg of BRRI dhan44 seeds after training from the WAVE Foundation and IRRI personnel.

selected farmers in four villages (Fig. 3). All 32 farmers grew BRRI dhan44, covering 7 ha in total. Its good performance generated interest and demand for BRRI dhan44 seeds. On average, each farmer kept about 18 kg of his produced BRRI dhan44 seeds for his own use in the next aman season and sold about 48 kg to other farmers. In addition, the WAVE Foundation also procured 3.1 tons of seed from the farmers, which was sold before the 2006 aman season to 146 farmers in four upazillas of the district. Thirty-two kg of BRRI dhan44 seed were given to 32 farmers in 2005, multiplied by many fold, and more than 5,200 kg of seed were used in the 2006 aman season by several hundred farmers of at least 50 villages.

Conclusions

BRRI dhan44 is a promising variety in tidal nonsaline areas of Barisal and Khulna regions for replacing currently popular TVs as well as MVs grown in the area such as BR11 and BRRI dhan31. It has the potential of producing 5.11 t/ha in this subecosystem, which was 44–47% and 121% higher than BR11 and BRRI dhan31, and TVs, respectively. BRRI dhan44 was also suitable in nontidal areas of the Khulna region, where it produced 5.28 t/ha, 20–25% higher than popular MVs such as BR11 and Indian variety Lal Swarna. In both cases, farmers preferred its grain quality, which was on a par with that of the TVs. Thus, its market price is similar to that of TVs, but about 10% higher than that of BR11 and BRRI dhan31. Because of higher yields and market price, one can derive additional benefit of about Tk 15,660 ($220) per ha over MVs and Tk 20,700 ($300) per ha over TVs by adopting BRRI dhan44. The benefits to the nation of its large-scale adoption would be enormous. However, seed scarcity and inappropriate promotion efforts are limiting its rapid adoption.

C. Additional Information

Date of release

February 2007

Resource persons on the technology

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Rice variety Durga for the semideep and deepwater ecosystems of Orissa, India

A. Introductory Section

Source of the technology:	Central Rice Research Institute, Cuttack, India
Source of funding:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Increase rice yield, household food security, and farm income
Crops and enterprises:	Rice
Agroecological zones:	Coastal plains and western-central tableland zones of Orissa, India
Targeted country:	India
Key words:	Durga, rice variety, yield, flood-prone ecosystems

B. Main Text

Summary

The semideep (up to 60 cm) and deepwater (up to 100 cm) ecosystems cover about 500,000 hectares in Orissa State of India. This environment is characterized by waterlogging, submergence, and flash floods during the wet season. Direct-seeded rice is the main crop in these areas. Rice-fallow, rice-mungbean, and rice-rice are the main cropping systems. Farmers grow traditional rice varieties with traditional management practices in the absence of appropriate technologies. The main reason for coverage of traditional varieties is the nonavailability of suitable MVs for these unfavorable hydrological conditions. In 2000, the Central Rice Research Institute (CRRI) at Cuttack, Orissa, released variety Durga to replace traditional kharif (wet season) rice varieties in the semideep and deepwater ecosystems for higher production. Durga plants are semitall with submergence tolerance, produce medium slender grains, and have higher yield potential. Efforts were made to validate the performance of Durga in semideep and deepwater ecosystems of Orissa through farmer participatory and farmer-managed experiments.

Fig. 1. Durga at the ripening stage in Orissa, India.

Technical details

Durga was developed by CRRI by crossing Pankaj and CR-1014. Semitall (125–135 cm) and stout plants of Durga are suitable for large areas of the semideep and deepwater ecosystems of Orissa. It performs well if the maximum water depth remains below 100 cm and can produce as much as 4.5 t/ha (Fig. 1). Farmers prefer its medium slender grains.

Characteristics of the genotype

Durga is a semitall photosensitive variety that flowers during the second week of November. Its medium slender grains are suitable for watery rice (cooked rice water soaked overnight), which state residents consume as breakfast. Durga possesses kneeing ability and is tolerant of bacterial leaf blight, rice tungro virus, blast, and brown planthopper. It responds to low amounts of nitrogenous fertilizers. The crop can be established by direct dry seeding in lines or by broadcasting, or by transplanting seedlings. Durga is also suitable for late planting up to the first week of September by using 50–60-day-old seedlings.

Seed selection and seed rate

Use good-quality, healthy, and clean seeds. Chaffy and immature seeds can be separated and removed from good ones as follows:

- Prepare a salt solution of 1.06 specific gravity by dissolving 60 grams of common salt in 1 liter of water.
- Pour the seeds into the salt water and remove all the floating material.
- Wash the remaining seed with fresh water, then dry and use for sowing.

The seed rate is 40 kg/ha for transplanting at 20 × 20 spacing, 80 kg/ha for direct seeding in lines that are 20 cm apart, and 100 kg/ha for broadcasting.

Land preparation and time of seeding

Plow the field two to three times at appropriate moisture to get a fine tilth for direct dry seeding. Use a rotavator, if required, to obtain fine tilth for uniform germination and seedling emergence. Mid-May to the first week of June is the optimum period for direct dry seeding. The field needs to be puddled and leveled for transplanting of seedlings. The optimum time for transplanting is the first week of July.

Nutrient management

Apply well-decomposed farmyard manure at 5 t/ha during final land preparation. Use 40-20-20 kg of NPK per ha. Apply entire P and 50% of N and K fertilizers at final land preparation and 25% N after *beushening* (plowing of field with rice seedlings in 15–20 cm of standing water for weed control and uniform distribution of rice seedlings) in the broadcast crop, if field water conditions permit. Otherwise, the rest of the N and K fertilizers can be applied at panicle initiation stage, if water conditions in the field permit.

Weed management

It is important to keep weeds under control until flooding. Weed management in line-sown and transplanted crops is relatively easier than in broadcast crops. Weeds in line-sown and transplanted fields can be controlled by using a finger weeder or manual weeding. However, *beushening* can be done in broadcast fields if there is some standing water in the field. The chance of flooding is high from the second week of July to the second week of September. If flood occurs and the crop survives the flooding, gaps should be filled by aged seedlings or splitting the surviving plants or hills.

Cropping system

After harvest of Durga in December, mungbean, watermelon, or sesame can be grown under residual soil moisture or under limited irrigated conditions.

Alternatives

The earlier released variety Panidan is an alternative to Durga. However, Durga has several advantages over Panidan. It can tolerate more waterlogging and submergence and can be grown up to 100-cm water depth and thus has wider adaptability over Panidan. It can withstand 10 days of complete submergence, and possesses elongation and kneeing ability, that is, if plants lodge after the water recedes from the field, the plants keep the panicles upright by kneeing on the surface. Durga has a yield advantage of about 0.5 t/ha over Panidan.

Fig. 2. After floodwater receded, the traditional variety lodged (in the foreground) while Durga was still standing at the ripening stage in the plot behind.

Expected impact

In validation trials, grain yield of Durga averaged 3.77 t/ha, which is about 111% higher than that of traditional varieties (Table 1). Cultivation of Durga requires about Rs 2,000 per ha additional cost but ultimately farmers get net benefit of about Rs 8,300 per ha against Rs 1,000 per ha only from traditional varieties. Despite higher yields, genetic traits such as semitall plant type, elongating ability, and submergence tolerance increase its chances of survival in flooding that affects traditional varieties severely. In 2004, the study areas were inundated by flood for 6 days in mid-August and 10 days in early September, yet Durga survived and yielded much higher than the traditional varieties. Adoption of Durga contributes to household food security and brings additional income (livelihood).

An estimated area of 500,000 ha is suitable for cultivation of Durga in Orissa. The districts where such ecosystems exist are Balasore, Bhadrak, Jajpur, Kendrapara, Jagatsinghpur, Cuttack, Puri, Sonepur, and Sambalpur. Even if Durga were adopted on only 30% of the potential area to replace local varieties, it would produce about 300,000 tons of additional rice worth 150 million rupees ($3.4 million).

Constraints to adoption

The lack of availability of good-quality seeds and lack of promotion activities are the major constraints to up-scaling Durga.

Validation status

The superiority of Durga over existing traditional varieties was validated by about 200 farmers of 10 villages over three successive kharif seasons starting in 2004. In spite of its more than 100% higher yield and 85% additional economic benefits over traditional cultivars, adoption of Durga beyond the study locations is very low mainly because of the weak research and extension linkage, lack of promotion efforts, and unavailability of seeds. The development of strong linkage between research and extension in the state and a seed production program by the state seed corporation and promotion by the Department of Agriculture and other agencies involved in agricultural and rural development are important.

Conclusions

Durga is a superior variety for fragile flood-prone semideep and deepwater situations, where flood water does not exceed 100 cm. Validation trials in 10 villages involving about 200 farmers over three successive seasons demonstrated that it can produce more than 100% yield, and provide about 85% higher benefits than the existing traditional rice varieties. Weak linkage between research and extension, the lack of appropriate promotion efforts, and unavailability of seeds are the major constraints to its up-scaling beyond the study locations.

Table 1. Average yield and economics of variety Durga (2004-06 wet seasons).

Attribute	Local variety	Durga	Difference over traditional variety
Grain yield (t/ha)	1.79	3.77	1.98 (111%)
Straw yield (t/ha)	5.00	6.67	1.67 (33%)
Cost of cult. (Rs/ha)	10,133	12,133	–2,000 (20%)
Gross returns (Rs/ha)	11,093	20,452	9,359 (84%)
Net returns (Rs/ha)	960	8,318	7,358 (766%)
Benefit-cost ratio	1.09	1.69	0.60

C. Additional Information

Date of release

March 2007

Sources of additional information

Chaudhary D. 2001. Durga: a high-yielding rice variety for waterlogged and deepwater rice areas of coastal Orissa. CRRI Technology Bulletin No. 3. Central Rice Research Institute, Cuttack, Orissa, India.

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Joymati, Jyotiprasad, and Kanaklata: promising *boro* rice varieties for Assam, India

A. Introductory Section

***Sources of technology*:**	Assam Agricultural University, Jorhat, India
***Sources of funding*:**	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Medium-long-duration *boro* rice varieties escape flood, increase production, and improve food security
***Crop and enterprises*:**	*Boro* rice
***Agroecological zones*:**	Flood-prone *boro* rice areas of Assam, India
***Targeted countries*:**	Assam and West Bengal states of India
***Key words*:**	*Boro* rice variety, Joymoti, Jyotiprasad, Kanaklata, medium-long duration, escape early flood

B. Main Text

Summary

Bao (deepwater rice)–fallow, and *bao-boro* (dry-season) rice are the dominant cropping systems in the flood-prone environments of Assam. In the boro season, farmers generally grow either low-yielding traditional boro rice varieties, which yield between 1.5 and 2.0 t/ha, or some long-duration high-yielding rice varieties (MVs) such as Mahsuri (190–200 days), No. 9 (200–210 days), and Jai Bangla (180–190 days), and *sali* varieties such as Lachit (180–190 days) and Luit (170–180), among others. The long-duration MVs are not suitable in flood-prone areas. Thus, maturing boro rice is frequently damaged by early floods in May. To escape early flood damage, the Assam Agricultural University (AAU) has developed three medium-long-duration (160–170 days) MVs that were validated at three locations by farmers during three successive boro seasons, starting in 2004-05.

Technical details

The performance of three high-yielding MVs (Joymoti, Jyotiprasad, and Kanaklata) in flood-prone environments in the boro season was validated by farmers in three villages—Disangmukh in Sibsagar District, Ganakabari in Jorhat District, and Joraguri in Golaghat District.

Seeds were sown in nurseries in November-December. About 30 35-day-old seedlings were transplanted in December-January at 20 × 20-cm spacing. Weeds were controlled by 2–3 manual weedings. Irrigation was provided to 5 cm of standing water 3 days after the disappearance of ponded water. Standard recommended rates of fertilizer (60-15-25 kg NPK per ha) were used. One-third of N and all of P and K were applied as basal at the last puddling. The rest of the N fertilizer was applied in two equal splits as topdressing at 30 and 75 days after transplanting (DAT). Need-based application of pesticides was adopted.

Expected impact

On average, the test varieties produced 1.56 t/ha or 44% more grain yield than the existing boro varieties (Table 1). The highest yielder, Kanaklata, produced slightly higher yield than Joymoti and 0.27 t/ha higher yield than Jyotiprasad. However, variations in yield between villages were significant (0.84–1.18 t/ha). Growth duration of the test varieties was 30–40 days shorter than that of current varieties, creating chances of escaping early floods in May.

The three tested boro rice varieties yielded on average 44% more than the current varieties. In Assam, boro rice is grown on about 310,000 ha, and yields on average about 2.93 t/ha (1.96 t/ha of clean rice). If these varieties replace current varieties on 50% of boro rice area, this will result in additional production of 200,000 tons, worth Rs 1,600 million (US$37 million) per year.

Alternatives

The introduction of AAU-developed medium-long-duration modern boro varieties has shown a 44% yield advantage over farmers' varieties. The most important advantage of the test varieties is that they mature about 30–40 days before most of the farmers' varieties. Adoption of these varieties in flood-prone areas not only increases yield but also reduces the chance of crop damage by early flood in May. Because of shorter growth duration, farmers will have a longer turnaround time for the next sali rice crop.

Constraints to adoption

An appropriate statewide scaling-up program for these varieties has not yet been put in place. Linkage between research and extension in the state is weak. The lack of availability of seeds is a major constraint. Because of higher fuel prices, the cost of boro rice production is high. Unlike traditional varieties, the short seedlings of modern boro varieties limit adoption in some fields.

Validation status

These three boro MVs were evaluated over several seasons in different research stations of AAU. Validation was concentrated in farmers' fields in three villages in three successive seasons. In total, 56, 112, and 115 farmers participated in the 2004-05, 2005-06, and 2006-07 boro seasons, covering about 66, 143, and 133 hectares, respectively (Fig. 1). In the test villages, about 30% of the boro rice area is covered by these three varieties. Among them, Kanaklata gained the most popularity, covering about

Table 1. Grain yield of modern boro rice varieties and a farmers' variety in the boro season in 2004-05 and 2005-06 in Assam, India.

Village	Grain yield (t/ha)				
	Joymoti	Jyotiprasad	Kanaklata	Average of MVs	Farmers' variety
Disangmukh	4.70	4.45	4.70	4.62	Lachit: 1.90 No. 9: 4.20
Ganakabari	5.00	4.65	5.24	4.96	Luit: 2.20 No. 9: 4.30
Joraguri	5.80	5.85	5.75	5.80	No. 9: 4.30 Biplab: 4.50
Average	5.17	4.98	5.25	5.13	3.57
Growth duration (days)	170	160	170		200

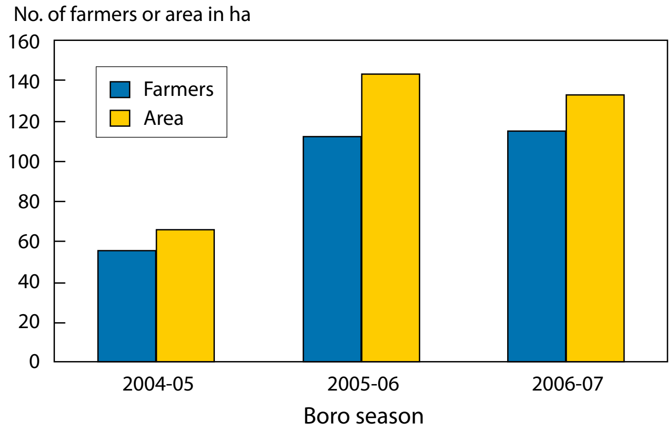

Fig. 1. Adoption of modern boro rice varieties Kanaklata, Jyotiprasad, and Joymoti in three villages over three seasons in Assam, India.

60% of the 30% boro area under these three MVs; the remaining 40% area is almost equally shared by Joymoti and Jyotiprasad.

Conclusions

Low yields of sali rice, frequent flood damage, and small landholdings are the main reasons for poverty and food insecurity among the rural population in the flood-prone areas of Assam, India. The introduction of boro rice has created high potential for increasing rice production and improving livelihoods. In most areas, appropriate modern boro varieties have not reached farmers. The use of sali and unknown varieties (probably from Bangladesh) is common. These varieties are long-duration ones, taking about 180–200 days for maturity, which sometimes damages them at ripening because of early floods in May. Medium-long-duration varieties Kanaklata, Jyotiprasad, and Joymoti developed by AAU have higher yield potential than most of the current varieties and can escape flood. A validation trial in three villages over three seasons confirmed the superiority of these varieties over the farmers' varieties. However, an appropriate program for dissemination of these varieties is missing, mainly because of the weak linkage between research and extension systems. The production of good-quality seeds, an appropriate scaling-up program, and good and effective linkage between research and extension are vital for improving the rural livelihood of flood-prone areas in Assam.

C. Additional Information

Date of release

March 2007

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Quality protein maize (QPM) hybrids for higher income and better nutrition

A. Introductory Section

Source of technology:	Rajendra Agricultural University, Bihar, India
Source of funding:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project project
Expected benefits:	Increasing farmers' profit and improving household nutrition
Crop and enterprises:	Maize and potato
Agroecological zones:	From temperate hill zones to semiarid and humid zones of India
Target states/countries:	Indian states of Gujarat, Rajasthan, Utter Pradesh, Bihar, Andhra Pradesh, and Karnataka
Key words:	Quality protein maize hybrids, variety, yield, nutrition, protein, intercropping, potato

B. Main Text

Summary

In Bihar (India), maize is the third most important crop after wheat and rice. It is a high-yielding cereal crop and its grains contain higher levels of nutrition than most other cereals. It is grown year-round in three seasons, of which production is highest in the *rabi* (winter) season. The Rajendra Agricultural University at Pusa in Bihar developed composite varieties of quality protein maize (QPM). In fact, cultivation of maize in Bihar became more popular with the development and release of higher yielding hybrids and QPM. The performance of QPM hybrid varieties such as Shaktiman-1, Shaktiman-2, Shaktiman-3, and Shaktiman-4 as a sole crop and as a component crop in cropping systems was validated in two villages through participatory farmer-managed experiments.

Technology details

Among the cereal crops, maize is higher yielding and more efficient in using residual moisture in rainfed environments such as Bihar than rice and wheat. Maize is a multipurpose crop. Mature grains or flour are used for food, starch production, oil extraction, etc. Baby corn is used for salad, soup, and *kheer* (sweet dessert) preparations and as a vegetable. Besides human consumption, it is also used as feed and fodder. The recent phenomenal growth of the poultry industry in South Asia is largely dependent on maize as a source of carbohydrate. Among the Indian states, Bihar ranks fifth in maize area and second in production, with an average productivity of 2.41 t/ha. In Bihar, maize is grown in three seasons: *kharif* (monsoon), *rabi* (winter), and *prekharif* (summer). The yield of rabi maize (3.15 t/ha) is highest, followed by summer maize (2.39 t/ha) and kharif maize (1.68 t/ha). QPM is a new crop in Bihar. QPM hybrids have higher yield potential and more diverse use than normal maize hybrids and local cultivars. QPM grains contain more protein, vitamins, fats, and phosphorus than most other cereal crops.

Fig. 1. QPM hybrid field in North Bihar, India.

Quality protein maize (QPM)

QPM varieties: Shaktiman-1, Shaktiman-2, Shaktiman-3, and Shaktiman-4 (Figs. 1 and 2).

Land preparation: One deep plowing by a soil-turning moldboard plow, followed by two cross plowings by a disc or *deshi* (local) plow are enough for the maize crop.

Sowing time: The rabi season (mid-October to mid-November) is the best time for sowing in Bihar. For intercropping of maize into potato, maize can be sown 2 weeks after the planting of potato.

Seed rate: The seed rate for QPM is 20 kg/ha.

Pest management: Apply 5% chlorpyriphos dust (insecticide) at 25 kg/ha at final plowing. Treat seeds before planting with thiram at 2 g/kg of seed.

Spacing: Row-to-row and plant-to-plant spacing of QPM should be 60 and 20 cm, respectively.

Manure and fertilizer management: The recommended rate of fertilizer use in maize is 120-60-40 kg/ha NPK and zinc sulphate at 25 kg/ha. Apply all P, K, and Zn, and one-third of N and well-rotted farmyard manure or compost at 1.0 t/ha at the time of final plowing. Apply the remaining N in two equal splits at 35 days after sowing and at the time of silking.

Weed management and intercultural operations: When the crop is about 15 cm high, weeds should be controlled by using either a hand-held weeding device (*khurpi)* or a 5-tire cultivator. Alternately, herbicide atrazine or atrataf can be used at 2.5 kg in 1,000 liters of water per ha applied as preemergence spray.

Irrigation: Rabi maize cultivation depends on irrigation. Generally, presowing irrigation is not required as residual moisture is sufficient for germination and initial growth. Usually, three to four irrigations are required during the season. If the crop is sown later, more irrigations will be needed. It is important to have sufficient moisture from tassling to silking and in grain-filling stages, otherwise yield will decline drastically.

Harvesting: Maturity of QPM is assessed when the husk turns gray. The mature cobs should be plucked and dehusked, dried under sun, and shelled with a maize sheller.

Yield: As a sole crop, QPM hybrids produce about 2.5 t/ha or 53% more grain than local maize varieties (Fig. 3). The potato + QPM hybrid intercropping system produced about 5.0 tons of maize and 14.3 tons of potato per ha. Although intercropping reduces maize yield by about 2.2 t/ha or 31%, system productivity increases greatly.

Intercropping: Rabi maize can be successfully intercropped with potato, radish, rajmash, pea, and tobacco. Intercropping with potato is the most popular in north Bihar (Fig. 4). In the intercropping system, after the harvest of potato in January-February, it is important to topdress nitrogen fertilizer, do earthing-up, and apply irrigation for better yield.

Fig. 2. QPM hybrid variety Shaktiman-1 (white) and Shaktiman-3 (yellow) cobs.

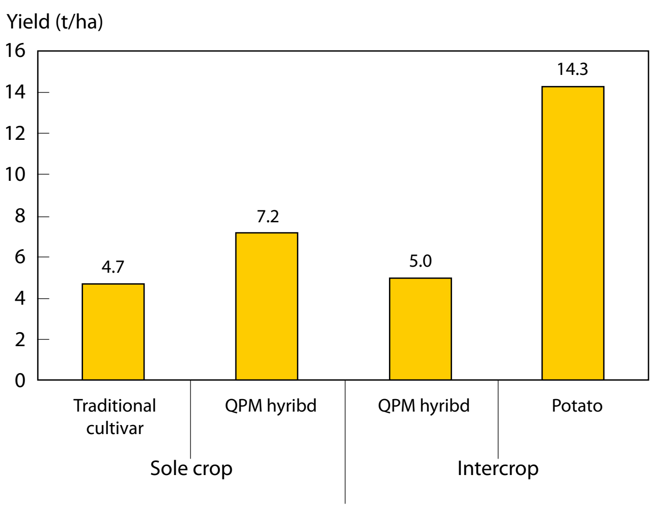

Fig. 3. Yield of traditional cultivar and QPM hybrids and potato under the sole crop and intercrop system in Kalyanpur and Meenapur in North Bihar, India.

Validation status

QPM hybrids outperform existing traditional maize varieties as a sole crop and as a component crop in the potato + maize followed by rice system. Because of better taste and protein quality, farmers are getting a higher market price for QPM than for their local cultivars. QPM hybrids have much higher yield potential than existing cultivars. As a result, cultivation of QPM has gained popularity but seed limitations appear to be a major constraint for scaling up its adoption. In addition, maize intercropping with potato is a unique system through which farmers can derive significant economic benefit, and this system gained popularity in the area. However, the use of QPM hybrids in the

Fig. 4. Intercropping of a QPM hybrid with potato in North Bihar, India.

Constraints to adoption

The unavailability of QPM hybrid seeds is a major constraint to adoption. Since the production of quality hybrid seeds requires technical expertise, the seed-growing process at the farmers' level is difficult. However, efforts are being made to organize innovative farmers to involve them in the seed production process under the technical guidance of the university.

maize + potato followed by rice system remains limited because of the limited QPM hybrid seed production capacity of RAU.

Conclusions

With the introduction of QPM hybrids along with suitable varieties of potato, farmers in the project areas are being benefited significantly through intercropping of maize with potato. A significant increase in the yield of both crops has given an attractive boost to farmers' income. The strength of the intervention can be judged from the rapid growth of QPM hybrids and maize intercropping with potato. However, immediate initiatives are needed to increase QPM hybrid seed production for scaling up of these technologies beyond the study sites.

C. Additional Information

Date of release

January 2007

Sources of additional information

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Crop Establishment Methods

Rice crop establishment using a drum seeder for direct wet seeding

A. Introductory Section

Technology source:	International Rice Research Institute (IRRI) and Bangladesh Rice Research Institute (BRRI)
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634)
Expected benefits:	Reduced labor cost and higher grain yield and income
Crops and enterprises:	Rice
Agroecological zones:	Flood-prone and flood-free areas of Bangladesh
Domain of potential application:	Bangladesh, India, and Vietnam
Key words:	Rice establishment, direct wet seeding, drum seeder, cost savings, higher yield

B. Main Text

Summary

Rice in Bangladesh is predominantly cultivated using transplanting, which involves raising, uprooting, and transplanting seedlings. This is a rather resource- and cost-intensive method since preparing a seedbed, raising seedlings, and transplanting are labor- and time-intensive operations. The cost of rice production is increasing as a result of the increase in labor wages, and labor scarcity is common during peak agricultural operations such as planting and harvesting of rice.

In the boro (dry) season, ripening paddy is sometime submerged by flash floods in low-lying areas during April-May or damaged by hailstorms. Direct seeding using a drum seeder is one method of crop establishment that has potential to overcome this problem. To achieve the desired performance from direct wet-seeded rice (DWSR), seeding has to be done before a cutoff date in mid-December (much earlier than most transplanting) to avoid possible flash floods and hailstorms. Experiments conducted at a research farm and on-farm have very clearly demonstrated that, irrespective of rice varieties, DWSR using a drum seeder has a 10–15% yield advantage over conven-

tional transplanted rice (TPR). The absolute difference between DWSR and TPR yields was from 0.5 to 1.0 t/ha. The seed requirement for direct wet seeding using a drum seeder was only about 30 kg/ha, which is less than half of that normally used by farmers for transplanting. The technology has been tested vigorously under both on-station and on-farm conditions. Drum seeders are now manufactured in Bangladesh and they are in the mainstream of extension work in the country. DWSR currently covers about 20,000 hectares, and is increasing.

Technical details

The IRRI-designed drum seeder, improved by researchers and manufacturers in Vietnam, is a simple machine made of high-density plastic (Fig. 1). The plastic drum seeder can accommodate six to eight drums each having 16-cm diameter. Each drum has a pair of rows of holes (8–9 mm in diameter) on each side. It is suitable for seeding sprouted rice seeds in rows on well-prepared puddled soil directly in the field. Inside the drum, a device pushes the seeds toward the holes as the drum rotates. The machine with six drums weighs only about 6 kg when empty and is very easy to transport from one place to another. When loaded with pregerminated seeds, it weighs about 16–18 kg. Two people can sow rice in lines on 1 hectare of land per day (Figs. 2 and 3).

Fig. 2. Direct wet seeding using a drum seeder.

Fig. 3. Rice plants emerging in lines seeded by a drum seeder.

How to use a drum seeder

Direct wet-seeded rice using a drum seeder is a knowledge-intensive technology. Farmers must be trained before they apply the technology for achieving desired results. Some important tips follow.

Fig. 1. A Vietnamese-made plastic drum seeder and sprouted rice seeds for planting.

Seed preparation and seeding: Good-quality seeds should be used. Seeds should be dried and soaked for 24 hours, followed by incubation for 2–3 days depending on temperature. Well-sprouted seeds (with 4–5-mm radicles) can be sown by the drum seeder. Before loading them in the drums, the sprouted seeds should be lightly dried for 1–2 hours in a shady place. Two-thirds of the drum space should be filled by seeds. Two people can complete seeding of about 1 hectare per day.

Land preparation: The land must be well prepared and reach puddled conditions. All weeds and stubble should be decomposed. Particular attention has to be given to land leveling. This is crucial to direct wet seeding because standing water would result in seedling mortality and uneven crop establishment. Any standing water must therefore be drained out before sowing.

Water and fertilizer management: There is no need to apply irrigation up to 5 days after sowing. After that, water should be applied to keep the soil moist and water can be applied as the seedlings grow. However, 5–7 cm of standing water is enough for the growth of rice crops. The fertilizer requirement is that used for transplanted rice; however, the leaf color chart can be used for urea management.

Fig. 4. A happy farmer beside his crop. He planted more than one-half hectare using a drum seeder.

Weed management: Weeds are major constraints to DWSR using a drum seeder. Therefore, appropriate measures should be taken to control weeds in time. Appropriate land preparation should aim to reduce the weed seed bank, and weed and stubble decomposition is important. Right from seeding, DWSR faces intense competition from weeds. The initial surge of weeds has to be controlled, which is very difficult unless herbicides are applied. Until the development of better techniques, an initial surge of weeds can be controlled by applying herbicides (such as Ronstar) at 25–30 mL per 10 liters of water on 5 decimals of land at 7–10 days after seeding in the boro season and at 4–5 days after seeding in aus and aman seasons. There must be a thin film of water at the time of herbicide application. Inappropriate use of herbicides could result in seedling mortality. From mid-tillering onward, weeds can be controlled by a push weeder such as the “BRRI Weeder” or simply by hand weeding.

Alternatives

Manual broadcasting of sprouted seeds on well-puddled and drained fields can be an alternative to DWSR using a drum seeder. But, under broadcast situations, weed management will become more difficult.

Expected impact

Household impact

Direct wet-seeded rice has the advantage of producing significantly higher grain yield (0.5 to 1.0 t/ha), saving seeds by about 50%, and saving labor compared with transplanted rice. Seeding of 1 ha using a drum seeder needs only 2 people compared with 45 people needed for transplanting. Although additional costs are involved with weed management in DWSR, it is still more profitable than the traditional transplanting method. Economic analysis showed that DWSR brings about Tk 8,500 (US$130) per hectare more profit than TPR in both the aman and boro seasons (Tables 1 and 2).

Most farmers perceived that DWSR using a drum seeder is a cost-saving technology that also produces higher yields (Table 3). A majority of them also reported that weeds are the major constraint and a delay in irrigation water supply is an important

Table 1. Partial budget analysis for DWSR versus TPR methods under a single-crop production environment, during boro 2005 (n = 50).

Item	Debit (Tk/ha)	Item	Credit (Tk/ha)
Cost of rice production under DWSR	28,012	Return from rice production under DWSR	55,605
Revenue forgone for not following TPR	48,681	Cost saved for not practicing TPR	29,875
Profit/loss	+8,787		
Total	85,480		85,480

Table 2. Partial budget analysis for DWSR versus TPR during aman 2005 in Chuadanga (n = 30).

Item	Debit (Tk/ha)	Item	Credit (Tk/ha)
Cost of rice production under DWSR	20,673	Return from rice production under DWSR	43,234
Revenue forgone for not growing TPR	42,040	Costs saved for not growing TPR	27,865
Profit/loss	+8,386		
Total	71,099		71,099

Table 3. Advantages and disadvantages of using a drum seeder for direct wet-seeded rice, boro 2005, as perceived by farmers.

Advantages/disadvantages		% of farmers
Advantages	Cost-saving technology	100
	Promotes higher yield	76
	Requires less irrigation	3
	Low pest and disease infestation	3
	Easy for weeding by weeder	3
Disadvantages	High weed infestation	70
	Delay in irrigation water supply	40
	Essential to seed before winter	10
	Requires good land leveling	10
	Difficult in aman season due to frequent rain	100

constraint for DWSR. Almost all farmers reported that direct wet seeding in the aman season is difficult due to frequent rain at seeding. However, in spite of these constraints, adoption of DWSR is increasing. DWSR in the boro 2006 season covered 20,000 hectares.

Community impact

Labor scarcity at rice planting time is common in most areas. Adoption of a drum seeder on a wide scale is likely to improve the situation and surplus laborers could be used for rabi (non-rice) crop production and/or other rural activities. There is no possibility that adoption of DWSR using a drum seeder will cause large-scale rural unemployment.

Environmental impact

DWSR could increase herbicide use in rice, which might affect the environment. One application of herbicide at a low rate (70% of the recommended rate) is enough for controlling the initial surge of weeds in DWSR. So far, the use of herbicides in rice in Bangladesh is very low, and such applications at low rates will not greatly increase their use in the country. Moreover, the use of herbicides in DWSR is a temporary technique that could be discontinued if a better weed management package for DWSR is developed.

Constraints to adoption

Despite the clear superiority of DWSR to transplanted rice, adoption of the technology seems to be rather slow because of some technical and socioeconomic constraints:

1. Heavy rainfall immediately after seeding can wash away seeds, thereby causing a poor stand of aman rice.
2. Weed infestation is higher and is perhaps the major problem in DWSR, which discourages farmers.
3. The absence of community intervention to start using an irrigation system 30–40 days earlier than normal (for transplanted rice) often does not allow farmers to adopt DWSR.
4. Cold weather in the boro season may cause seedling mortality after sowing as we do not have cold-tolerant rice varieties.

While the risk of establishment during the rainy season is a genuine concern for the aman season, the remaining concerns could be overcome through appropriate measures. A community participatory approach can help provide a timely supply of irrigation water.

Validation status

The drum seeder was tested and validated during the boro and aman seasons of 2003-06 under both on-station and on-farm conditions in many areas of Bangladesh. An up-scaling program was undertaken by the Department of Agriculture Extension starting in the 2005 aman season. The technology has been tested by farmer groups in all 64 districts of Bangladesh and, so far, 20,000 hectares of land were covered in the 2006 boro season. Some farmers have started experimenting with the drum seeder in the aus season.

Conclusions

Direct wet-seeded rice using a drum seeder is an emerging technology that has the potential to increase rice production substantially, reduce seed demand, and reduce pressure on the labor market at critical times. In addition, early planting and harvesting rather than traditional transplanting aid in the timely establishment of subsequent crops and in avoiding unprecedented flash floods and hailstorms in the boro season. Farmers who switch to DWSR could earn an additional net income of about Tk 5,000–8,000 per ha. Adoption of DWSR technology is somewhat slow, mainly because of the knowledge-intensive nature of the technology. Proper training of farmers and extension agents is essential for rapid adoption. Development of a weed management package for DWSR and cold-tolerant boro varieties at the seedling and reproductive stage are crucial. So far, policy support for the incorporation of the technology in the mainstream of extension work and imports and local manufacturing of the drum seeder are encouraging. However, further policy support for a timely supply of irrigation water and training of farmers and extension agents will be needed.

Date of last release

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C. Additional References

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Direct wet seeding of rice using a plastic drum seeder for higher profit in West Bengal, India

A. Introductory Section

Technology source:	International Rice Research Institute (IRRI), Philippines, ad Rice Research Station (RRS), Chinsurah, West Bengal, India
Sources of funding:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefit:	Save labor and seeds, and increase grain yield and profit
Crops and enterprise:	Rice
Agroecological zones:	Irrigated or partially irrigated medium lands and lowlands
Domain of potential application:	West Bengal and other eastern Indian states
Key words:	Rice, direct wet seeding, plastic drum seeder, seed, labor, yield, and profit

B. Main Text

Summary

Rice occupies about 5.8 million hectares in West Bengal, of which approximately 2.0 million hectares (35%) are under full or partial irrigation, where two to three crops are grown. Rice production became less profitable because of rising input costs and little change in market price. The rice crop is established by transplanting seedlings grown in a nursery. Raising of rice seedlings and crop establishment through manual transplanting account for a significant portion of the total cost of production. Transplanting of rice seedlings on 1 ha requires about 50 person-days and availability of laborers at this peak activity period often becomes scarce. Timely rice crop establishment is very important for obtaining optimum yields and reducing chances of suffering from climatic hazards such as hail storms at ripening in the boro (dry) season and cyclones in the wet (aman) season.

Rice crop establishment by direct wet seeding on puddled soil using a plastic drum seeder (Fig. 1) is one of the methods of crop establishment that has potential to deal with these problems. Direct wet seeding of rice (DWSR) with a plastic drum

Fig. 1. The plastic drum seeder for direct wet seeding of rice.

seeder has been widely adopted in the Mekong Delta in South Vietnam as a seed-saving technology. Farmers' participatory on-farm trials conducted in West Bengal (India) as well as in Bangladesh in both the wet and dry seasons indicated that drum seeder technology has potential to save labor and seed, and increase yield and profit over the traditional practice of transplanting seedlings.

Technical details

The plastic drum seeder:
The IRRI-designed drum seeder, improved by researchers and manufacturers in Vietnam, is made of high-density plastic (Fig. 1). It is a simple tool with six plastic drums joined to a metal axle. Each drum is 16 cm in diameter with two rows of holes (8–9 mm in diameter) on each side of the drum. There is one row with a dense series of holes and one row with a sparse series of holes on each side of the drum. The drum seeder is used for seeding pregerminated (sprouted) rice seeds in rows or lines on puddled soil of the main field. The seeder weighs only 6 kg (when empty) and it is easy to carry and to use on puddled soil. It requires minimum power for operation—one person can easily pull the seeder with seeds on puddled fields using one hand.

Management practices

Seed preparation
Before seeding, seeds need to be pregerminated or sprouted (Fig. 2). Duration for sprouting depends on temperature. The usual practice is 24-hour soaking in water followed by 48–72 hours of incubation depending on the season. The sprout length should be less than 8 mm or shorter than the grain. Longer sprouts affect seed drop, resulting in poor stands.

Land preparation
Proper puddling, leveling, and draining of excess water, if any, from the field are prerequisites for successful seeding using a drum seeder. Seeding a day after final land preparation allows loose mud to settle, producing an ideal bed for seeding. Seeding within June for aman (kharif) rice and before mid-December for boro (dry season) rice is ideal.

Seeding
Sprouted seeds need to be air-dried under shade for an hour before filling in the drum. Seed requirement varies depending on

Fig. 2. Sprouted rice seeds and loading for direct wet seeding in lines using a drum seeder.

Fig. 3. Sprouted rice seeds planted in lines by using a plastic drum seeder.

Fig. 4. A direct wet seeded rice field in West Bengal, India.

which series of holes is used. Seeding through a dense series of holes requires about 40 kg/ha (or 5 kg per bigha, and 1 bigha = 33 decimals) and seeding through a sparse series of holes needs about 25 kg/ha (3 kg per bigha). The capacity of each drum is 2.0 kg and one-third of each drum should be kept empty to facilitate proper agitation required for seed drop. One series of holes on each side of each drum needs to be blocked by using masking tape or string. The seeder should be pulled by one person at a gentle steady pace with the triangle mark pointing forward (Fig. 3). From the second pass onward, one wheel should follow the wheel track of the previous pass. Wheel tracks remain visible (Fig. 4), which facilitates movement for interculture operations. Two persons seeding and helping in turn should be able to cover 1 hectare in a day.

Fertilizer management

Full doses of phosphate and potash fertilizers should be applied at the time of final land preparation. It is recommended to use the leaf color chart (LCC) for real-time N management, which recommends feeding the plant when needed to minimize excess use of fertilizer, losses, and environmental pollution. Start leaf color measurement using the LCC from 15 DAS in aman and 25 DAS in the boro season. If an LCC is not available, N fertilizer (urea) can be applied as topdressing in three splits as in Table 1.

Weed management

Weeds cause a major problem during the first few weeks after direct wet seeding. An integrated weed management approach needs to be adopted. The seed bank in the field can be reduced by staggered repeated tillage. Use of preemergence herbicide at 70% of the recommended rate at 3–4 DAS in aman and 7–8 DAS in the boro season is helpful. A thin film of water needs to be maintained for 3–4 days from herbicide application, and the water level can be increased later to suppress weed growth. Butachlor 50% and pendimethalin 30% are commonly used in DWSR. Afterward, weeds can be controlled by hand weeding or by using a hand weeder.

Insect pest and disease management

An integrated pest management (IPM) approach needs to be adopted for insect pest and disease management. If the area is prone to certain pests, resistant or tolerant varieties, if available, should be used. Rational application of N fertilizer should be adopted by using the LCC. Inorganic synthetic insecticide or fungicides should be avoided unless pest pressure is really high, approaching damaging status. Cultural practices such as draining of irrigation water or drying from time to time, the use of perches for predatory birds, and the rational use of N fertilizer and insecticides will help keep the pest population below economic injury level, in most cases.

Benefits of direct wet seeding

Grain yield advantage

The performance of DWSR compared with traditional transplanted rice was validated through farmers' participatory valida-

Table 1. Time and portion of N fertilizer dose recommended to apply as topdressing in rice in boro and aman seasons.

Season	1st topdressing[a] (1/4 of urea)	2nd topdressing (1/2 of urea)	3rd topdressing (1/4 of urea)
Aman (wet/kharif)	15 DAS	35 DAS	PI
Boro (dry)	20–25 DAS	50–55 DAS	PI

[a]DAS = days after seeding, PI = panicle initiation.

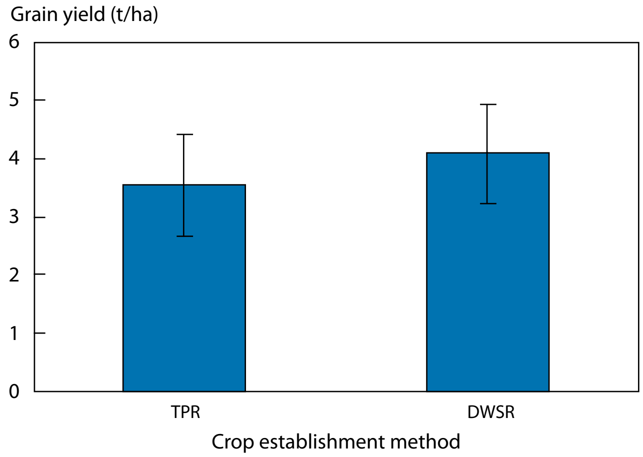

Fig. 5. Grain yield of transplanted rice (TPR) and direct wet-seeded rice (DWSR) in 2005 aman season (n = 5, bar indicates standard deviation).

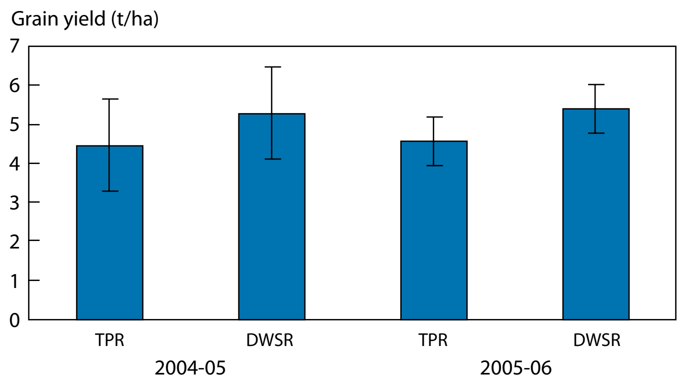

Fig. 6. Grain yield of transplanted (TPR) and direct wet-seeded rice (DWSR) in 2004-05 and 2005-06 boro rice in West Bengal, India (n = 7 and 9, bar indicates standard deviation).

tion experiments by five farmers in the 2004-05 aman season and by seven and nine farmers in the 2004-05 and 2005-06 boro seasons. In the aman season, grain yield of DWSR crops averaged 4.08 t/ha, which was 15% higher than that of corresponding transplanted rice (Fig. 5). Seed-to-seed growth duration of DWSR was about 9 days shorter but occupied main fields about 20 days more than transplanted crops.

In the 2004-05 boro season, TPR and DWSR yields averaged 4.46 t/ha and 5.29 t/ha and in 2005-06 4.58 t/ha and 5.41 t/ha (Fig. 6). In both cases, DWSR outyielded transplanted crops by about 830 kg/ha, which was 15–19%. This extra yield gave Rs 4,400 ($100) per ha extra return to farmers.

Cost savings

Cost of production data were collected from five participating farmers during the boro season. DWSR eliminated the seedling nursery and reduced the cost of seeds and labor, while weed control was more costly than in transplanted crops (Table 2). On average, the cost of production of DWSR was 23% or Rs 3,400/ha lower than that of the transplanted crop, mainly because of significant labor savings for crop establishment.

Alternatives

Transplanting of rice seedlings grown in a nursery is a traditional and common practice for the establishment of rice crops. Broadcasting of sprouted seeds in puddled fields can be an alternative to DWSR using a plastic drum seeder, which will save labor but require more seeds. Similar to DWSR using a plastic drum seeder, the broadcast crop will suffer severe weed problems at the early stage and weed management will be more difficult and expensive.

Table 2. Cost of production of rice under direct wet seeding and transplanting methods of crop establishment in boro season, West Bengal, 2005-06.[a]

Cost component	Transplanted crops		DWSR crops	
	Cost (Rs/ha)	Percent	Cost (Rs/ha)	Percent
Seedbed	150	1	0	0
Seeds	450	3	345	3
Land preparation	4,225	28	3,422	30
Fertilizer	2,250	15	2,570	22
Weeding	2,100	14	1,250	11
Pesticides	500	3	406	4
Labor	5,325	36	3,571	31
Total	15,000	100	11,564	101

[a]US$1 = Rs 45.

Expected impact

Adoption of DWSR technology using a plastic drum seeder was found to be superior in grain yield and seed and labor savings over the traditional method of transplanting. The Department of Agriculture of West Bengal, India, recommended this technology for intensively cropped areas, especially where boro rice is widely grown and where temporary labor shortages often delay rice establishment, thereby reducing grain yield and income. Adoption of this technology will increase rice production and reduce the cost of production, resulting in higher profit and leading to improved livelihoods of rice farmers.

Risk and constraints to adoption

Despite the superiority of DWSR using a plastic drum seeder over the transplanted method of crop establishment, adoption of the technology in West Bengal has been slow because of the following constraints:

Cold spells in early boro season: Severe cold spells can coincide with seeding in the boro season in December or early January, causing poor crop stand. This problem could be overcome by seeding before mid-December.

Heavy rain at seeding in the aman season: Well-puddled and leveled fields with mud settled without standing water are ideal for seeding using a drum seeder. Frequent rain at planting time of the aman season sometimes makes it difficult for direct wet seeding. Heavy rainfall immediately after seeding disrupts lines (rows), making weed control difficult.

Severe early weed infestation: Soon after planting, emerging rice plants face severe competition from weeds. Farmers are not used to and do not have knowledge of weed control at such an early crop stage, which may lead to replanting by transplanting of seedlings by some first-time adopters.

Timely availability of irrigation water: Irrigation water starts flowing through the canals from the end of December or early January. Seeding before mid-December in the boro season is crucial for optimum yields. Policy intervention for the early release of water is necessary for DWSR. Community adoption is necessary for the early release of canal water as well as efficient use of water.

Validation status

In West Bengal, a validation experiment began in 2004 on government farms as well as in farmers' fields through farmers' participatory demonstrations, NGOs and farmers' clubs, and farmers' cooperative societies. Plastic drum seeders were given to each district agricultural office. So far, about 200 drum seeders are in the field. The Department of Agriculture is promoting the technology. TV stations, All India Radio, and print media have covered the technology for promotion. In 2006, special efforts were made through the Department of Agriculture for a number of compact block demonstrations in three intensive rice-cropping districts—Nadia, Hooghly, and Burdwan. The state has also included this technology in the national front-line demonstration program since the wet season of 2006.

Conclusions

DWSR cropping using a plastic drum seeder produces 15–18% higher yield than that of transplanted rice in both aman and boro seasons and also saves seeds and labor, thus improving profit and livelihoods of rice farmers. Weed management from crop establishment to early tillering stage, heavy rain at seeding in the aman season, and severe cold soon after planting in the boro season affect crop stand and adoption. Because it is a knowledge-intensive technology, farmers' training and follow-up with frequent field visits at planting and in the early crop stage are essential for its success. A community approach should ensure its rapid adoption.

C. Additional Information

Date of TAN revision

December 2006

Sources of additional information

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Zero-tillage technology: a boon to wheat farmers

A. Introductory Section

Source of technology:	G.B. Pant University of Agriculture. and Technology, Pantnagar, Uttaranchal, India
Source of funding:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Increasing wheat yields and conserving soils
Crop and enterprises:	Wheat
Agroecological zones:	Semiarid to humid zones of India
Target states/countries:	Indian states of Punjab, Uttaranchal, Uttar Pradesh, Bihar, West Bengal, Andhra Pradesh, and Karnataka
Key words:	Zero tillage, seed drill, wheat, grain yield, resource conservation

B. Main Text

Summary

In the rice-wheat system, wheat planting is delayed, resulting in poor wheat yields. To reduce turnaround time, the zero-tillage seeding concept was introduced in the late 1980s. Initial experimentation with zero-tillage wheat started through the importation of a zero-till drill machine from New Zealand. This machine was subsequently adapted for India by the G.B. Pant University of Agriculture and Technology, for which it is known as the Pantnagar Drill. This machine makes a narrow groove in the soil and places seed and fertilizer in one pass. This machine made it possible to plant wheat immediately after the harvest of rice.

Technical details

Bihar has large areas of lowlands. These natural depressed lands are called *chaur* lands, which have poor drainage and a shallow water table. Wheat is grown in lowlands as well as in medium lands after *kharif* (wet-season) rice. The optimum time for wheat seeding is mid-November to mid-December. But, in the traditional system, wheat seeding was often delayed, resulting

Fig. 1. The zero-tillage drill.

Fig. 2. A line-sown wheat crop established by a tractor-drawn zero-till drill.

in low yields. Within the existing rice-wheat system, a zero-till drill machine (Fig. 1) reduces turnaround time and wheat can be planted 10–15 days earlier, thus boosting production. It was also observed that this technology controls the notorious weed *Phalaris minor* because reduced soil disturbance results in fewer weeds germinating than with conventional tillage. The performance of zero-tillage wheat was validated through participatory farmers' managed experiments at Kalyanpur and Meenapur villages in North Bihar, India.

Agronomic practices

Planting: Use good-quality wheat seeds of a high-yielding variety. Plant wheat seeds just after the harvest of rice using a tractor-drawn zero-till drill. The cut-off date for wheat planting is 10 December.

Fertilizer management: Apply 120-60-40 kg NPK per ha as basal at planting using the zero-till drill.

Irrigation: Timing and frequency of irrigation depend on the crop and soil moisture conditions. However, in general, irrigation at 20–25, 40–45, and 60–65 days after sowing improves crop conditions and grain yield.

Alternatives

So far, an alternative to this technology is the conventional practice of planting wheat when field conditions become suitable. But this system delays planting, which results in a yield penalty.

Expected impact

The zero-till drill enabled farmers to plant wheat about 10–15 days earlier than when using the conventional practice. Early planting resulted in 0.57 t/ha or 18% additional grain yield over the conventional practice (Fig. 3). The additional wheat production from zero-tillage technology gives about 4,000–5,000 rupees per ha additional income. Adoption of this technology in about 50% of the wheat area of the state will increase production by about 0.4 million tons per year. Zero-tillage technology is a cost-saving (saves cost of land preparation) and resource conservation technology; it reduces soil erosion and incidence of the notorious weed *Phalaris minor.*

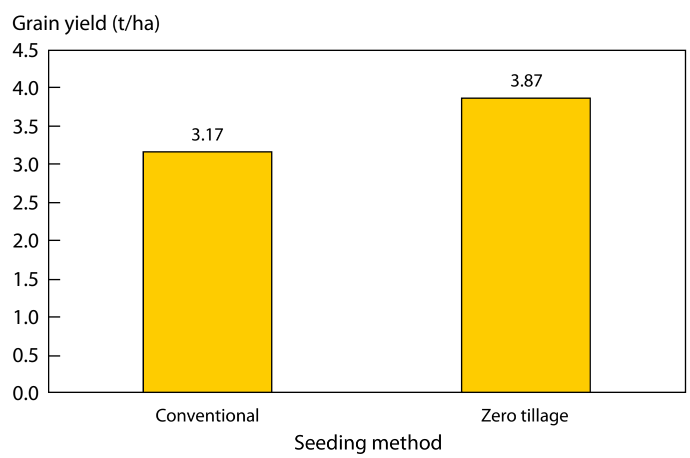

Fig. 3. Performance of zero-tillage wheat in the rice-wheat system at Kalyanpur and Meenapur villages in North Bihar, India.

Constraints

A tractor is needed to use the zero-till drill. The tractor and drill are beyond the economic reach of most farmers, except for a few large ones. Currently, most zero-till drills are with large farmers. To make this technology available to more farmers (medium, small, and marginal farmers), there is a need to develop service providers so that they can rent their services for wheat planting.

Validation status

The low productivity of wheat in Bihar is closely linked to late sowing. The presence of high soil moisture at planting time contributes to late planting. In North Bihar, wheat is sown up to the first week of January. There is a penalty for late planting after early December because yield declines by 35–40 kg/ha/day. The performance of zero-tillage technology was validated in the 2005-06 dry season through participatory farmers' managed trials at two villages. In total, 5, 10, and 16 farmers tried zero-tillage wheat in the 2004-05, 2005-06, and 2006-07 seasons in these villages, covering approximately 3, 8, and 15 ha, respectively. With the zero-till drill, farmers were able to plant wheat 10–15 days earlier and harvest 0.58 t/ha (18%) more grain than with the conventional tillage system. The tractor owners in the area are mostly providing tillage service and a few have a seed drill to provide zero-tillage service. For zero-tillage wheat service, they charge Rs 1,400–1600 (US$32–36) per ha.

Conclusions

Rice-wheat is a dominant cropping system in Bihar. The rice-wheat system occupies about 80% of crop lands in the state. Wheat is the second most important crop after rice. Wheat covers about 2.3 million ha. The average yield of wheat in North Bihar is only 2.26 t/ha, which is lower than in Punjab and Haryana. Validation trials revealed that farmers can derive substantial benefits (more than half a ton per ha additional yield worth Rs 4,000–5,000) by timely planting with the help of the zero-till drill. Large-scale adoption of this technology will bring enormous benefits to the state and to the nation. Policy support provided by the state government as a subsidy on the cost of the zero-till drill will help make the technology available to resource-poor marginal, small, and medium farmers of Bihar.

C. Additional Information

Date of release

January 2007

Sources of additional information

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Nutrient Management

The leaf color chart: a low-cost technology for need-based nitrogen management in rice

A. Introductory Section

Technology source:	International Rice Research Institute (IRRI), Philippine Rice Research Institute (PhilRice)
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Increase N-use efficiency, reduce N fertilizer use and cost, and reduce water pollution
Crops and enterprises:	Rice
Agroecological zones:	Warm humid and subhumid tropics
Domain of potential application:	All rice-growing countries of tropical and subtropical Asia
Key words:	Rice, need-based N management, N-use efficiency, leaf color chart, environmental protection

B. Main Text

Summary

Nitrogen (N) is the most important nutrient for rice, but is also the most limiting element in almost all soil types. Proper application of N fertilizer is vital for crop growth and grain yield. Farmers generally apply N in excess of the requirement compared with other nutrients because N fertilizer is relatively cheap and is often sold at subsidized prices. Farmers can also observe its visible impact on plant growth. Overuse and/or improper timing of N fertilization are inefficient and sometimes damaging to the crop. N recovery by rice is low, ranging from 20% to 40%, because of N loss via ammonium volatilization, denitrification, runoff, and leaching. Proper timing of N application is critical to minimize N loss and increase recovery. To overcome these problems, the Crop and Resource Management Network (CREMNET) at IRRI and the Philippine Rice Research Institute (PhilRice) jointly developed a leaf color chart (LCC) having 6 color panels from a Japanese prototype in the late 1990s. In Bangladesh, the LCC critical value for most popularly grown varieties was determined and recommended for use (Alam et al 2004). In 2003, the project Reaching Toward

Optimum Productivity (RTOP) of the Irrigated Rice Research Consortium (IRRC) of IRRI converted the 6-panel LCC into a 4-panel LCC for reduced cost and easy use, and it is now being used in Bangladesh and West Bengal, India. Under a special IFAD-IRRI project, the LCC was validated in Bangladesh and the Indian state of West Bengal through farmer participatory farmer-managed trials. Results revealed that the LCC can save 19–21% N in rice with a slight increase in grain yield. In addition, adoption of the LCC can reduce insecticide application by about 50% because of low pest incidence. These benefits are about Rs. 600–1,140 per ha or 9–14% of profit. As a result, LCC technology has been taken up as one of the mainstream extension services in Bangladesh.

Technical details

The LCC is a simple, easy-to-use, and inexpensive tool for improving N management in rice. The first leaf color chart was developed in Japan. Chinese researchers developed a modified LCC and calibrated it for indica, japonica, and hybrid rice. This chart later became a model for the LCC that was distributed by IRRI-CREMNET as an alternative to the very expensive chlorophyll (SPAD) meter for real-time N management. A new 4-panel LCC with standardized colors based on the spectral reflectance of rice leaves was developed by IRRI in 2003 and it has replaced the IRRI-CREMNET LCC. It costs less than a dollar, which most Asian rice farmers can easily afford. It measures leaf color intensity, which is related to the N status of the leaf. The LCC helps farmers to determine the right time for N fertilizer application by measuring leaf color intensity. In collaboration with IRRI, the Bangladesh Rice Research Institute (BRRI) has been validating the LCC in Bangladesh under farmers' conditions and Bidhan Chandra Krishi Viswavidyalaya in West Bengal (India) has been validating it through farmer participatory farmer-managed experiments.

Critical value

There is a critical value for the LCC at which the need for N fertilizer application is determined. This value may differ slightly with the method of crop establishment, rice type, and variety. The recommended critical value for transplanted aman (wet season) and boro (dry season) rice is 3.5, and for high-density direct wet-seeded rice it is 3.0. If the greenness of the paddy canopy is at or below the critical value, this means that the paddy needs N fertilizer. If the canopy greenness is above the critical value, this indicates that there is an adequate N supply in the field for the rice crop and thus no need to apply N.

How to use the LCC

- Start taking an LCC reading from 15 days after transplanting (DAT) for transplanted rice (TPR) or 15 days after seeding (DAS) for a direct wet-seeded aman crop. In the boro season, this should be done 21 DAT for TPR and 25 DAS for direct wet-seeded rice.
- The reading should be taken on a clear sunny day between 0900 and 1100 or 1400 and 1600 with the sun at your back to shade the leaf being measured. The same person should take the leaf color readings throughout a crop period.
- Select at least 10 rice plants free from disease and insect pest damage at random. Compare the color of the fully expanded uppermost leaf of each selected plant by placing its middle part on top of the color strip (Fig. 1). Do not detach or damage the leaf for measurement.
- The number of the color panel of the LCC that matches the leaf color will be the LCC value of the leaf. If the leaf color falls between two panels, the mean of the two values is taken as the LCC reading. For example, if the leaf color lies between chart values 3 and 4, it is noted as 3.5.
- Among the 10 LCC readings, whenever six or more leaves read below a set critical value, apply 25 kg/ha N in aman and 30 kg/ha N in the boro season.
- Repeat the process every 10 days or at critical growth stages such as early tillering, active tillering, panicle initiation, and first flowering. If the LCC value on the day of measurement is above the critical value, take the LCC reading again after 5 days and apply N fertilizer, if needed.

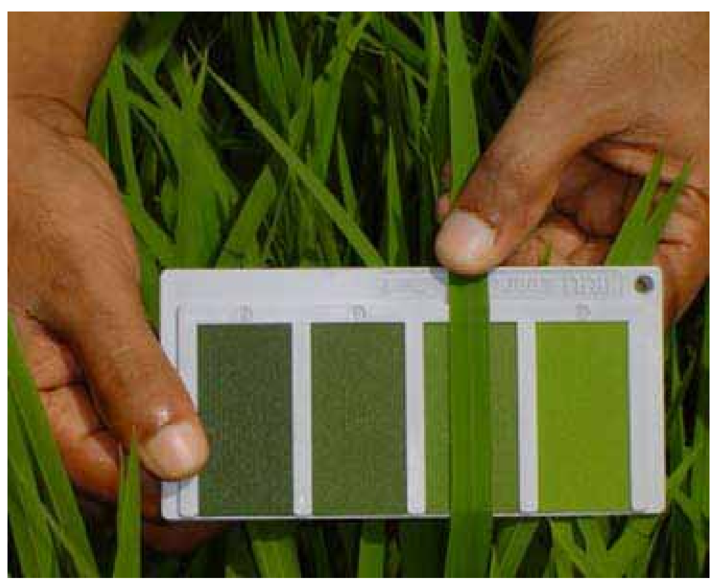

Fig. 1. N content of the rice leaf is measured with an LCC.

Alternatives

At present, there are different alternatives for managing N fertilizer in rice:

Farmers' practice of N management: Many farmers apply N fertilizer on the basis of their perception for higher yield. Most of them believe that more nitrogen means more yield, which leads to overuse. Many farmers also do not know the recommended fertilizer rate and timing of application, which also leads to misuse.

Research-recommended N use: In this approach, farmers are advised to apply a particular amount of N based on growth duration, season, and average soil fertility status on a fixed-time basis. Although these recommendations are based on a large number of trials, they do not consider the N status of a particular plot. This practice therefore may result in overuse or underuse of N.

Soil test-based N application: Soil test-based N application involves determining the nutrient-supplying capacity of the soil of an individual plot. Proper collection and handling of the soil sample are critical for a reliable test. However, this nutrient management technique is not widely adopted by rice farmers because of a lack of knowledge and limited analytical facilities.

Chlorophyll meter or SPAD: The chlorophyll meter or SPAD is a simple electronic tool that can monitor plant N status within 2 seconds (Fig. 2). Fertilizer is applied when the SPAD value is less than the set critical value. Use of the chlorophyll meter for N management can reduce N fertilizer application by 13–25% over the farmers' practice. The SPAD meter gives more precise values than the LCC and is also commercially available, but its unit price ($1,300–1,800) is far beyond the reach of most Asian rice farmers.

Fig. 2. A chlorophyll meter or SPAD meter.

Expected impact

In West Bengal, the use of the LCC for N management significantly reduced N use in all three rice seasons, boro, aus (prekharif/summer), and aman (Table 1). N savings averaged 25 kg/ha or 19% over the farmers' practice. N savings were 31 kg/ha in boro, 23 kg/ha in aus, and 21 kg/ha in the aman season. LCC adoption

Table 1. The effect of need-based N management with use of the LCC on nitrogen use by rice, West Bengal, India.

Season	N used (kg/ha)		N saved		t-value
	Farmers' practice (control plot)	LCC plot	kg/ha	% over farmers' practice	
Aus	115.7	93.2	22.6	19.5	5.81**
Aman	121.2	100.4	20.8	17.2	13.63**
Boro	151.4	119.6	31.4	21.0	4.42**
Average[a]	129.4	104.4	25.1	19.4	

[a]There were 148 LCC adopters and 240 nonadopters in the sample.

Table 2. Grain yield and amount of N fertilizer used in LCC-based N management and farmers' practice in boro 2005, Bangladesh (n = 174).

Attribute	LCC	Farmers' practice
Average grain yield (t/ha)	6.08	5.56
N used (kg/ha)	107	133
N saved due to LCC (%)	19.5	

did not affect grain yield. LCC adopters also reduced insecticide applications by about 50% as a reduction in N use contributed to less pest pressure.

In Bangladesh, use of the LCC enabled farmers to save 20% N in the boro season (26 kg N/ha) (Table 2). Grain yield was about half a ton per ha or 9% higher in LCC plots versus the farmers' practice. Diseases and insect pests were comparatively lower in LCC-based N-management plots.

The economic benefit of LCC adoption from N and pesticide savings and additional yield was estimated at Rs. 1,140/ha or 10% of profit in boro, Rs 720/ha or 14% of profit in aman, and Rs 600/ha or 13% of profit in aus seasons (Fig. 3). The combined effects of reduced N and insecticide use on environmental protection may be enormous, if the technology is adopted over large areas.

Validation trials in two countries revealed that adoption of the LCC can save about 17–21% N and 50% insecticide use in rice. Individual farmers can achieve these financial benefits by adopting the LCC in rice for N management. However, large-scale adoption can bring environmental benefits through a reduction in pollution of water bodies and the overall environment by N and insecticides.

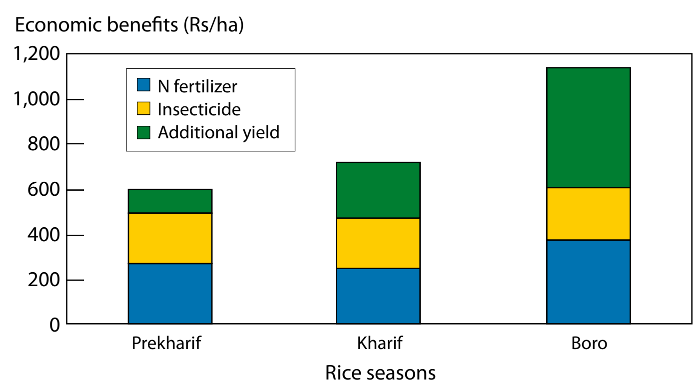

Fig. 3. Economic benefits of adoption in different rice seasons, West Bengal, India.

Constraints to adoption

A lack of farmers' awareness about the benefits of LCC-based N management and unavailability of the LCC at the grass-roots level limit its adoption. Large-scale community-based demonstrations are necessary to promote effective use of the LCC. In addition, the LCC needs to be manufactured in the country and made available to farmers. Government and nongovernment extension service providers should make strong efforts to promote the LCC.

Validation status

LCC technology validation started in Bangladesh in 2000 under IRRI-BRRI collaboration and was strengthened under the IFAD-IRRI (TAG 634) project beginning in 2004. In West Bengal, validation began in 2003 through farmer participatory experiments. In addition, many validation experiments were conducted under several other IRRI-managed projects. So far, enough validation has been done and efforts in the future should be concentrated on promotion.

Conclusions

The LCC is an effective and inexpensive N-management tool. Adoption of the LCC can avoid overapplication or misuse of N fertilizer in rice without any negative impact on grain yield. The LCC is also a cost-saving and environmental protection technology. Individual farmers can derive benefit by saving nitrogen fertilizer and insecticide while community-wide adoption will benefit the environment from pollution from nitrogen and insecticides.

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C. Additional Information

Date of release

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Biofertilizer-based integrated nutrient management in rice for cost savings, higher production, and environmental conservation

A. Introductory Section

Sources of technology:	Assam Agricultural University, Jorhat, India
***Sources of funding*:**	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Reduce inorganic fertilizer use and pollution, and increase rice production
Crop and enterprises:	*Boro* rice
Agroecological zones:	Flood-prone *boro* rice-growing areas of Assam
Domain of potential application:	*Assam***,** West Bengal, India, and Bangladesh
***Key words*:**	*Boro* rice, *Azospirillum*, phosphate-solubilizing bacteria, integrated nutrient management, cost savings

B. Main Text

Summary

Bao (deepwater rice)–fallow and *bao-boro* (dry-season) rice are the major cropping systems in the flood-prone ecosystems of Assam, India. Most farmers do not use the recommended dose of fertilizers due to their high cost. Biofertilizer-based integrated nutrient management (BINM) can reduce production costs and produce higher yields, leading to increased profit. The performance of BINM in modern variety (MV) boro rice was validated through farmers' participatory research at three sites in Assam.

Technical details

The performance of recommended nutrient management (RNM) and BINM was validated by farmers at Disangmukh village in Sibsagar District, at Ganakabari village in Jorhat District, and at Joraguri village in Golaghat District in the 2004-05 and 2005-06 boro rice seasons. High-yielding modern boro rice varieties Kanaklata, Jyotiprasad, and Joymoti, developed by Assam

Agricultural University (AAU), were used. Need-based application of pesticides was adopted. Doses and application of RNM and BINM treatments follow.

Recommended nutrient management (RNM): N, P, and K were applied at 60, 15, and 25 kg/ha. P, K, and one-third of N were applied as basal at final land preparation. The rest of the N was applied in two equal splits as topdressing at 30 and 75 days after transplanting (DAT).

Biofertilizer-based integrated nutrient management (BINM): Under BINM, one quintal of dry cow dung, 4 kg of biofertilizer (*Azospirillum* + phosphate-solubilizing bacteria), 56 kg of rock phosphate, 33.3 kg of murate of potash (MP) per ha, and one-fourth of the recommended N were used. The biofertilizer, cow dung, and rock phosphate were mixed with mud on about a 4 × 4 area in a corner of the main field and roots of rice seedlings were dipped for 2 hours. Seedlings were removed 2 hours after root dipping and the biofertilizer mixture, MP, and urea were applied to the main field before the transplanting of rice seedlings.

Expected impact

Two seasons of validation experiments conducted by farmers at three villages involving three boro rice modern varieties revealed a similar performance of BINM and RNM (Fig. 1). BINM and RNM outyielded the farmers' practice by 1.82 t/ha (52%) and 1.88 t/ha (54%), indicating poor nutrient management by farmers. Benefit-cost (B:C) ratios revealed that BINM is more economical (B:C = 3.18) than RNM (B:C = 2.74) and the farmers' practice (B:C = 1.89) (Table 1). Under BINM, three-fourths of nitrogen (45 kg/ha) was saved without sacrificing grain yield, which resulted in reduced costs of water pollution by nitrogen. The benefits of large-scale adoption of BINM in terms of a reduction in water pollution would be enormous.

Alternatives

Nutrient management in rice at recommended doses may be an alternative to BINM. Although recommended nutrient management will increase rice production over the farmers' practice, similar to BINM, it will also increase nitrogen fertilizer use, costs, and environmental pollution.

Constraints to adoption

The lack of availability of biofertilizer (*Azospirillum* + phosphate-solubilizing bacteria) at the right place and time and lack of promotion efforts are the major constraint to up-scaling of

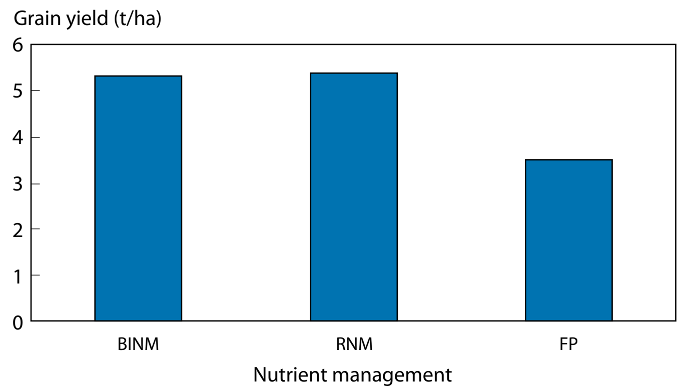

Fig. 1. Effects of biofertilizer-based integrated nutrient management (BINM), recommended nutrient management (RNM), and farmers' practice (FP) on grain yield of three modern rice varieties at three locations of Assam, India, during the 2004-05 and 2005-06 boro seasons.

Table 1. Effect of nutrient management practices on costs and returns of boro rice cultivation in Assam, India.

Treatment	Total costs (Rs/ha)	Net returns (Rs/ha)	Income advantage over FP (Rs/ha)	B:C ratio
BINM	5,973	19,027	9,810	3.18
Recommended practice	6,691	18,309	8,499	2.74
Farmers' practice (FP)	5,190	9,810	–	1.89

this technology. Further, the low market price of boro rice has a negative influence on boro cropping, while cost reductions through BINM may have some counter-balancing effect.

Validation status

The BINM package for boro rice developed by AAU was tested at the university research stations, in KVKs, and in farmers' fields. Its performance was validated in farmers' fields at three villages involving three modern boro rice varieties in two boro seasons.

Conclusions

Nutrient management in boro rice in Assam is poor, resulting in low yields and food insecurity. BINM saves 75% of nitrogen without affecting grain yield in comparison with RNM, and produces almost 50% higher yield than the farmers' practice. These techniques can substantially increase rice production over the current farmers' practice. This technology is highly beneficial over recommended nutrient management practices in conserving water bodies from pollution by applied nitrogenous fertilizer. However, up-scaling of this novel technology requires strong collaboration between research and extension as well as the availability of biofertilizer at the grass-roots level, which is currently lacking.

C. Additional Information

Date of TAN Release

February 2007

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Supplementary Technologies

Mushroom cultivation for nutrition and supplementary income for resource-poor farm families of Jharkhand

A. Introductory Section

Technology source:	Holy Cross KVK Hazaribag, Jharkhand
Funding source:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Overcome health problems related to nutrient deficiency and develop a supplementary income source for resource-poor farm families.
Crops and enterprises:	Oyster mushroom—indoor production
Agroecological zones:	Rainfed uplands of Jharkhand
Domain of potential application:	Jharkhand, Bihar, Chhattisgarh, Utter Pradesh, West Bengal, etc.
Key words:	Oyster mushroom, nutrition, supplementary income

B. Main Text

Summary

Much of Jharkhand's population is resource poor and lives below the poverty line. Their employment opportunities are seasonal, mainly only in the wet (kharif) rice season. In the off-season, male members seek employment outside. Female members remain in the household, mostly without an income source. In a joint effort in 2005, the IFAD-IRRI project and Holy Cross KVK in Hazaribag trained about 160 women of two villages and introduced oyster mushroom cultivation. In the first season (October 2005-March 2006), more than 60 women experimented with the technology on a small scale and most of them were successful. All 60 women cultivated mushrooms in the second year, and several increased their capacity (2006-07). In 2006, another 100 women of five villages were trained. Of these, about 60 tried mushroom cultivation and most were successful (Fig. 1). As these villages are a long way from the town, scope for marketing is very limited. Some women used to walk 10 km to Hazaribag town to sell their product. They made net returns of Rs 100 from 1 kg of spawn on a full-cost basis and Rs 155 on a capital-cost basis. Several made

Fig. 1. Flush of oyster mushroom on paddy straw substrate.

pickles out of mushrooms or dried them for selling or consumption later. However, a majority of them used their product for home consumption and it became a popular dish. The technology seems to have potential to engage women in work in the off-season, providing family nutrition as well as opening a supplementary livelihood support system for resource-poor farm families of Jharkhand.

Technical details

More than 60% of the households of Jharkhand live below the poverty line. They are resource-poor, their employment is seasonal, and they suffer from health problems caused by nutritional deficiency. Employment is generally available in the wet (kharif) rice season. In the off-season, male family members seek jobs in distant places, including towns and cities. However, female members remain in the village to take care of the family as well as the meager property they have. IFAD-IRRI and KVK, Hazaribag, made a joint effort to validate whether mushroom cultivation by these resource-poor women could open a supplementary source of income and nutrition. As mushroom cultivation is a knowledge-intensive technology, training was provided to 160 women of two villages in 2005 and they were given technical assistance for cultivation in their home during the October 2005-March 2006 season. In 2006, another 100 women of five villages were trained and technical assistance was extended for cultivation in the 2005-06 season.

Oyster mushroom: Mushrooms are a kind of fungi. They lack chlorophyll and hence cannot produce their own food; they depend on organic matter for their nutrition. Mushrooms are a nutritious food, containing high-quality protein, vitamins, and minerals. One cup of raw pieces (200 g) of oyster mushroom (*Pleurotus florida*) contains 17.5 calories, 2.0 g of protein, 2.8 g of carbohydrate, 0.23 g of fat, and 0.84 g of fiber. Oyster mushrooms are a good source of niacin (2.8 mg), riboflavin (0.29 mg), and vitamin D (53 IU). They are free from cholesterol and their intake reduces cholesterol; hence, they are considered as an ideal food for heart patients. There is no sugar or starch so they are good for diabetic patients. However, all mushrooms are not edible; some are poisonous. It is not wise to eat wild mushrooms if one is not sure. However, all cultivated mushrooms are not poisonous.

Cultivation of oyster mushroom

Substrate preparation: Oyster mushrooms can be grown on various substrates. Since paddy or wheat straw is easily available, it can be used. Use fresh, clean, and well-dried straw. Chop the straw into 2.5–5.0-cm-long pieces and then soak them in water for 10–12 hours. Soaking helps to remove surface contamination, and straw absorbs water. After soaking, drain out excess water by spreading the straw on a clean wire mesh or sloping surface. Chopped straw needs to be sterilized to control mold and for higher production of mushrooms. Sterilization can be done by hot water or chemical treatment.

Hot-water treatment: Dip the wet straw in hot water at 70–80 °C for 30 minutes. After sterilization, place the straw on a clean wire mesh or a sloping surface for cooling and draining of excess water. Keep straw moisture content at 60–70%.

Chemical treatment: Mix 50 mL of formaldehyde and 5 g of Bavistin or Dithane M-45 fungicide in 50 L of clean water in a drum or trough. Dip about 5 kg of chopped straw in the solution and mix properly (Fig. 2). Remove the straw after 10–12 hours of soaking from water and place it on a clean wire mesh or sloping surface to drain excess water. Keep straw moisture content at 60–70%.

Fig. 2. Hot-water treatment of chopped straws.

Spawning

Make an 8-cm-deep compressed (by hand) layer of chopped and sterilized straw in a 35 cm × 50 cm (150 gauge) polythene bag. Spread a total of about 200 g of mushroom spawn (seeds) on top of the compressed straw layer in a polythene bag (Fig. 3). A pinch of lime and chickpea powder sprinkled over gives higher yield. Prepare three to four layers with 50 g of spawn on top of each layer except the top of the topmost layer, which is only 2 cm deep. Close the bag and make a few small holes on each side of it for better mycelium development. The closed spawn bags are then stacked on racks in a clean and dark room at 25 ± 5 °C. Maintain 80% ± 5% relative humidity by spraying water on the walls and floor. Keep the room dark and prevent free air movement. Incubation takes about 3 weeks; by then, the straw will be covered with white mycelium.

Crop management

When the straw is covered with white mycelium, remove the polythene cover (Fig. 4) and keep the open blocks on racks with about a 20-cm gap between blocks and 60 cm between rows. Maintain humidity at 80–90% and temperature at 25 ± 5 °C. Wide variations in temperature and humidity may delay fruiting and reduce yield. After opening the bags, there should be diffused light in the room where mushrooms are produced, along with ventilation.

Fig. 4. Straw blocks are covered with mycelium, time for polythene bag removal.

Harvest

Mushrooms should be harvested just before the inward rolling of the margins of the fruit body or when they reach a size of about 6–8 cm. One should not allow the mushrooms to shed

Fig. 3. Spawning of mushroom bags.

spores as this results in poor quality. The fruit bodies should be harvested by twisting the stalk so that broken pieces are not left out of the substrate surface, which may cause bacterial infections and rotting of the substrate. The subsequent second, third, and fourth flushes of mushrooms usually appear 6–8 days after the previous one. However, almost 75% of the crop is usually harvested by the second flush. Mushroom production can range between 80% and 100% of the dry weight of the substrate depending upon care and hygienic conditions. Fresh mushrooms can be dried under the sun and stored for future use. If properly dried, 1.0 kg of fresh mushrooms becomes 100 g.

Costs and returns

One kg of spawn using 5–6 kg of paddy straw produces about 4–5 kg (average 4.5 kg) fresh mushrooms within 45 days. Capital costs are expenses for spawn, straw, straw treatment chemicals or fuel for hot-water treatment, and polythene bags. All other activities such as straw chopping, spawning, watering, and harvesting, etc., need labor. The gross returns from 1 kg of spawn are about Rs 225. The net returns from 1 kg of spawn on a full-cost basis are Rs 100 and Rs 155 on a capital-cost basis (Table 1).

Alternatives

There is no alternative to mushroom production inside the house. However, rearing of chicken for meat or eggs is another viable supplementary option that could be adopted along with mushroom in the same household.

Expected impact

Mushroom cultivation provided some employment for women during the off-season. Whether the product (mushrooms) is consumed or sold or both, it offers a supplementary source of income and nutrition. Success in mushroom production gives confidence to resource-poor women for taking the initiative for improving their livelihood by adopting nontraditional technologies.

Constraints to adoption

Finding proper space for mushroom cultivation within the household of resource-poor farmers is a major constraint. Marketing of mushrooms in rural areas is also a problem.

Validation status

After the training in 2005, more than 60 resource-poor women of two villages tried oyster mushroom cultivation for the first time in the October 2005-March 2006 season. Most of them were successful and all of them also cultivated it in the 2006-07 season. In the first year, on average, they were using 5–10 bags per woman, which they increased to 10–25 bags in the second year, with several using 25–50 bags. In 2006, another 100 women of five villages were trained and 60 of them tried cultivation of mushrooms in the 2006-07 season for the first time. The number of women growing mushrooms and number of bags they are using per woman are increasing, indicating that mushrooms are gaining popularity among the resource-poor women of Jharkhand. A TV program highlighting the importance of mushroom cultivation in the villages for improving income and nutrition was developed and aired on 3 February 2007, which created interest among growers as well as the general public. Currently, many women are coming to Holy Cross KVK to inquire about training on mushrooms, and the source and availability of spawn.

Conclusions

Efforts to introduce oyster mushrooms to the resource-poor women of Jharkhand had preliminary success. Although there is limited scope for marketing in rural areas, the number of women growing mushrooms has doubled from 60 to 120 within two years. They are also increasing their capacity by increasing the number of bags. The main reason for the increase in mushroom cultivation is mainly home consumption, as growers themselves consume their produce. The nutrition of mushrooms may play an important role in reducing health problems caused by nutrition deficiency if mushroom cultivation and consump-

Table 1. Costs and returns of mushroom production based on 1.0 kg of spawn, Hazaribag, Jharkhand, India.

Costs (Rs)		Returns (Rs)	
Spawn (1 kg)	50	Average yield from 5 bags = 4.5 kg	
Straw (5 kg)	8	Price of 1 kg of mushroom	50
Labor for straw chopping, spawning, watering, and harvesting	50	Gross returns	225
Straw treatment	10	Net returns on full-cost basis	100
Total	118	Net returns on capital-cost basis	155

tion spread in most villages, not only in just a few study villages. Some women are turning to mushroom cultivation as an alternate source of income, but they face difficulties in marketing. In addition, the availability of good-quality spawn is a constraint. Currently, mushrooms are grown in the dry season (October-March) and they need to be extended for year-round cultivation by using another species in the wet season.

C. Additional Text

Date of TAN release

December 2006

Sources of additional information

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Cultivation of elephant-foot yam for supplementary livelihood support for resource-poor farm women of Jharkhand

A. Introductory Section

Source of funding:	Accelerating Technology Adoption to Improve Rural Livelihoods in the Rainfed Eastern Gangetic Plains (TAG 634) project
Expected benefits:	Household food security and petty cash income for resource-poor farm families
Crops and enterprises:	Horticulture—homestead gardening
Agroecological zones:	Undulated rainfed terrains of Jharkhand
Targeted states/countries:	Jharkhand, Chhattisgarh, Bihar, and West Bengal states of India
Key words:	Elephant-foot yam, *Amorphophallus paeoniifolius*, suran or jimmikand, supplementary livelihood support

B. Main Text

Summary

More than 60% of Jharkhand's population is resource-poor and living below the poverty line. Resource-poor farm women usually have employment during the wet (kharif) season and remain unemployed afterward, except for their household work. To create scope for some supplementary income in the off-season, elephant-foot yam was introduced in selected villages under the IFAD-IRRI project implemented by KVK, Hazaribag, Jharkhand. In total, 160 members belonging to 12 self-help groups in two villages were selected and trained on elephant-foot yam cultivation. In 2006, all the trained women planted elephant-foot yam in small plots in an upland situation and harvested about 10 times more corms than with what they planted 6 months earlier. The produced yam is playing an important role as a supplementary source of household food and nutritional security as well as a petty cash supply for these resource-poor farm families.

Technical details

Elephant-foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) belongs to the Araceae family and is a tropical tuber crop. It originated in Southeast Asia. In India, it is commonly known as suran or jimmikand. It is traditionally cultivated in Andhra Pradesh, Gujarat, Maharashtra, Tamil Nadu, and Kerala states. Cultivation is limited outside of the traditional states, which include West Bengal, Bihar, Jarkhand, and Chattisgarh. Elephant-foot yam is generally used as a vegetable, pickle, and flour. The corms of wild plants are highly acrid and cause irritation in the throat and mouth due to their excessive amount of calcium oxalate. However, variety Gajendra is free from acridity and is high yielding. Elephant-foot yam is a nutritious tuber crop containing 79% moisture, 18.4% carbohydrate, 1.2% protein, 0.8% minerals, and 0.1% each fat and fiber. The fresh tuber is rich in minerals (calcium, phosphorus, and iron) and vitamins (vitamin A, thiamine, niacin, and riboflavin).

Climate and soil

Elephant-foot yam grows well in hot and humid climate. Humid climate helps in the initial stages of crop growth, whereas dry climate facilitates tuber bulking. Well-drained, fertile sandy loam soil is ideal for elephant-foot yam. Stagnant water at any stage adversely affects crop growth, corm bulking rate, and corm quality.

Cropping season

Planting time is April-June. Under rainfed conditions, planting can usually be done in the latter part of June. Early-planted crops outyield late-planted ones. The crop requires regular rains or irrigation throughout the cropping season. Elephant-foot yam matures in approximately 6–7 months.

Planting material and planting

Planting material constitutes small whole corms (bulbs) or small cut pieces from big corms. Planting material of 400–500 g is ideal for optimum yield. Planting should be done in pits (40 × 40 × 40 cm) filled with farmyard manure, soil, and fine sand in a ratio of 1:1:1. Pit spacing depends on corm size; for example, for 400–500-g corms, 75 × 75 cm; for smaller ones, 60 × 60 cm. Corms are planted 10–15 cm below the soil surface and covered with paddy straw. It is important to do earthing-up after weeding and apply fertilizer at 30–35 and 60–65 days after planting.

Manure and fertilizer

Apply decomposed farmyard manure in pits, before planting. Also apply nitrogen, phosphorus, and potash at 80-60-100 kg/ha. Apply all of the phosphorus and one-third of the nitrogen and potash at the time of planting. Apply the remaining dose of nitrogen and potash in two splits at 30 and 60 days after planting, immediately after weeding and followed by earthing-up.

Irrigation

Depending on soil moisture availability, provide irrigation until the arrival of monsoon. Prevent water stagnation at all stages of crop growth.

Harvesting and yield

Elephant-foot yam takes about 6–7 months to mature. Leaf yellowing and drying up of the plants indicate that the crop is ready for harvest. Harvest tubers by carefully digging, avoiding injury to the corms. Soil and roots should be removed from the corms. Use or sell damaged corms as soon as possible. The ratio between the quantity of planting material used and corm yield is generally 1:10. Depending on market demand, harvesting can begin after 5–6 months.

Marketing

Demand for elephant-foot yam is usually high because of its popularity as a vegetable and its use as a major component of several indigenous medicinal preparations. The corms can also be used to make various value-added products such as flour, dried cubes, pickles, etc.

Alternatives

Short-duration vegetables can be grown on these lands. In fact, vegetable production is popular and competing with elephant-foot yam cultivation.

Expected impact

Elephant-foot yam grown on as small as a 40-m^2 area can provide both a supplementary food and income. Farmers are using elephant-foot yam as a supplementary staple food and vegetable as well as a supplementary source of petty cash. There is demand for it and farmers can easily sell it in the market. When there is a need for petty cash, they take one or two corms to the market for sale. As elephant-foot yam is a cheap source of carbohydrates and is rich in minerals and vitamins A and B, it has potential to provide household food and nutritional security among resource-poor farm families. So far, negative impact of the technology on the environment has not been observed. The adoption of elephant-foot yam on a large scale will play a positive role in improving livelihood among resource-poor farmers by providing household food and nutritional security and supplementary income as well as empowering women.

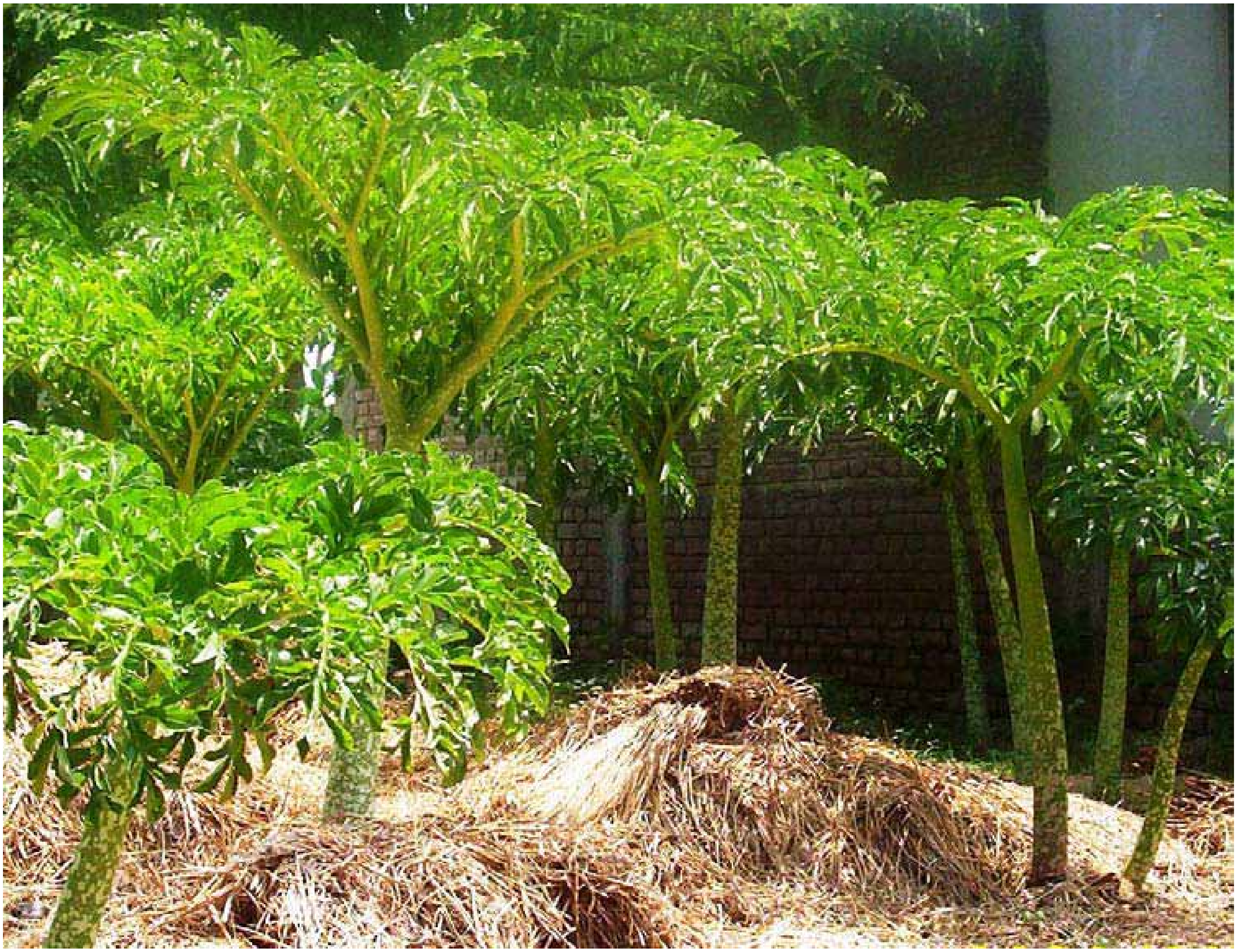

Fig. 1. Elephant-foot yam plants on a homestead.

Constraints to adoption

Because elephant-foot yam is a long-duration crop, it takes 6–7 months to mature. When resource-poor farmers use their land for 6–7 months for elephant-foot yam from their very limited land supply, this is a hard decision for them to make because during that period they can grow 2–3 short-duration vegetable crops in succession on that same land. However, intercropping of some vegetables with elephant-foot yam could be a viable system, which needs validation through farmer participatory experiments.

Validation status

Some farmers were growing elephant-foot yam (mostly wild ones) under traditional practices. The Holy Cross KVK introduced improved variety Gajendra to some farmers in the Hazaribag area in 1993-94. The introduction was reinforced in 2005 by organizing 160 resource-poor women into 12 self-help groups and providing training on elephant-foot yam production, storage, and consumption, and extending field supervision. In 2006, the trained women cultivated elephant-foot yam mostly in their uplands in small plots (Fig. 1). In most cases, success was spectacular. They harvested about 10 times more than what they planted. There is demand in the market and the price is Rs 8–10 per kg. The main demand is for vegetables and there is some demand for pickles. However, growers are using the crop as a supplementary staple food and also as a vegetable. Its storability of 5–6 months gave farmers flexibility in marketing and consumption depending on family needs and market price.

Conclusions

Elephant-foot yam has great potential for providing food and nutritional security as well as a supplementary source of petty cash for resource-poor farmers. It also provides employment for farm women and empowers them through its role as a cash and food supply for the household. The adoption of elephant-foot yam may play a positive role in improving livelihood and overcoming poverty in Jharkhand. However, land is a scarce resource among resource-poor farmers and elephant-foot yam appears to compete with short-duration vegetables. Intercropping of some short-duration vegetables with elephant-foot yam may overcome this constraint and make an additional contribution to household income. However, farmer participatory validation is necessary to understand the actual outcome of such a potential system in Jharkhand's agroecological and socioeconomic context.

C. Additional Text

Date of TAN release

November 2006

Source of additional information:

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