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Improving the livelihood of farmers by intensifying the rice-potato-rice system through double-transplanting of rice in West Bengal, India

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Preface

This working paper is based on collaborative work conducted by scientists from the International Potato Center and the Rice Research Station of the Department of Agriculture of West Bengal, India. It reports the proceedings and results of participatory trials conducted in two locations in West Bengal, to evaluate and disseminate rice double-transplanting technology to intensify potato-rice cultivation system, enhance sustainable productivity and alleviate poverty. The reported work is based on the fact that rice is a staple food and potato is an important cash crop for farmers in the Sub-Tropical Eastern Indo-Gangetic Plains of India and Bangladesh. Recognizing the importance of potato and rice for poor farmers, the Department of Agriculture of the Government of West Bengal and the International Potato Center undertook a study to evaluate and validate an innovative double-transplanting technology of boro (summer season) rice and improved management of existing resources to obtain higher productivity and profitability of the kharif (wet season) rice-potato-boro rice system, without sacrificing the yield of either potato or boro rice.

Acknowledgements

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INTRODUCTION

Rice is a staple food and potato is an important cash crop for farmers in the Sub-Tropical Eastern Indo-Gangetic Plains of India and Bangladesh. Among the Indian states, West Bengal stands first in rice production and contributes 14.6% of the country's production (Anon. 2004-2005). The gross cropped area of West Bengal State is 9.52 million ha with a cropping intensity of 177%. Rice occupies nearly 62% of the total gross cropped area and contributes nearly 36% of the total agricultural production of the state. West Bengal also produces nearly 7 million tonnes of fresh potato from 0.31 million hectare and contributes 31% to the total potato production in the country. The state has the highest potato productivity (23 t/ha) and stands second highest in potato production in India (Anon. 2003a).

As potato provides carbohydrates, proteins, minerals, vitamin C and a number of B group vitamins and high quality dietary fiber, it was previously utilized by the growers as a dietary component to be eaten with rice and wheat rather than selling it as a cash crop (Gopalan *et al.* 1972). However, since the early 1970s, potato production has increased more rapidly in the irrigated sub-tropical lowlands of Asia than in any other part of the world and has become an important cash crop. The most impressive example of the area expansion occurred in West Bengal, where land cultivated to potato expanded five fold over the past 25 years (Bardhan Roy *et al.* 1999).

This working paper reports the proceedings and results of participatory trials conducted in two locations in West Bengal, to evaluate and disseminate rice double-transplanting technology to intensify potato-rice cultivation system, enhance sustainable productivity and alleviate poverty.

AGRO-ECOLOGY OF WEST BENGAL

West Bengal State is situated in the flood plains of the Ganga and Bramhputra rivers, between 23^0 N and 87^0 E, and has a land area of 88,752 km^2. The boundaries of the state are Nepal, Bhutan and the State of Sikkim (India) in the North; Assam (India) and Bangladesh in the South, and Bihar (India) in the West. It has a population of 82 million (2001 census) and at 904 people per km^2, so the state ranks first in population density in the country. More than 70% of the population lives in 38,000 rural villages. Rural communities living in West Bengal villages depend mostly on agriculture for their livelihoods, directly or indirectly. Net cultivated land area in West Bengal is 5.40 million ha and the average land holding is 0.82 ha, fragmented in various numbers of scattered parcels. Thirty-two percent of rural families live below the poverty line, with an average per capita income of less than US$8 per month. Per capita energy intake is less than 2400 kcal/d (Anon. 2004-2005).

The climate of the region is characterized by hot summers and mild to moderately cool winters. The mean annual rainfall varies from 1400 to 1600 mm in the Gangetic plains and 1600 to 2000 mm in the Bramhputra plains. The potential evapotranspiration (PET) ranges from 1100 to 1400 mm and the water deficit is about 400 mm. A water balance diagram reveals that the precipitation exceeds PET for a greater part of the year and that soils remain dry only for a month or so. The crop-growing period (GP) is more than 270 days/year (Sehgal *et al.*1990). The monthly PET ranged between 23.6 and 105.5 mm in southwest Bengal and 31.5 and 88.4 mm in northwest Bengal, respectively. The region is characterized by alluvium-derived soils (ICAR 1990).

The work reported in this paper was conducted in two different sites, namely the Hooghly (southwest Bengal) and Jalpaiguri (northwest Bengal) districts. The former is located in the Gangetic Plains whereas the latter is located in the Brahmaputra Plains The mean of four-year rainfall data shows that there is little rainfall in both Hooghly (southwest Bengal) and Jalpaiguri (northwest Bengal) districts during the potato-growing period (Figure 1). However, sporadic rains in October delay potato planting in both districts. The mean monthly PET varies at the two sites (Figure 2). The mean monthly maximum and minimum temperatures of Hooghly and Jalpaiguri districts are given in Figure 3. The monthly mean temperature of Hooghly district was higher than the corresponding mean at Jalpaiguri district. Due to temperature differences, the potato crop is planted earlier in Jalpiaguri than in Hooghly district. The significant difference in temperature regimes in the two districts indicates that in Jalpaiguri the potato crop gets longer periods for bulking compared to Hooghly, where maximum temperature rises to 35^{o}C by early March.

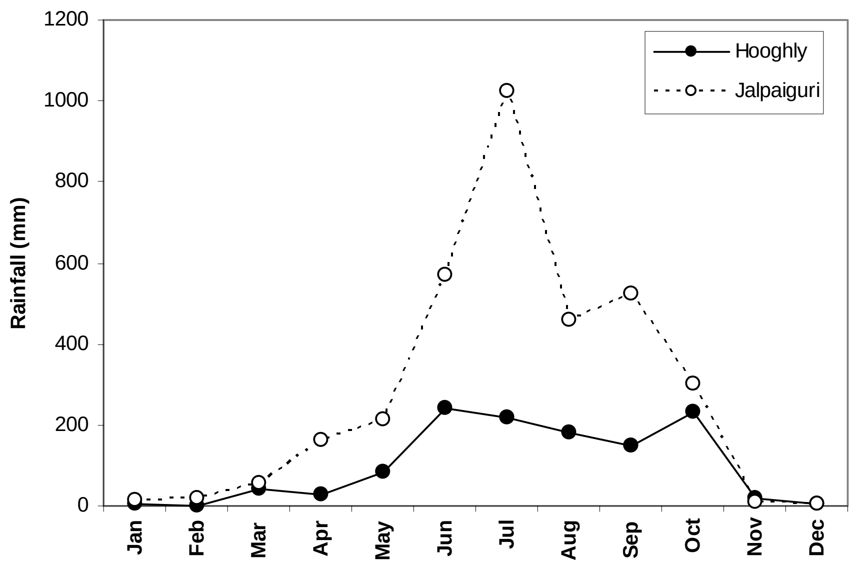


Figure 1.
Mean monthly rainfall in Hooghly and Jalpaiguri districts in West Bengal.

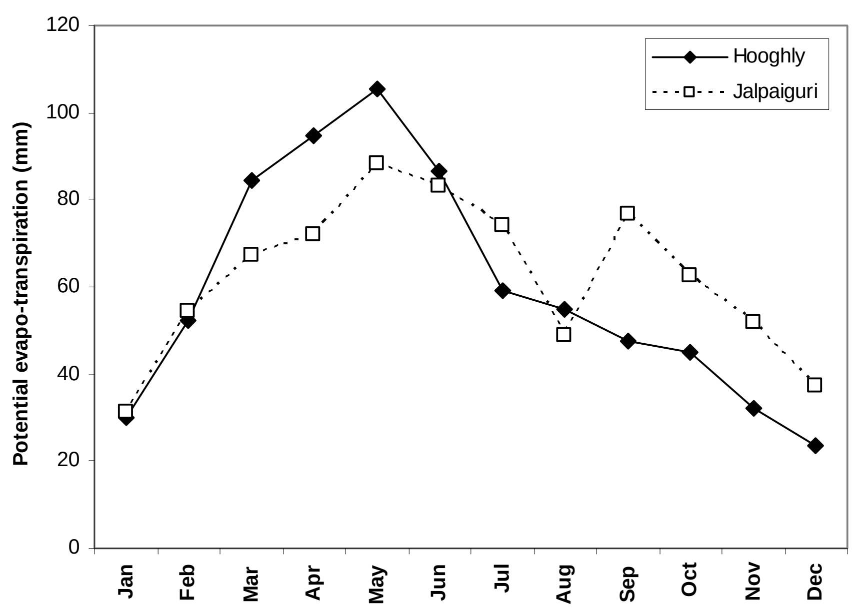


Figure 2.
Mean monthly potential evapo-transpiration in Hooghly and Jalpaiguri districts in West Bengal.

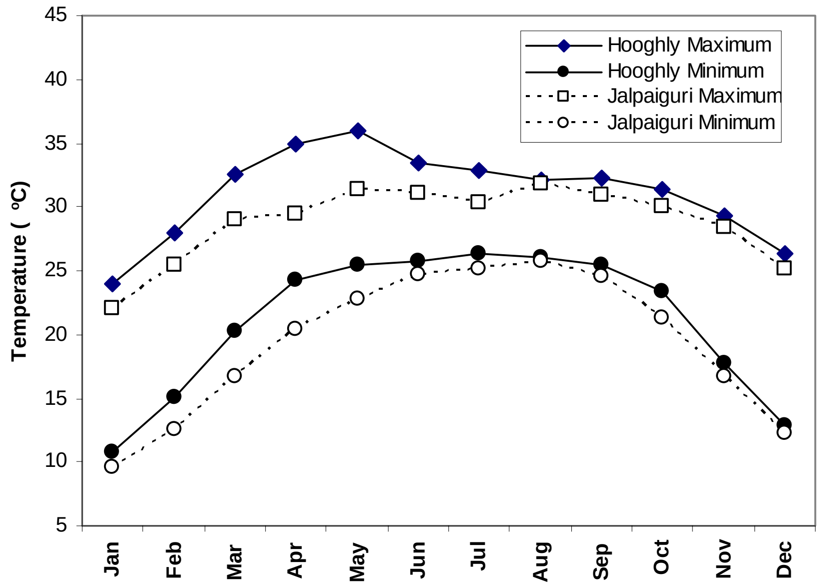


Figure 3. Mean monthly maximum & minimum temperatures of Hooghly and Jalpaiguri in North of West Bengal.

CROPPING SYSTEMS PRACTICED IN WEST BENGAL

Declining profitability has compelled farmers to diversify their existing traditional cropping system by introducing new crops for increased income by maximizing land use. The kharif (wet season) rice-potato-boro (summer season) rice is the emerging cropping system in the Eastern Gangetic Plains (Bangladesh and West Bengal, India) for rural poor people. In addition to this, other cropping systems are also practiced in West Bengal (Table 1). The cropping systems in the rain-fed areas are different from those in the irrigated areas. All crops in the different systems except kharif rice and mustard require irrigation. Kharif rice and mustard are grown in winter during the rainy season. Wells are the major source of water for irrigation.

Table 1. Cropping systems practiced in the West Bengal, India.

S. No.	Cropping Systems
1	Kharif Rice-Boro Rice (boro rice in irrigated lands)
2	Kharif Rice-Potato-Jute (potato in irrigated lands)
3	Kharif Rice-Potato-Sesame (potato in irrigated lands)
4	Kharif Rice-Mustard (mustard under restricted irrigation)
5	Kharif Rice-Potato-Boro Rice (potato/boro rice in irrigated lands)
6	Kharif Rice-Potato-Vegetable (potato/vegetable in irrigated lands)
7	Kahrif Rice-Potato-Groundnut (potato/groundnut in irrigated lands)

The land use patterns defined by the growing periods of rice-, wheat- and potato-based cropping systems in the sub-tropical lowland of West Bengal are presented in Figure 4 (Bardhan Roy *et al.*1999). The Kharif rice is grown in the wet season and the boro rice is planted in spring/summer.

The potato is cultivated during the winter season between November/December to February/March. The kharif rice and wheat both remain about 140 days in the field whereas potato is a 90-day crop. The boro rice grown by traditional practices remains 100 days in the field. The crops in the systems are selected based on their adaptability to the environment, accessibility to water, availability of better seed, improved technologies and better market prices.

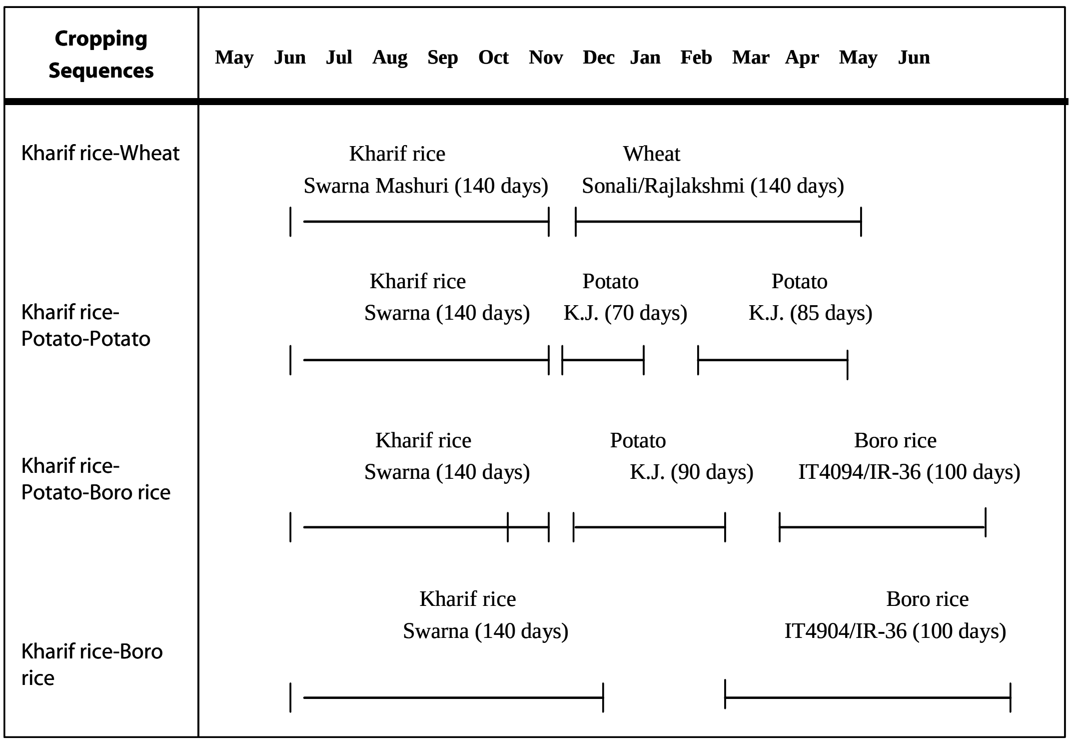


Figure 4. Predominant cropping sequences in the Eastern Indo-Gangetic Plains of India.

AGRICULTURAL DIVERSIFICATION IN WEST BENGAL

India's food grain production has increased significantly over the years, and there is evidence that food consumption patterns are changing from grains towards high value foodstuffs such as vegetables, fruits, milk, meat and eggs. Factors such as rainfall, temperature, photoperiod, soil nutrients, availability of location-specific appropriate technologies, socio-economic conditions of farmers and marketing opportunities define the cropping pattern in a region. The increased income and enhanced food security are the important factors in adopting new diversified cropping system. For example, the wide adoption of boro rice and groundnut due to increased productivity and enhanced income for farmers in some parts of West Bengal has changed the cropping pattern from kharif rice-jute and kharif rice-mustard to kharif rice-potato-boro rice and kharif rice-potato-groundnut cropping systems (Bardhan Roy *et al.*, 1999, 2004). The increase in potato area and production in the last decade can be attributed to the crop's ability to produce large amounts of food in a short time and generate an income greater than other crops grown during the same period. Crop diversification facilitates effective land use, efficient on-farm management systems, optimum water use, effective and efficient integrated pest management and judicious use of nutrients. Diversification currently aims to increase productivity by the introduction into the rotations of alternate vegetables, field crops, fruit crops, flowers and other options (Modgal 1998), but ideally, diversification should also aim at improving diet diversity and nutritional balance for the farm families and the local population dependent on them.

LIMITATIONS FOR INTENSIFICATION OF POTATO-BORO RICE SYSTEMS

The farmers in West Bengal would like to grow three crops in a year, kharif rice, potato and boro rice in sequence, to earn more money from irrigated land by enhanced production of potato and boro rice. However, most farmers are not able to practice this cropping system and obtain the potential yields and benefits of boro rice or potato due to the following constraints:

i) The harvesting of potato at full maturity delays the transplanting of boro rice, which automatically reduces the boro grain yield.
ii) Harvesting of the potato crop before maturity for timely transplanting of boro rice reduces the potato yield.
iii) The delayed transplanting of boro rice after potato enhances the water requirement of the crop due to a delayed maturity. Water is a major input for boro rice because it is cultivated in the spring-summer period. Traditionally, boro rice planted after Kharif rice is harvested in late April whereas boro rice planted after potato takes 20-25 extra days to mature, and the higher temperature in May increases the water requirement of the crop.
iv) The boro rice planted after potato in the traditional system has a matures later and is more prone to attack by insects and diseases due to increased exposure to higher temperatures. Therefore, farmers have to spend more money for pesticides to control pests and diseases on boro rice planted after potato.
v) The frequent hail and rainstorms during May damage the boro rice crop planted after potato, while the boro rice crop maturing in April escapes from such abiotic stress.

The resource poor farmers that constitute the majority of farming families in West Bengal are not able to accommodate the cultivation of potatoes in the cropping sequence because of constraints imposed by small landholdings. However, all farmers having irrigation facilities are curious about growing potato because this is an important cash crop in the region. Recognizing the magnitude of the above mentioned constraints and the importance of potato and boro rice in the cropping system, the Department of Agriculture of the Government of West Bengal and the International Potato Center undertook a study to evaluate and validate an innovative double-transplanting technology of boro rice and improved management of existing resources to obtain higher productivity and profitability of the kharif rice-potato-boro rice system, without sacrificing the yield of either potato or boro rice. The double-transplanting is a technique of establishment of the same rice tillers twice to complete their life cycle. This age-old technique is practiced by farmers of Eastern India with their traditional long duration (145-150 days) or photoperiod sensitive kharif rice varieties, as a contingency measure to recover the crop damaged by floods during the rainy season. However, the application of the double-transplanting technique has never been practiced for the cultivation of boro rice, particularly in the rice-potato cropping system.

OBJECTIVES

The main objective of the present work was to assess the potential of the double-transplanting technology of boro rice to increase the productivity and profitability of the kharif rice (wet season)-potato-boro (summer) rice cropping system, for improved livelihoods and enhanced food security of rural farmers in the Eastern Indo-Gangetic Plains of India.

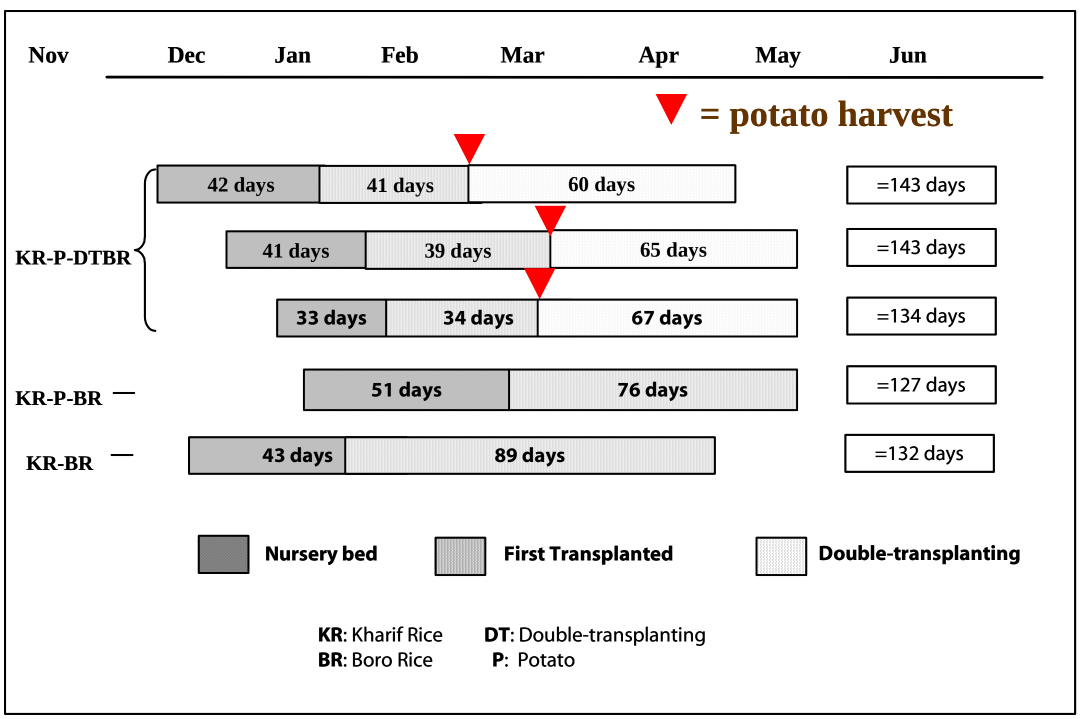
SPECIFIC OBJECTIVES

- To evaluate and validate agronomic practices of double-transplanting technology of boro rice in the kharif rice-potato-boro rice cropping system.
- To increase the productivity and profitability of the existing kharif rice-potato-boro rice cropping system by introducing the double-transplanting of boro rice and an efficient utilization of natural resources
- To increase the area of potato cultivation in the smallholdings without affecting the production of rice required by the domestic demand.
- To enhance stakeholders' crop-management capacity by providing on-farm training to implement the double-transplanting technology successfully at farm-level.
- To study the cost-benefit ratio of the double-transplanting technology and its adoption by the end users.

MATERIALS and METHODS

The double-transplanting technology of boro rice in the kharif rice-potato-boro rice system was evaluated in farmer's fields. Three different cropping systems were compared: a) novel kharif rice-potato-double-transplanted boro rice system; b) traditional kahrif rice-potato-boro rice system; and c) traditional kharif rice-boro rice. In all systems that included potato, the variety Kufri Jyoti was planted, which is a popular variety in West Bengal, planted by more than 80% of potato-growing farmers. This variety is resistant to late blight and matures in 90 day after planting. The Kufri Jyoti potato was planted at three different dates from November 23 to December 15. The short duration rice variety IET 4094, maturing in 132-145 days, was planted for boro cultivation and the rice variety Swarna maturing in 145 days was planted for the kharif season. The boro rice nurseries for double-transplanting were seeded at three different dates. The first, second and third seed sowings in nursery beds were done between November 30 to December 9, December 10-20, and December 21-31 respectively, to find out the optimum growing period for maximum productivity. The sowing dates differed among the farmers and between years and therefore the range of sowing dates are provided. The boro seeding in nursery beds was done one week after the potato planting date. Boro rice in the traditional system of kharif rice-potato-boro rice system was seeded between December 27 to January 15 whereas in the kharif rice-boro rice system, seeding of boro rice was carried out between November 25 to December 20. The sowing dates and the number of days from nursery bed to maturity required by boro rice in the three compared systems are shown in Figure 5.

Figure 5. Period from seeding to maturity of boro rice in different systems.



The process of double-transplanting of boro rice was as follows:

- Rice seed was sown in the nursery bed in December, a week after potato planting,

- 45-day-old rice seedlings were uprooted from nursery beds and transplanted into a small plot. This was the first transplanting. The seedlings were transplanted at 15x15 cm spacing with 10 seedlings per hill. The ratio of area covered from nursery to the first transplanted plot was about 1:3,
- From the first transplanted plot, 35-40-day-old rice tillers were uprooted and transplanted for a second time into the main field vacated by the potato harvest. The tillers were transplanted at 20x15 cm row to row and plant to plant spacing with five tillers per hill. The split tillers planted in the main field covered 8 times the area of the first transplanted plot.
- The mature boro rice was harvested 60-65 days after the second transplanting.

The first transplanting of seedlings into small plots was carried out between January 15and February 10 according of the date of seeding in the nursery beds. The second transplanting, this time into the main fields vacated after potato harvest, was done 40-42 days after the first transplanting. In the traditional cropping system of kharif rice-potato-boro rice, nearly 50-day-old seedlings were directly transplanted from nursery beds into the main fields following potato harvest. This single transplanting is done sometime between February 22 and March 5. The harvesting of potato at maturity delays the establishment of boro rice as compared to the kharif rice-boro rice cropping pattern, in which the boro seedlings are transplanted from nursery beds to the main fields sometime between January 15 and February 10. In this system the boro rice is transplanted earlier because kharif rice is harvested in November/December, vacating the fields for a timely seeding of the boro crop. In the kharif rice-boro rice cropping system of our trial, the boro rice seedlings were transplanted from nursery beds to the main fields between January 15 to February 10 corresponding to the first transplanting in the double-transplanting system.

FERTILIZER APPLICATION

For potato cultivation, fertilizers were applied at the rate of 200:150:150 kg/ha NPK. Half of the nitrogen was applied during field preparation and the remaining half was incorporated at earthing-up time. Full amounts of P and K fertilizers were incorporated as a basal application. In the case of the double-transplanting of boro rice, 30:15:15 kg/ha of NPK were applied for the first transplanting and 60:0:63 kg/ha of NPK were applied to the main field at the second transplanting. In the traditional kharif rice-potato-boro rice system, 40:0:40 kg/ha of NPK were applied to the transplanted boro rice after potato harvest. A rate of 120:60:60 kg/ha of NPK was applied to the boro rice in the kharif rice-boro rice cropping system. For kharif rice in all three cropping systems, the fertilizer dose was 60:30:30 kg/ha of NPK.

COST-BENEFIT ANALYSIS OF CROP PRODUCTION IN THE DIFFERENT SYSTEMS

Information on seed cost, fertilizers including farm-yard manure, chemicals, irrigation and labor utilized for boro cultivation in the three different cropping systems were recorded to calculate the cost of production. Percentage contribution of different cost components to total costs of boro rice production from double-transplanted and traditionally transplanted systems were analyzed from data from farmers' fields in three locations i.e. Hooghly and Burdwan districts in southwest Bengal and Jalpaiguri district in northwest Bengal.

The field data of 16 on-farm participatory trials of kharif-rice-potato-boro rice, kharif-rice-potato-double-transplanted rice and kharif rice-boro rice each conducted at different sites during 2002-2005 were collected to analyze the productivity and the cost-benefit ratio of different cropping systems. Productivity was calculated by averaging grain yields of rice and tuber yield of three crop cuttings from each participating farmer field. The gross value of potato and rice including straw were calculated based on the market price prevailing at the time of harvest.

ASSESSMENT OF THE IMPACT OF THE DOUBLE-TRANSPLANTING TECHNOLOGY

The impact of the double-transplanting technology of boro rice on the kharif rice-potato-boro rice cropping system in West Bengal was assessed by: a) interviewing the participatory farmers, b) group discussion with the non-participatory farmers who adopted the technology and c) field visits at the time of standing crops.

CAPACITY BUILDING OF STAKEHOLDERS

Field training at different growing stages of potato and boro rice were conducted at participating sites in Hooghly and Burdwan districts in southwest Bengal and in Jalpaiguri and Cooch Bihar districts in northwest Bengal. Stakeholders such as farmers, extension workers, members of the Local Government Body of Panchayat village, non-governmental organizations, farmers' cooperative societies providing inputs and local media were trained. Field demonstrations were also organized to explain the procedures and different steps of the double-transplanting technology in the fields.

RESULTS and DISCUSSION

The introduction of the double-transplanting technology in West Bengal was assessed from different angles to avoid future bottlenecks in its widespread adoption. The following sections describe how this technology competes for scarce land resources, how it affected yield and yield components, together with a comparative analysis of the components of the production costs and net returns. At the end of the section, an analysis of the initial adoption is presented.

AREA COVERED AT DIFFERENT STAGES OF THE DOUBLE-TRANSPLANTING OF BORO RICE

The results of the field trials indicated that under different dates of seed sowing, the seedlings from nursery beds covered three times the area at the first transplanting plots (Table 2). However, at the second transplanting, the extent of the area covered by the split tillers coming from the first transplant plots varied accordingly to the original sowing date. In the case of the November-sown boro rice nursery, the split tillers from the first transplanted plot covered six times the supplying area in the second transplanting. In the December-sown crop, the delayed seeding in the nursery bed and the successive delay of the first transplanting into a small plot meant that the split tillers covered more area when second-transplanted into the main field. The overall ratios of area covered from nursery bed to main field were 1:18, 1:24 and 1:24 for the 1st, 2nd and 3rd sowing dates, respectively. This indicates that the moderate temperatures in late December and early January enhanced the vegetative growth of tillers. Following the first transplanting, the crop remained nearly 40 days in an active tillering stage. During this period the plants attained 100% vegetative tiller growth and this contributed to the higher area coverage obtained in the second transplanting. The multiplication rate of the vegetative tillers from nursery bed to main field via double-transplanting was 12% to 50% higher than the 1:16 ratio observed in the traditional kharif rice-potato-boro rice and kharif rice-boro rice systems. The results revealed that compared to the traditional boro transplanting, the double-transplanting technology is more efficient in enhancing vegetative growth to cover more crop area in the main fields.

Seed sowing date in beds	Seed bed to first transplanting	First transplanting to second transplanting	Seed bed to second transplanting via first transplanting
1st Sowing	1:3	1:6	1:18
2nd Sowing	1:3	1:8	1:24
3rd Sowing	1:3	1:8	1:24

Table 2. Ratio of area covered by different stages of double-transplanting technology. (Values in table are mean of three years).

Ist sowing: November 30– December 9, IInd sowing: December 10-20, IIIrd sowing : December 21-31.

EFFECT OF DOUBLE-TRANSPLANTING ON THE YIELD OF BORO RICE PLANTED AFTER THE POTATO HARVEST

Traditionally, boro rice cultivation starts with nursery seeding in mid-November to early December. However, seeding in the nursery often continues up to the end of December because: a) canal water is discharged from mid-December to the end of December and many farmers are completely dependent on this water, b) the farmers who intend to grow boro rice after potato have to delay the sowing of nursery so that 50-day-old seedlings can be transplanted directly into the field vacated by the potato harvest, and c) the delayed harvest of kharif rice in the lowlands postpones the release of land until late November or early December and thereby delays the sowing of nursery beds for boro rice.

Seeding of boro rice in the nursery beds after mid-November produces lower grain yields. The delayed seeding in nursery beds beyond November shortens the vegetative phase of boro rice in response to increases in temperature. The reduction of grain yield of boro rice in the kharif rice-potato-boro rice system is due to the shortening of its growing period. Thakur *et al.* (2003) reported that in Bihar, highest boro rice yield was achieved by seeding rice in the nursery prior to November 20. Similar trends have also been observed in West Bengal. It may be hypothesized that cold conditions extend the vegetative growing period of boro rice, contributing to greater grain yield from early sowings. However, the results of on-farm trials over a 4-year period revealed that the double-transplanting of boro rice after the harvesting of potato at full maturity enhanced the grain yield of the rice crop, compensating for the delay in sowing. The highest grain yield was obtained from the November 30 nursery bed sowing. Yield declined gradually with delayed sowing of seed in the nursery bed (Table 3). In spite of this declining trend, boro rice sown in the nurseries between November 30 and December 9 and December 10 to 20 and then double-transplanted after the potato harvest produced 49% and 34% higher grain yields, respectively, compared to boro rice yield obtained from the third date of nursery seeding in the traditional kharif rice-potato-boro rice system. Also, the grain yield of the double-transplanted boro rice was on a par with the yields obtained in the kharif rice-boro rice system, when the seeding of the former in the nursery was done between November 30 and December 20. (Singh *et al.* 2003; Thakur *et al.* 2003) also reported higher grain yields of double-transplanted boro rice from early sown nursery beds in Assam and North Bihar, areas that have climatic conditions similar to West Bengal. As grain yield of boro rice is reduced by delayed seeding in the nursery beds, the results of field trials suggest that farmers should practice early sowing of rice in the nursery beds to maximize the benefits of the double-transplanting technique. In the traditional systems involving a potato crop, the farmers are not able to grow rice in the nurseries early enough for a timely transplant to the main field after the potato harvest.

Table 3. Comparative grain yield of boro rice in double-transplanted and traditional systems in Hooghly district, West Bengal.

Cropping systems	Sowing date in nursery beds	Mean grain yield (t/ha)
		Second transplanting
Kharif rice-potato-double-transplanted boro rice	1st Sowing 2nd Sowing 3rd Sowing	5.70 5.13 3.81
Kharif rice-potato boro rice (traditional system)	Dec. 27– Jan. 15	
Kharif rice-boro rice (traditional)	Nov. 25 – Dec. 20	

sowing: November 30 – December 9, 2nd sowing: December 10-20, 3rd sowing: December 21-31.

FACTORS CONTRIBUTING TO HIGHER GRAIN YIELD OF DOUBLE-TRANSPLANTED BORO RICE

Larger panicles and a higher number of filled grains per panicle in double-transplanted boro rice compared to panicles in the traditional system of boro cultivation, contributed to enhanced yield. The length of the panicles in the double-transplanted boro rice increased by 8%, whereas the number of filled grain/panicle were 18% and 16% higher (Table 4), in the same variety. In boro rice, the number of effective tillers and the panicle length are negatively correlated under different sowing dates (Bardhan Roy and Biswas, 1982). After the second transplanting, the split tillers do not get sufficient time to produce secondary tillers and therefore each tiller acts like a primary tiller. Consequently, the panicle length of double-transplanted tillers is greater than the panicle length of tillers that have been transplanted just once. It shows that the development of secondary tillers from primary tillers in traditional systems (i.e. kharif rice-potato-boro rice and kharif rice-boro rice) reduces the panicle length. In the double-transplanted tillers the photosynthates are translocated to just one or two panicles for filling up of grains. Therefore, the double-transplanted boro rice produces more filled grains per panicle. Further research is required to exploit the maximum yield potential of double-transplanted rice by adjusting the crop geometry.

Cropping system	Panicle length (cm)	Effective tillers/plant	Filled grain number/panicle
Kharif rice-potato-double-transplanted boro rice	26	13	116
Kharif rice-potato-boro rice	24	14	98
Kharif rice-boro rice	24	21	100

Table 4. Comparative data of yield contributing factors on boro rice in different cropping systems.

Data in table are average of 4 years; Total number of participants – 16

COMPARATIVE INPUT COSTS IN DOUBLE-TRANSPLANTED AND TRADITIONALLY TRANSPLANTED BORO RICE

Rice seed, fertilizers, chemicals, labor and irrigation costs were the major components considered for the analysis of production costs. The cost of rice seed used for the nursery bed was comparatively lower for the double-transplanted technique than for the traditional practice, as shown in Figure 6. The seed requirement in the double-transplanted system was reduced due to the use of split tillers from the first transplanted plot for the second transplanting into the main field after potato. The tillers in the first transplanted plot got 40 additional days to multiply and that reduces the nursery seed requirement compared to the traditional systems. In the traditional kharif rice-potato-boro systems, more rice seed is required to cover similar areas planted by the double-transplanting. Also in the traditional systems, the sowing of the rice nursery in the last week of December increases the mortality rate of plantlets. The lower temperatures during the early part of January (about 10^{0}C) inhibit seedling growth and often kill the germinated plants (Bardhan Roy and Biswas 1980).

Cost of fertilizer was 17% of total costs in the double-transplanted system compared to 9% in the traditional kharif rice-potato-boro rice system. In double-transplanting, the fertilizer was applied both at the first transplanted plot as well as to the second transplanted stand in the main field (Figure 6). In the kharif rice-potato-boro rice system a lower dose of fertilizer is applied to the boro rice after potato harvest due to the uncertainty of a satisfactory yield, caused by late transplanting. Likely residual effects of the fertilizer applied to potato are also considered. On the other hand, the fertilizer requirement was highest in the kharif rice-boro system, as the boro crop planted after kharif rice does not receive any significant residual fertilizers from the previous crop. The cost of plant protection chemicals was 3.0% of the total cost in the double-transplanted boro rice compared to 4.5% and 4.0% in kharif rice-potato-boro rice and kharif rice-boro rice, respectively (Figure 6). The delayed maturity of boro rice in the kharif rice-potato-boro rice system, caused by the late transplanting after potato, make the boro rice more prone to pest and disease incidences due to the favorable environmental condition for their growth and multiplication.

The labor cost was higher in double-transplanted boro rice compared to traditional kharif rice-potato-boro rice system as rice is transplanted twice in the former system (Figure 6). However, the total labor cost of double-transplanted rice was similar to the kharif rice-boro rice costs since boro rice occupied the main field for a longer period in the traditional system and more labour was needed for cultural operations. Weeds are a greater problem in boro rice planted after kharif rice because the field after kharif rice remains fallow for almost 2 months. On the other hand, weeds do not pose a serious problem to boro rice planted by the double-transplanted technique after potato as most weeds are removed at the time of potato harvest.

The comparative cost of boro rice irrigation was higher (25%) in the traditional kharif rice-potato-boro rice system due to the late maturing of boro rice. The boro rice required frequent (almost every other day) irrigation in May due to enhanced evapotranspiration caused by high temperatures. The irrigation cost for double-transplanted boro rice was 15% of total costs compared to 11% for boro rice grown in the traditional system after kharif rice. The double-transplanted boro rice technique was practiced in potato fields having sandy loam soils whereas the traditional kharif rice-boro rice system is practiced in clay-loam lowland soils. Clay-loam soils have more water-holding capacity than sandy loam soils, hence less irrigation is required for boro rice planted in the lowlands. Potatoes are not planted in hard lowland soils due to uneconomic production.

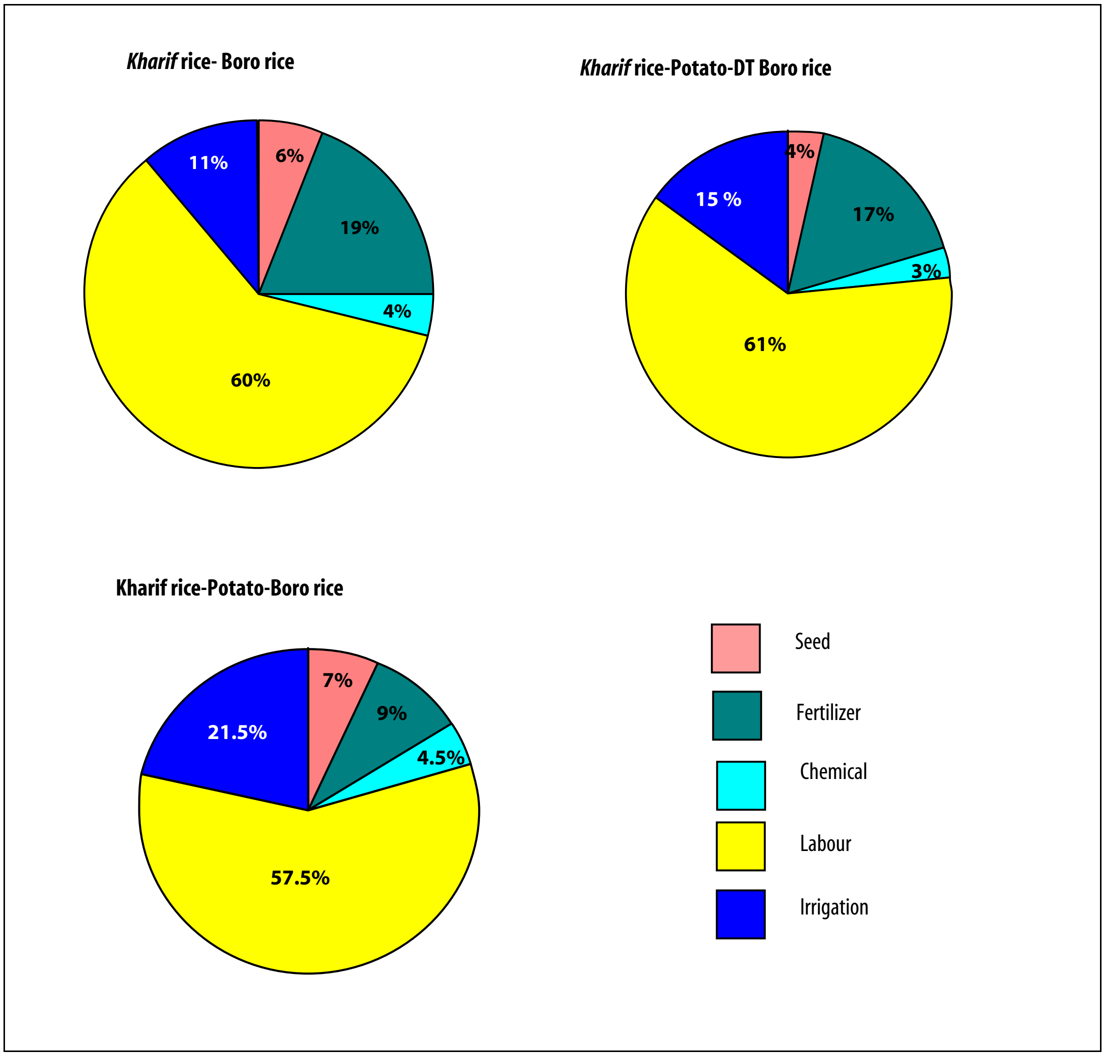


Figure 6. Percent contribution of different components to cost of production of boro (summer) rice in different cropping systems. (DT=double-transplanted).

COST-BENEFIT RATIO OF DIFFERENT CROPPING SYSTEMS

To assess the profitability of different cropping system the data on cost of production, yield, gross value of produce and net return from 3 years (2002-2005) on-farm participatory trials conducted in different locations were analyzed (Table 5).

The mean grain yields of kharif rice were similar in both kharif rice-potato-boro rice and kharif rice-potato-double-transplanted boro rice systems. Also, potato yields in the same two cropping systems were similar due to comparable growing conditions. The kharif rice does not affect potato establishment and similarly the potato does not interfere with the kharif rice cultivation because these two crops have different growing periods. As to boro rice, the grain yield of the double-transplanted crop was 5.32 t/ha; nearly 38% higher than the 3.86 t/ha obtained in the traditionally grown kharif rice-potato-boro rice system. The grain yield of double-transplanted boro rice after potato and boro rice yield after kharif rice were at par.

The cost of production of both kharif rice and potato remained similar (US$293 and US$906/ha respectively) in all three cropping systems (Table 5). On the other hand, the cost of production of double-transplanted boro rice differed with the costs of boro rice planted in the traditional practice. It was 14% higher in double-transplanting compared to the cost of boro rice in the kharif rice-potato-boro rice system. However, the gross return from the double-transplanted boro rice was 41% higher compared to traditionally grown boro rice after potato. Thus, double-transplanting enhanced gross return by 41% in spite of an additional 14% cost of production over the boro rice grown in the traditional way after potato. Furthermore, the cost of double-transplanted boro rice was 11% lower than the boro rice grown in fallow fields after kharif rice. The increased use of fertilizers, chemicals and seed had raised the cost of production of boro rice in the kharif rice-boro rice cropping system.

The net return from the kharif rice-potato-double-transplanted boro rice was US$1039, which was 18% higher than the US$884 net return from the kharif rice-potato-boro rice system and 178% higher than the US$373 return from the kharif rice-boro rice system (Table 5). The double-transplanted boro rice contributed 32% to the total income of the kharif rice-potato-double-transplanted rice system compared to the 20% contribution of boro rice in the kharif rice-potato-boro rice system. It shows that the double-transplanting technology of boro rice enhanced net return/ha. Similar results were obtained by a study conducted earlier in West Bengal (Anon. 2003b).

As shown in Table 5, potato plays a dominant role in the generation of income in the rice-potato-based cropping system. Farmers of West Bengal prefer to grow both potato and boro rice in the same land where irrigation is available. However, due to the uneconomic grain yield of boro rice in the traditional kharif rice-potato-boro rice system, the area under boro rice is declining. The introduction of double-transplanting technology in the traditional cropping systems (kharif rice-potato-boro rice and kharif rice-boro rice) would increase the productivity of the overall system, enhancing the income and well being of poor farmers of West Bengal.

Cropping systems	Yield (t/ha)	Cost of production (US$/ha	Gross value of product (US$/ha)	Net return (US$/ha)
A. Kharif rice-potato-DT boro rice				
i) Kharif rice	4.51	293	394	101
ii) Potato	27.09	906	1509	603
iii) Double-transplanted boro rice	5.32	333	668	335
Total net return from system	------	**1533**	**2572**	**1039**
B. Kharif rice-potato-boro rice (traditional cropping system)				
i) Kharif rice	4.51	293	394	101
ii) Potato	27.09	906	1509	603
iii) Boro rice	3.86	291	471	180
Total net return from system	------	**1491**	**2375**	**884**
C. Kharif rice-boro rice (traditional cropping system)				
i) Kharif rice	4.51	293	394	101
ii) Boro rice	5.09	369	641	272
Total net return from system	------	**662**	**1036**	**373**

Table 5. Productivity and cost-benefit ratio of different cropping systems in West Bengal.

ADOPTION OF DOUBLE-TRANSPLANTING RICE TECHNOLOGY IN WEST BENGAL

The introduction of double-transplanting technology of boro rice has provided an effective way for both potato and boro rice to grow in sequence, allowing for a better use of natural resources for enhanced and sustainable productivity and profitability of the system. The farmers were encouraged to adopt the kharif rice-potato-double-transplanted boro rice system by the reduced requirement of irrigation, seed and chemicals for boro cultivation and the overall increase in income from the system, shown in Figures 6 and 7. The timely harvest of boro rice allowed by the introduction of the new technology has reduced the effects of risk factors such as hailstorms, unusual rains and higher temperature at maturity stage. The traditional boro rice cultivation in the kharif rice-potato-boro rice system is affected by abiotic and biotic stresses due to delayed maturity. The double-transplanting of boro rice in the potato fallows was first evaluated in 2000-2001 in three on-farm participatory trials at two sites in Burdwan and Hooghly districts. These trials, which continued until 2002-2003, assessed the feasibility and economic viability of double-transplanting to enhance the productivity and profitability of the kharif rice-potato-boro rice cropping system. Based on the initial observations the participatory trials were extended to 14 farmers during 2003-04. Other farmers of the same and adjoining villages also introduced the double-transplanting technology after seeing the encouraging results from the fields of fellow farmers. The enhanced grain yield of boro rice planted after full maturity of the potato crop and the higher income from the overall cropping system promoted by the double-transplanting technology, encouraged confidence among the farmers of the region. In 2004-2005, forty-six farmers had incorporated the double-transplanting of boro rice in their farms. In addition to the old locations in southwest Bengal, two new sites in north Bengal were selected for validation of the technology at farm-level. Eleven farmers in Jalpaiguri and Cooch Behar districts tested the double-transplanting at their farms. The performance of the innovative technology created enthusiasm among the farmers and during 2005-2006, 203 farmers adopted it over 53 ha, at four sites in the state. The extent of adoption of double-transplanting of boro rice in the kharif rice-potato-boro rice cropping system in four districts is presented in Table 6.

Table 6. Net sown area, cropping intensity, area under boro rice/potato and adoption of double-transplanting (DT) in the project sites in West Bengal in 2005.

District	Net sown area (ha)	Cropping intensity (%)	Area (ha)		Area (ha) of crops at the project sites		No. of farmers adopting DT	Area (ha) under double-transplanting
	(1)	(1)	(1)	(1)	(2)	(2)	(2)	(2)
			Boro	**Potato**	**Boro**	**Potato**		
Burdwan	458,000	183	202,000	56,000	106	266	53	15
Hooghly	220,000	237	101,000	80,000	393	348	110	33
Jalpaigur	339,000	166	20,000	21,000	10	4	30	3
Cooch-Behar	254,000	194	21,000	26,000	120	250	10	2
Total	**1,271,000**	**-**	**344,000**	**183,000**	**629**	**868**	**203**	**53**

Source: 1 Economic Review, Development and Planning Department, Government of West Bengal. 2005-2006,
2 Field survey data of the project sites

Double-transplanting for boro rice has so far been adopted in 8.4% of the total area where boro rice is cultivated after potato in the four project sites. This has occurred within 2 years of its introduction through participatory on-farm trials (Table 6). The interaction with farmers in Hooghly district following the harvest of double-transplanted boro rice during 2005-2006 indicated the possibility of obtaining more than a 50% increase of double-transplanting in the boro rice area in 2006-2007. Involvement of the developmental agencies and extension services like the State Department of Agriculture, Village Panchayats, and leading non-governmental organizations engaged in rural development activities will speed up the dissemination of the technology to enhance food security and improve the livelihood of resource-poor farmers of West Bengal.

CONCLUSIONS

- Rural people of West Bengal, India, depend mostly on agriculture for their livelihood. Rice is a staple food and potato is an important cash crop for the communities. As such the area under potato and boro (spring-summer) rice has expanded over the decade.
- Farmers wish to grow both potato and boro rice in their same irrigated lands since both crops give higher productivity and more income compared to other crops grown during the same period, such as mustard/wheat and sesame.
- Cultivation of potato and boro rice in sequence in the same land affects productivity either of the two crops due to early harvest of potato or delayed planting of boro rice. The Department of Agriculture, West Bengal in collaboration with CIP evaluated for the first time the sustainability and viability of double-transplanting technology of boro rice in the rice-potato-boro rice system. The introduction of double-transplanting of boro rice has enabled the farmers to grow both potato and boro rice in sequence in the same land without sacrificing yields of either of the crops.
- The double-transplanting technology reduced the cost of seed, chemical and irrigation for boro rice cultivation compared to the traditional kharif rice-potato-boro rice system.
- The net return from the kharif rice-potato-double-transplanted boro rice was 18% higher than the traditional practice of cultivating kharif rice-potato-boro rice and 178% higher than the net return from the kharif rice-boro rice system.
- Intensification of potato production and introduction of double-transplanting of boro rice have improved the efficiency of utilization of natural resources such as water and nutrients, increased food availability, reduced hunger and poverty level, enhanced rural employment opportunities and lowered the health hazards by decreased pesticide use. The effects of abiotic risks such as hailstorms, unusual rains and higher temperature on the boro rice maturity have been reduced by the double-transplanting technique. Double-transplanting of boro rice in both districts helped to avoid both abiotic and biotic stresses and to produce higher grain yields in the rice-potato-boro rice system.
- The farmers who were not growing potato after kharif rice due to the risk of delayed transplanting of boro rice would be able to grow potato as an additional source of income. Also, some farmers who were not planting boro rice after the potato crop due to uneconomic returns from boro rice would now be able to grow it after potato by adopting the double-transplanting technology.
- Nearly 200 farmers have adopted the double-transplanting in 53 ha under kharif rice-potato-boro rice systems in four project sites in South and Northwest Bengal. The double-transplanting of boro rice after potato has emerged as a proven yield and

income enhancement technology. Its promotion by various rural developmental agencies such as the Department of Agriculture, Village Panchayats and non-governmental organizations will help to enhance food security and improve the livelihoods of poor farmers of West Bengal.

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