Validation and delivery of new technologies for increasing the productivity of flood-prone rice lands of South and Southeast Asia
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Foreword

Around 10 million ha of rice land in South and Southeast Asia are subjected to uncontrolled flooding and about 4 million ha are subjected to tidal flooding. Consequently, rice yields are low. In spite of recent advances in rice production technology, farmers in such areas did not get as much benefits as did their counterparts in the favorable areas. To improve the livelihood of the poor farmers in the flood-prone ecosystem, the project “Validation and delivery of new technologies for increasing the productivity of flood-prone rice lands of South and Southeast Asia” was conceived by IRRI in collaboration with national agricultural research and extension systems in Bangladesh, India, Sri Lanka, Thailand, and Vietnam. With assistance from the International Fund for Agricultural Development (IFAD), the project began operations in 1999 and ended in June 2004.

The main objectives of the project were 1) to conduct farmer participatory testing, adaptation, and productivity of improved cultivars; and 2) to test new resource management technologies and thus support dissemination of the most appropriate ones. The project activities identified location-specific appropriate production technologies for (i) boro (winter) rice crop in flood-prone areas, (ii) deepwater rice, (iii) rice in the coastal saline, and coastal nonsaline areas; and analyzed the farmers’ resource management practices and constraints to adoption of technologies. The results were made available to policymakers.

A good number of technologies have been identified for the flood-prone ecosystem through participatory on-farm research activities conducted by farmers and researchers in the participating countries. These technologies are already contributing to the food-security and economic well-being of the adopting farmers. Attempts are being made to scale these up through transfer of these technologies through mainstream national extension systems and nongovernment organizations. This volume includes Technical Advisory Notes (TAN) based on some of the promising technologies identified. The TANs have been prepared following the guidelines developed by IFAD. We hope that this publication will become a valuable source of information for development planners, researchers, and extension workers interested in improving the livelihood of resource-poor farmers in the flood-prone rice ecosystem.

IRRI is grateful to IFAD for the financial support given to implement the project activities.

RONALD P. CANTRELL
Director General
International Rice Research Institute
Acknowledgements

This publication is the result of excellent teamwork among a diverse group of people working in different places. We express our heartfelt thanks to the farmers who took keen interest in carefully testing and evaluating the various technologies. We are also thankful to the researchers, extension workers, and NGO partners for their hard work and high-quality support in implementing the project activities. We are grateful to the scientists who drafted some of the Technical Advisory Notes (TAN). We benefited much from the guidance and encouragement given by Dr. Mahabub Hossain, head of IRRI’s Social Sciences Division and Dr. Nigel Brett of IFAD. Dr. V. Pal Singh, former coordinator of the project, prepared the first TAN in this volume, which became the model of the succeeding issues. We thank him for this and for giving us technical advice in preparing the other TANs. We gratefully acknowledge the editorial assistance of Mr. Bill Hardy, Ms. Teresita Rola, and Mr. George Reyes of the Communication and Publications Services and the technical/administrative assistance of our colleagues in the Social Sciences Division.

M. Zainul Abedin
Ma. Romilee Bool
Summary

Millions of hectares of lowlands in South and Southeast Asia are subjected to annual flooding. Farmers in these areas had been using indigenous technologies to grow only one crop of rice per year. Improved practices are now available to the farmers for intensifying the cropping and growing better crops.

Technical summary

Rice farming intensification in flood prone rice lands has been demonstrated to be highly successful not only in terms of increased productivity and cropping intensity, but also in terms of increased income and better nutrition and social equity to the poor and landless, especially the women. A number of alternatives for mixed and relay cropping, bringing in legumes in the system and timely crop establishment and the management of natural resources at the farm and community level are available for a wider use in these ecologies.

Alternatives

Rice in the flood-prone areas is grown in two situations:

- Deepwater situation (stagnant flood); and

Deepwater rice

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This is an output of the project “Validation and Delivery of New Technologies for Increasing the Productivity of Flood-prone Ricelands of South and Southeast Asia” funded by the International Fund for Agricultural Development (IFAD) for the benefit of the rural poor. The views expressed are not necessarily those of IFAD.
Rainfed shallow lowlands (with flash flood).

A. Deepwater water situation (DWS; stagnant flood)

Rice Culture Options in DWS

1. Deepwater rice

Deepwater rice varieties can either be sown directly in the soil during the dry season (e.g. in Feb-Mar in India and Bangladesh) or transplanted in the fields during May before the floodwater accumulates. This crop is harvested in Nov-Dec.

Promising deepwater rice varieties:

For India - NDGR 70, NDGR 63, and Barh Avarodhi, Vaidehi; for Bangladesh - Habiganj Aman VIII, BR224-2B-2-5, PCR89114-B-R-2-2-2-1, IR60436, IR62653, and IR64588; for Vietnam - PCR92093-6-B-2, HTA89038-4B-2, MTL 225, MTL 221, MTL 275 and MTL 208.

2. Boro (summer) rice

After water recedes, the boro rice can be grown from November-December to Apr-May. Boro rice crop is usually a transplanted crop, but it can also be grown as direct seeded one in the wet soil.

Establishment of boro (summer) rice

- Prepare seedbed during Oct-Dec.
- Take steps to control yellowing in the seedlings.
- Prepare the field for transplanting.
- Transplant three to four seedlings per hill of four to six leaf stages by following the locally practiced spacing between plants and rows.

Promising Boro rice varieties:

- For Kuliarchar and Karimgonj, Bangladesh - BR4828-54-4-1-4-9, BR5877-21-2-3, and BRRI Dhan 29; for Bihar, India - Gautam, PSRM2-1-4B-1 5, IR59471-28-20-20-1, Richharia, Dhan Laxmi; for Assam, India - Panjasaii, Sonamukhi, Banglami, Joymati and IR 50.

If yellowing appears in Boro seedlings:
- Add organic matter to the seedbed
- Irrigate the seedbed in the night and drain out the water in the morning.
- Shake-off the dew drops from the leaf tips.
- Use low plastic tunnel.

3. Relay cropping of boro rice-deepwater rice

In certain areas, a delay in boro harvesting or early floods after boro crop delays the planting of next deepwater rice. For such areas, the integration of boro-deepwater rice farming allows timely crop establishment, saves expenses on crop establishment and increases farm productivity and profits. This is possible by direct seeding (45 kg ha\(^{-1}\)) of sprouted seeds of deepwater rice in a standing crop of boro rice (which is usually a transplanted crop) 15 d before the harvesting of boro rice.
The pure-stand boro crop (variety Gautam) had given an average grain yield of 7.1 t ha\(^{-1}\) in the growth duration of 195 d.

By integrating boro with deepwater rice (variety Vaidehi), an additional rice grain yield of 1.5 to 2.5 t ha\(^{-1}\) has been consistently obtained without any other inputs.

The total crop duration for the two crops is around 350 d.

This technique is helpful in increasing total rice production in flood-prone lands.

4. Ahu/aus (pre monsoon) rice

In some places, boro rice cultivation is not possible due to very low temperature or irrigation inadequacy. Such areas can grow short duration pre monsoon ahu/aus rice by direct seeding. The crop is sown in Feb/Mar and harvested in May before the planting of next deepwater (bao/aman) rice. Ahu/aus rice can also be grown as a mixed crop with bao/aman rice as in explained next.

**Promising ahu/aus rice varieties:**

The promising ahu rice varieties are generally short duration varieties, maturing in about 100 d duration. For India such varieties include Prabhat, Turanta dhan, Sneha, Ghanteswari, Heera, Luit, and Kapilee. For Bangladesh, the varieties are Hashikalmi, Kataktara, BR-14, and BR-3; and for Vietnam are MTL 141, MTL 300, and IR 56279.

5. Mixed cropping of ahu/aus (pre monsoon) and bao/aman (deepwater during monsoon) rice crops

In areas where boro rice cropping is not feasible, and pure ahu/aus crop delays the planting of successive deepwater rice, two rice crops are still possible by mixed cropping of ahu/aus and bao/aman rice. In this new system, mixed seeds of rice specific to these seasons are directly sown during Feb-Mar so that the short duration ahu/aus rice can be harvested (usually in May) before the occurrence of flood and the bao/aman continues thereafter.

- Prepare the land during Feb-Mar.
- Apply 50% nitrogen as neem extract coated urea (NECU) and full dose of phosphorus and potassium at final ploughing.
- Sow the seed mixture of ahu/aus + bao/aman at 4:1 ratio (total 70-80 kg ha\(^{-1}\)).

During Feb-Mar, crop mixtures of ahu/aus and bao/aman are broadcast in the dry field so that ahu/aus can be harvested before flooding in DWS.

- Cover the seed by a shallow ploughing and laddering.
- Apply the remaining 50% nitrogen as NECU or farmyard manure (FYM) incubated urea at maximum tillering.

6. Deepwater rice + mungbean or other cropping systems (pulses, oilseeds, vegetables)

In places where mixed cropping of deepwater rice either with ahu/aus or boro rice is neither feasible nor preferred, the cropping intensity can still be increased by growing an upland crop, e.g. mungbean with rice. The basis of this mixed cropping is that mungbean, being a short duration crop, when seeded together with the deepwater rice, usually in Mar, completes its life cycle in about 2 months time and is harvested before the onset of the rainy season. In this period, rice usually grows very slowly for the lack of soil moisture,
whereas the mungbean does not suffer from moisture shortage as it is a hardy crop and thus, there is minimal competition between the two crops.

- Deepwater rice and mungbean are very compatible in mixed cropping.
- The two crops can be direct seeded together at the beginning of the season.
- Seed rates of the mixed crops are adjusted to 80% of the normal for rice (e.g. 80 kg ha\(^{-1}\)) and 25% of the recommended seed rate for mungbean.
- An average rice grain yield of not more than 3.0 t ha\(^{-1}\) is usually recorded when deepwater rice is grown alone.
- In the mixed cropping, the grain yield of deepwater rice is slightly reduced (about 2.8 t ha\(^{-1}\)), a 0.2 t ha\(^{-1}\) reduction from a sole rice crop.
- However, the mungbean grain yield of 0.36 t ha\(^{-1}\) more than compensates the rice productivity loss, reaching the total rice equivalent yield of both crops (deepwater rice + mungbean) in mixed cropping to 4.60 t ha\(^{-1}\).
- Thus, there is an over all increase in rice grain yield by 1.50 t ha\(^{-1}\) over the monoculture yield of deepwater rice.
- In other places, such as Eastern Uttar Pradesh (U.P., India), where rice + mungbean is not feasible, the productivity of flood prone lands could be intensified by the adoption of other appropriate cropping systems such as lentil or mustard-deepwater rice cropping systems. In this case, lentil or mustard is sown immediately after the recession of floodwater and the deepwater rice is sown in the standing lentil crop, usually in late Mar/early Apr, or after harvesting of lentil or mustard crop.
- A similar cropping system, where a double-cropped rice system (high yielding varieties + deepwater rice) is followed by upland crops (mungbean, groundnut, maize or watermelon) is very feasible in Vietnam.

Rice yields of 8.8 t ha\(^{-1}\) (4.2 t ha\(^{-1}\) in summer autumn season and 4.6 t ha\(^{-1}\) in Autumn-winter season) has been realized in addition to mungbean yield of 1.45 t ha\(^{-1}\) or groundnut yield of 1.85 t ha\(^{-1}\) throughout Tra Vinh Province of Vietnam.

Methods of rice crop establishment and management (DWS)

Direct-seeded rice

- Prepare the fields well before the onset of monsoon by repeated cross ploughing.
- Prepare neem extract-coated urea (NECU) using a locally available neem extract.
- Apply 50% of nitrogen as NECU and mix in the soil at final ploughing or apply full dose of nitrogen as NECU at sowing.
- Drill the seeds in rows 25 cm apart. Alternatively, broadcast seeds at 90-100 kg ha\(^{-1}\) depending upon the situation. Apply 50% of nitrogen as NECU at tillering stage if water regime is favorable.

Preparation of neem extract-coated urea

Add 10 ml of neem extract (available locally) to 1kg of urea. Mix the extract and urea with hands until urea becomes pink.
- Remove weeds by hand or bindha or ladder (patta) when the seedlings are 30-35 d-old.

Transplanted rice

- Prepare the seedbed and raise seedlings for about 35-45 d before the transplanting schedule.
  - Apply fertilizer in the nursery at least two weeks before pulling the seedlings for transplanting.
  - Apply all the recommended NPK as basal dose in the main field at the time of final puddling and mix with the soil.

- Keep the uprooted seedlings in fresh running water for 18-24 h before transplanting. This improves the survival percentage of the crop.
- Transplant 35-45 d-old seedlings with five to six seedlings hill⁻¹.

B. Rainfed shallow lowlands (RSL; flash flooded)

Heavy monsoon showers during Jun-Aug cause water stagnation up to 50 cm depth. These areas are also sometimes affected by flash floods. As a result, timely transplanting is not possible and standing crops are damaged. The options for growing rice in such situations are the following:

- Delayed transplanting using aged seedlings of long duration (160 d), traditional photoperiod-sensitive varieties such as Manohar sali, etc.
- Post-flood broadcast of sprouted seeds on wet soil of very early maturing (70-85 d) varieties.

### TIP
Sow the seed when the soil has adequate moisture. The soil is ready for sowing when pressing between fingers can break a piece of clod.

#### Seedbed preparation

1. Seedbed area should be 1/10 of the main field.
2. Add organic matter to the seedbed.
3. Puddle the bed and level it properly.
4. Prepare strip beds of 10m x 1.25m.
5. Apply 80g urea, 80g SSP and 40 g MOP in each bed.
6. Soak seeds for 24 h (48 h for Boro) and incubate for 48 h.
7. Sow 1kg of sprouted seeds uniformly on each seedbed.
Direct sowing

1. Delayed transplanting
   - Seedbed preparation and seedling raising start in Jun-Jul with available rainwater.
   - Apply all the locally recommended dose of NPK at final puddling in Sep after the recession of flood.
   - Transplant 45-60 d-old seedlings at four to six seedling hill$^{-1}$.

2. Post-flood broadcast (wet sowing)
   - Select a very early maturing variety suitable for direct seeding.
   - Soak seeds for 24 h and incubate them for 48 h.
   - Puddle the land and level properly.
   - Apply half of the recommended nitrogen and full phosphorus and potassium at final puddling so as to facilitate mixing with the soil. Topdress the remaining 50% nitrogen at panicle initiation stage.
   - Sow the sprouted seeds uniformly using a seed rate of 50-60 kg ha$^{-1}$.
   - Do not delay sowing beyond Sep 10 for 70-85 d duration varieties.

3. Rice - non rice cropping systems
   The rice-non rice-cropping systems in this situation are similar to that of the deepwater stagnant flooding conditions, as explained earlier.

Expected Output
- Increased cropping intensity in extended areas;
- Higher crop yields and farmers income; and
- Better use of available natural resources and reduced environmental degradation.

Constraints to adoption
- Non availability of seeds of the recommended varieties.
- Lack of farmers' awareness about the improved options in other areas where it was not validated.

Validation status
- Has been validated for three years with farmers' full participation from planning to the assessment in all the countries, as specified.

Conclusions
The alternatives, which have become available now for intensifying rice farming in flood prone areas, both in stagnant and flash flooded situations open up avenues for the economic and social development in these ecologies. When promoted at large scale, these technologies are expected to fetch benefits to a significantly large segment of weaker populations, particularly the poor and marginal farmers, landless and women.

Additional TAN
"Improved boro rice cultivation"
Summary

New, high-yielding modern varieties of boro rice, grown during the winter-spring period in Bangladesh and eastern India, have been identified. In areas where boro rice has replaced deepwater rice, new technologies to integrate boro rice with deepwater rice have been developed to increase farm productivity. Ratooning of boro rice is also being popularized. Technologies have also been developed and popularized to protect boro rice seedlings from the cold during winter months, particularly in northeastern India.

Technical details

Boro rice cultivation is a special system of rice cultivation in waterlogged lowlands or medium land areas with irrigation from Nov-May.

The boro rice system takes advantage of:

- Residual moisture in the soil after the harvest of rainy-season (kharif)
rice,
- Longer moisture retention capacity of the soil,
- Surface water stored in nearby low-lying ditches, areas adjoining canals, roads, chaur (saucer-shaped land depressions) land, etc., and
- Less frequent occurrence of natural calamities during the growing season.

Traditionally, boro rice was cultivated in river basin deltas where water accumulates during monsoons and which could not be drained out in winter months. With the introduction of irrigation, drainage, and flood control facilities, the age-old system of boro rice cultivation in Bangladesh and eastern India is now fast spreading, even outside traditional areas.

Boro rice is known for its high productivity (5-6 t ha\(^{-1}\)) in deepwater areas, where single deepwater rice with low yield potential used to be grown. Traditionally, the productivity of these areas has been very poor (<1 t ha\(^{-1}\)) during kharif. Boro rice can produce more than 7 t ha\(^{-1}\).

Types of boro cultivars

*Traditional varieties*

Traditional boro varieties are tall, weak-stemmed, and awned cultivars with poor grain quality. But these varieties are considered to have good tolerance for cold temperatures at the seedling stage. Grain yields for traditional varieties are very low. Despite this, boro rice helped the subsistence farmers produce additional food from their land, which was otherwise not suitable for growing field crops. Also, the straw of traditional varieties proved to be good cattle feed.

*High-yielding boro varieties (HYVs)*

- Except in a few areas, the traditional cultivars are being replaced by HYVs with various maturity periods.
- The HYVs are short and have high tillering capability.
- The popular HYVs at different locations are:
  - Barisal, Kuliarchar and Karimgonj, Bangladesh - BR4828-54-4-1-4-9, BR5877-21-2-3, and BRRI dhan29;
  - Bihar, India - Gautam, PSRM2-1-4B-15, IR59471-28-2020-1, Richharia, Dhan Laxmi; and
  - Assam, India – Panjasali, Sonamukhi, Banglami, Joymati and IR 50.
- These varieties can produce 2-3 t ha\(^{-1}\) more yield than local varieties and are usually 10-35 d shorter in growth duration.

Reasons for the high yield of boro rice

- Better water management during crop growing period;
- Boro rice responds better to higher doses of fertilizer, resulting in higher production;
- Less insect/pest infestation on the crop;
- Higher solar radiation available to the rice crop;
- Lower night temperature during the early stages of crop growth during winter (facilitates accumulation of photosynthates, thereby increasing the carbon-nitrogen ratio);
- Favorable higher temperature during ripening.
The variation in these parameters explains the variation in yield across the region. With the increase in boro rice area, both within and outside its traditional boundaries, new cropping patterns have also emerged and are adapted to local conditions.

Boro rice-based production systems

Boro rice is grown under various production systems. The major ones are:

- Boro rice after deepwater rice,
- Single boro in deeply flooded areas where deepwater rice used to be grown, and
- Boro rice after transplanted aman (kharif) rice.

Deepwater rice (DWR)-boro systems

- Boro rice can be grown after harvest of kharif-season DWR under partial or fully irrigated conditions.
- Various techniques are employed to adapt these crops within a year in the same piece of land using
  - selection of appropriate boro varieties,
  - early transplanting and harvesting, and
  - transplanting of aged DWR seedlings in the field.

Integration of boro with DWR

- When there is sufficient moisture in the soil, DWR may be sown by broadcasting dry or pregerminated seeds at 45 kg ha\(^{-1}\) in standing boro crop 15 d before maturity/harvest.
- In areas where flood may come late, dry or pregerminated seeds of DWR may be sown after harvest of boro rice. Dry seeds need to be incorporated into the soil by harrowing. For pregerminated seeds, one irrigation may be necessary if the soil is dry.
- Weeding and topdressing of 20 kg N ha\(^{-1}\) is required for a good DWR crop.
- Through this system, an additional yield of 1.5-2.0 t ha\(^{-1}\) can be obtained without extra investment.

Boro-boro ratoon system

- Boro ratoon refers to the crop, which grows from the stalk left after harvest of the main boro rice crop. Ratooning ability is a varietal characteristic and is therefore important for this system.

- The ratoon crop becomes ready within 5-6 weeks. Therefore, a ratoon boro crop could be taken in areas where flood does not occur at least within 45-50 d after harvesting the main boro rice crop.
- Ratooning is possible where boro rice is harvested early and where farms have irrigation facilities. The ratoon crop has the same irrigation requirements as the main crop.
- Topdress the ratoon crop with 25 kg N ha\(^{-1}\) after harvesting the main crop.
- Additional yield of 2.0-2.5 t ha\(^{-1}\) may be obtained from boro ratoon under favorable conditions.
Boro rice or wheat

- Boro rice or wheat is grown in the same season. Boro is grown as an alternative crop where wheat cannot be usually grown because of excessive water in the field or high temperature at the ripening stage.
- In some areas, it is not profitable to grow boro rice where wheat can be grown because boro rice, unlike wheat, requires frequent irrigation.

Seedling management

Sow seeds in Oct-Nov to avoid the cold period during crop growth. This ensures that the seedlings have sufficient growth before winter. There are many ways to protect seedlings from cold injury:

- Raise seedlings indoor (dapog system);
- Raise seedlings near riverbanks, swampy land, or chaur land where warmer soil temperature ensures proper root growth;
- Place a polythene sheet cover just above the seedlings at night to avoid yellowing;
- Prepare the seedbed in low-lying areas near the source of irrigation;
- Add sufficient organic manure to the seedbed (1-1.5 kg m\(^{-2}\));
- Dust the seedling leaves with fuel wood ash, straw ash, or cattle dung ash, periodically; and
- Remove dew drops from the tips of the seedlings every morning; and
- Use direct seeding.

Direct-seeded boro crop

- Cold injury to seedlings could be avoided by direct wet seeding of boro rice in well prepared fields, especially where night temperatures are not severely low.
- Direct wet seeding of boro rice in well-managed fields can have higher yield even higher than transplanted crop.
- Direct-seeded boro crop has shorter growth duration (by about 15 d); this enables the crop to avoid damage caused by early floods at maturity.
- Direct-seeding boro rice is cheaper because nursery operations and transplanting are eliminated.
- Direct-seeded boro rice needs more water and entails more weed management costs.
- Community action is required to grow direct-seeded boro rice.

Major biophysical constraints in boro rice cultivation

Seedling stage

At this stage, low temperature causes
- poor germination and emergence,
- slow and stunted seedling growth,
- yellowing of leaves,
- leaf spots, and
- slow and delayed tiller production.
The cumulative effects of these constraints lead to nonsynchronous and delayed flowering of the boro rice.

**Ripening stage**

At this stage, high temperature causes:
- grain sterility,
- drought when irrigation facility does not exist, and
- greater incidence of leaffolder and stink (gandhi) bugs.

Boro rice may also suffer from hailstorm, excessive rainfall and early flood during maturity stage. Growing of short-duration varieties may enable the boro rice crop escape damages brought about by natural calamities.

**Postharvest stage**

At this stage, drying of both grain and straw becomes difficult, particularly in areas where the monsoon starts early.

**Conclusions**

Boro rice produces higher grain yield than other rice crops. In flood-prone areas of Bangladesh and eastern India, the crop usually enjoys a flood-free growing period. Shorter duration varieties and appropriate management practices can ensure higher yield and income on a sustainable basis.

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**Sources of additional information:**

Prof. R. Thakur, Department of Plant Breeding, Rajendra Agricultural University, Bihar, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

For the boro season, the Bangladesh Rice Research Institute (BRRI) released two popular moderately long-grained rice varieties -- BRRI dhan28 and BRRI dhan29. However, these varieties have relatively low market demand in rural areas because the people, especially the poorer ones, prefer bold-grained rice. Thus, in spite of these varieties' high yielding potential, farmers opted not to grow them.

This conflict was resolved with the introduction of BR4828-54-4-1-4-9, a promising genotype with bold grains and potential yield equal to or slightly higher than those of BRRI dhan28 and BRRI dhan29.

Technical details

In Bangladesh, boro rice is grown in about 4.0 million ha, spread all over the country. It is grown on medium highlands and low lands after harvesting transplanted aman rice, on deeply flooded areas after deepwater rice, and on all land types in coastal nonsaline areas after transplanted aman rice. In the coastal areas, traditional local varieties with low yield potential predominate. Adoption of high-yielding modern varieties, such as BRRI dhan28 and BRRI dhan29, is low mainly because consumers dislike slender-grained types. Farmers in such areas usually prefer bold-grained types.
The BR4828-54-4-1-4-9 (Figure 1) is developed by crossing IR19160-11 and BR1080-43-1-4-3.

![Figure 1. Rice field planted to BR4828-54-4-1-4-9.](image)

**Characteristics of the genotype**

This genotype is known for its bold grains, with a 1000-grain weight of about 29 g, grain length of 5.9 mm, and grain width of 2.5 mm.

The plants reach a height of approximately 100 cm and, at maturity stage, the flag leaf remains green and erect. Growth duration under transplanted condition ranges from 150-155 d. Farmers growing this genotype obtained an average yield of 6.5 to 7.5 t ha$^{-1}$.

The milling out-turn of the genotype is approximately 73%, while protein and amylose content of the grain are approximately 7 and 28%, respectively. In addition, this genotype is considered to be moderately resistant to bacterial leaf blight.

**Time of seeding and transplanting**

Time of seeding in the seedbed usually takes place in mid-Nov until mid- or late Dec. About 40 kg of seeds are used per hectare. Transplanting is done in Jan using 45-d-old seedlings. Two to three seedlings per hill with a spacing of 20 x 20 cm are transplanted. However, if transplanting is delayed, more seedlings are required to be planted per hill. On the other hand, closer spacing should be observed when soil fertility is low. Harvesting usually takes place in May.

**Fertilizer management**

Table 1 shows the recommended fertilizer rates (kg ha$^{-1}$), which are similar to those recommended for other modern varieties.

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<th>Amount (kg ha$^{-1}$)</th>
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<tbody>
<tr>
<td>N</td>
<td>115</td>
</tr>
<tr>
<td>P</td>
<td>27</td>
</tr>
<tr>
<td>K</td>
<td>58</td>
</tr>
<tr>
<td>S</td>
<td>15</td>
</tr>
<tr>
<td>Zn</td>
<td>5</td>
</tr>
</tbody>
</table>

All fertilizers, except urea, are applied as basal. Urea is topdressed in three equal splits at 15, 30, and 50 d after transplanting (DAT). To ensure judicious N fertilizer application, the use of a leaf color chart (LCC) is recommended. This need-based N management technique promotes proper and timely application of N fertilizer and reduces of N fertilizer use.

**Weeding and insect pest control**

The crops are to be kept weed-free at least 40-50 DAT. Standard practices for insect and disease control should be implemented to get the desired yield.

**Irrigation**

Saturated field condition should be maintained throughout the crop’s growth period until panicle initiation stage. Adequate water is required from panicle initiation to soft dough stages. Water should be drained out at the hard dough stage.
Market price

Because of the bold and shiny grains, the market price of BR4828-54-4-1-4-9 was found to be slightly higher (Tk 16.50 kg\(^{-1}\)) than that of BRRI dhan28 and BRRI dhan29, which was Tk 16.00 kg\(^{-1}\). As the management practices for each of these varieties are the same, the new genotype may have only a slight or no economic advantage over the other two released varieties.

Alternatives

BRRI dhan 28 and BRRI dhan 29 are the popular rice cultivars for the boro season in Bangladesh. However, these are not widely adopted by farmers, particularly those in southern districts of Barisal and Patuakhali, because of their slender grain size. Though BR4828-54-4-1-4-9 does not have a significant advantage over BRRI dhan28 and BRRI dhan29 in terms of grain yield, it is definitely a preferred variety in the southern districts because of its bold grain size. Also, growing of BR4828-54-4-1-4-9 widens the range of options available to farmers in other parts of the country. This will enhance the adoption of higher yielding varieties.

BR4828-54-4-1-4-9 was tested in 10 locations in Bangladesh during 2002 boro. The rice yield, growth duration, grain weight, etc. of the promising genotype were compared with those of popular lines. Table 2 revealed that the average grain yield was about 7.0 t ha\(^{-1}\) (range of 6.41–7.7 t ha\(^{-1}\)).

In comparison with BRRI dhan28 and BRRI dhan29, average yield for this genotype was about 2.5% higher. In addition, growth duration in comparison with BRRI dhan29 was also shorter by about a week. Thousand grain weight was observed to be 22.61 and 21.48 g for BRRI dhan28 and BRRI dhan29, respectively, whereas that for the new genotype was about 28.74 g.

Table 2. Average grain yield and growth duration of BR4828-54-4-1-4-9 in various locations in Bangladesh during 2002 boro season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Yield (t ha(^{-1}))</th>
<th>Growth duration (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajshahi</td>
<td>7.13</td>
<td>162</td>
</tr>
<tr>
<td>Habiganj</td>
<td>6.41</td>
<td>150</td>
</tr>
<tr>
<td>Gazipur</td>
<td>6.63</td>
<td>160</td>
</tr>
<tr>
<td>Jhalokhati</td>
<td>6.73</td>
<td>153</td>
</tr>
<tr>
<td>Pirojpur</td>
<td>7.05</td>
<td>152</td>
</tr>
<tr>
<td>Bakergonj</td>
<td>7.21</td>
<td>150</td>
</tr>
<tr>
<td>Barisal</td>
<td>7.02</td>
<td>146</td>
</tr>
<tr>
<td>Faridpur</td>
<td>7.70</td>
<td>159</td>
</tr>
<tr>
<td>Average</td>
<td>6.99</td>
<td>154</td>
</tr>
</tbody>
</table>

Several reasons were given by farmers for preferring BR4828-54-4-1-4-9. These are the important characteristics that farmers liked in a variety:

a. Bold grains,
b. Higher yield,
c. Better quality of rice straw,
d. Less infestation of rats and insects,
e. Cooks faster than other rice varieties (requires less fuel), and
f. Flag leaf remains green and erect at maturity (prevents panicles from lodging).

Expected output

Some people from southern Bangladesh and the other poor farmers all over the country are used to eating bold-grained rice, a characteristic of BR4828-54-4-1-4-9. With this, it is expected that demand for this genotype would be relatively higher than that for the popular rice varieties. This genotype guarantees a wider market, which could be very beneficial to rice farmers.
Moreover, with the adoption of BR4828-54-4-1-4-9, rice yield is expected to increase slightly over the high-yielding popular rice varieties. The increase in yield would result in an increase in farm income and therefore in the improvement of the socioeconomic conditions of rice farmers.

Farmers also believe that this genotype produces better quality rice straws, which could be used as cattle feed. This could also be a source of additional farm income and a means to overcome the chronic shortage of feed in most parts of Bangladesh.

**Constraints to adoption**

No major constraints to adoption are envisaged. However, the availability of quality seeds could delay adoption by larger number of farmers. Quality seeds of BR4828-54-4-1-4-9 must be produced and widely distributed among farmers in different parts of the boro-growing areas.

**Validation status**

In the last 3 years, BR4828-54-4-1-4-9 was tested at different locations in Bangladesh - - Rajshahi, Habiganj, Jhalokhati, Pirojpur, Bakergonj, Barisal, Faridpur, and Gazipur. The study showed positive results. The National Seed Board has evaluated the genotype and its release as a variety is expected.

**Conclusions**

The introduction of BR4828-54-4-1-4-9 would cause farmers to shift from planting the popular boro varieties to cultivating this promising genotype. Average grain yield will be relatively higher, by 2.5%, than popular varieties. The adoption of BR4828-54-4-1-4-9 by farmers would help increase farm income, promote household-level food security, and solve the shortage of quality feed for cattle.

**Date of release:** August 2003

**Sources of useful additional information and resource persons on the technology:**

Dr. Musherraf Husain, Adaptive Research Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701, Bangladesh

Dr. M. Zainul Abedin, Social Sciences Division, International Rice Research Division, Los Baños, Laguna, Philippines
Summary

Single transplanted aman rice is the main cropping system for the tidal nonsaline subecosystem in Bangladesh. Crop yield is generally low and adoption of available modern varieties (MVs) is slow. BR6110-10-1-2, with a yield potential of more than 5 t ha$^{-1}$, was found to be widely acceptable to farmers. This genotype has high yield, bold grains, submergence tolerance, and short growth duration.

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 tide surge up to 1 m depth twice daily from April to October. The transplanted aman rice is the main crop in the area. Farmers follow traditional practices in the absence of appropriate technologies. Currently, the area coverage of high-yielding MVs is only about 27%. The major reason for nonadoption of available MVs is their finer grain size as farmers in the coastal areas prefer bold grains and these MVs do not quite fit well in the diverse agroecological conditions of the flood-prone areas, particularly the tidal non-saline areas.

BR6110-10-1-2 is a new genotype developed by the Bangladesh Rice Research Institute (BRRI). This was developed by crossing BRRI dhan30 and BRRI dhan31. The performance of BR6110-10-1-2 was found to be superior to that of...
MVs and local varieties in the tidal non-saline area.

Characteristics of the genotype

This genotype is known for its bold grains, 1000 grain weight of about 29-30 g, grain length of 5.6 mm and grain width of 2.6 mm.

The plant reaches a height of about 130 cm, but this varies with variation in water depth. Growth duration during transplanted aman takes about 135-140 d and 150-155 d during the boro season. The average yield potential under farmers’ condition is 5-6 t ha\(^{-1}\) for the transplanted aman crop and 7-8 t ha\(^{-1}\) for the boro crop.

This genotype contains 10.1% protein and 26.6% amylose.

Other characteristics of the genotype, as reported by the farmers, include the following:

- Plant height suitable for planting on medium highlands in the tidal areas;
- Non-lodging;
- Long, wide, and deep green flag leaf;
- Very late or no senescence of leaves at maturity;
- Rapid recovery from insect infestation after pesticide application and attainment of robust growth thereafter;
- Suitability for adoption in a wide range tide depths and increase in plant height with increasing depth of flood in the tidal areas;
- Ability to survive and recover from submergence in the seedbed;
- Ability to withstand submergence;
- Shiny and golden grain;
- High market price;
- Low sterility; and
- Good eating quality.

Time of seeding and transplanting

Standard recommended management practices are followed in raising quality seedlings. Quality seeds and nutrient management in the seedbed are critical in raising quality seedlings.

Thirty-five to 45-d-old seedlings of BR6110-10-1-2 are transplanted in July or August. Two to three seedlings per hill are transplanted with 20 x 15 cm spacing between hills.

Fertilizer management

Fertilizers are applied as recommended rate of 70-20-35-10-4 kg N, P, K, S and Zn ha\(^{-1}\).

All fertilizers, except urea, are applied as basal dose. Urea is top dressed in three equal splits at 15, 30, and 45 DAT, depending on depth of flooding at the time of topdressing. This is expected to be difficult in the medium highlands.

Weeding and insect pest control

Two hand weedings may be necessary to maintain weed-free crops. Standard practices for insect and disease control are implemented.
Irrigation

Irrigation is not crucial for this genotype when grown during the aman season, except those in the highlands, which may require adequate water, especially during the panicle initiation and grain-filling stages.

Alternatives

Several rice varieties are available for the tidal nonsaline coastal areas in Bangladesh for the aman season. These include MVs such as BR11 and BRRI dhan31 and local varieties such as Sadamota, Dudkolom, and Moulata. Yield potentials of existing MVs are relatively higher than those of local varieties. The average yield and growth duration of these varieties are given in Table 1.

Table 1. Grain yield and growth duration of different transplanted aman varieties/genotype in tidal non-saline areas of Bangladesh.

<table>
<thead>
<tr>
<th>Rice variety/ genotype</th>
<th>Ave. grain yield (t ha⁻¹)</th>
<th>Ave. growth duration (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR11</td>
<td>3.56</td>
<td>144</td>
</tr>
<tr>
<td>BRRI dhan31</td>
<td>3.47</td>
<td>138</td>
</tr>
<tr>
<td>Local varieties (Moulata and Sadamota)</td>
<td>2.31</td>
<td>161</td>
</tr>
<tr>
<td>BR6110-10-1-2</td>
<td>5.11</td>
<td>143</td>
</tr>
</tbody>
</table>

Among the rice varieties grown under the single transplanted aman cropping pattern, BR6110-10-1-2 was found to be superior in terms of yield, growth duration, and grain quality.

On-farm trials with BR6110-10-1-2 revealed that this genotype produced an average grain yield of 4.89 t ha⁻¹. On the other hand, BR11, considered the most popular transplanted aman variety, and local varieties gave much lower yields.

Expected Output

With the improved single transplanted aman cropping pattern with BR6110-10-1-2, average rice yield is expected to increase by about 37% over BR11, 41% over BRRI dhan31 and 111% over the local varieties. Also, farmers are more likely to adopt this genotype because it guarantees a wider market and a higher market price. The increase in yield and the higher price would contribute to additional farm income.

Table 3 shows that an estimated area of 406,940 ha is suitable for the cultivation of BR6110-10-1-2 in the greater Barisal region. An increase in total production is expected
with the adoption of the genotype. Even if only 50% of the area were utilized, a shift from BR11 to BR6110-10-1-2 would result in an increase in total production by 270,615 t with a value of Tk 2.3 billion. On the other hand, an additional production of 524,953 t (Tk 4.5 billion) is expected if farmers will adopt BR6110-10-1-2 instead of the local varieties.

Table 3. Potential area for cultivation of BR6110-10-1-2 in Barisal region, Bangladesh.

<table>
<thead>
<tr>
<th>District</th>
<th>Area (ha)</th>
<th>HL</th>
<th>MHL-1</th>
<th>MHL-2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barisal</td>
<td>2,000</td>
<td>26,000</td>
<td>7,093</td>
<td>35,093</td>
<td></td>
</tr>
<tr>
<td>Bhola</td>
<td>14,988</td>
<td>42,768</td>
<td>20,000</td>
<td>77,756</td>
<td></td>
</tr>
<tr>
<td>Patuakhali</td>
<td>232</td>
<td>77,300</td>
<td>40,000</td>
<td>117,532</td>
<td></td>
</tr>
<tr>
<td>Barguna</td>
<td>33,400</td>
<td>35,000</td>
<td>35,000</td>
<td>103,400</td>
<td></td>
</tr>
<tr>
<td>Jhalkathi</td>
<td>1,600</td>
<td>17,710</td>
<td>14,000</td>
<td>33,310</td>
<td></td>
</tr>
<tr>
<td>Pirojpur</td>
<td></td>
<td>24,850</td>
<td>15,000</td>
<td>39,850</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>52,220</td>
<td>223,628</td>
<td>131,093</td>
<td>406,941</td>
<td></td>
</tr>
</tbody>
</table>

HL= highlands, MHL= medium highlands

Farmers will benefit from the additional returns generated by the adoption of BR6110-10-1-2. The increase in income will improve the socioeconomic conditions of the farmers. In addition, this genotype will help increase food security at the household level. It is also expected that adoption of the genotype will generate additional employment opportunities in the area.

The additional production of rice straw will help farmers solve the problem of shortage of fodder and fuel.

Economic advantage

Because of its higher grain quality, the price for BR6110-10-1-2 may be slightly higher than that of BR11, BRRI dhan31, and the local varieties. Table 4 shows the average paddy price for the different transplanted aman varieties.

Table 4. Average paddy price after harvest of different transplanted aman varieties.

<table>
<thead>
<tr>
<th>Rice variety</th>
<th>Price (Tk kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR6110-10-1-2</td>
<td>8.50</td>
</tr>
<tr>
<td>BR11</td>
<td>7.75</td>
</tr>
<tr>
<td>BRRI dhan31</td>
<td>7.75</td>
</tr>
<tr>
<td>Moulata</td>
<td>8.75</td>
</tr>
<tr>
<td>Sadamota</td>
<td>8.50</td>
</tr>
</tbody>
</table>

Since management practices for the MVs are almost the same, the new genotype will have a large economic advantage over them because of the increased rice yield. On the average, it is expected that farmers growing BR6110-10-1-2 will have an additional gain of Tk 15,650 t⁻¹ over MVs and Tk 20,700 t⁻¹ over local varieties. In addition, growing of BR6110-10-1-2 was the most profitable as it showed the highest benefit-cost ratio (Table 5).

Table 5. Comparative economic analysis of BR6110-10-1-2, BR11, BRRI dhan31 and popular local varieties in the tidal nonsaline ecosystem of Barisal region, Bangladesh.

<table>
<thead>
<tr>
<th>Item</th>
<th>BR6110-10-1-2</th>
<th>BR11</th>
<th>BRRI dhan31</th>
<th>Local varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy yield (t ha⁻¹)</td>
<td>5.11</td>
<td>3.56</td>
<td>3.47</td>
<td>2.31</td>
</tr>
<tr>
<td>Price (Tk t⁻¹)</td>
<td>8,500</td>
<td>7,750</td>
<td>7,750</td>
<td>8,625</td>
</tr>
<tr>
<td>Gross return (Tk ha⁻¹)</td>
<td>44,780</td>
<td>29,390</td>
<td>28,940</td>
<td>22,630</td>
</tr>
<tr>
<td>Gross cost (Tk t⁻¹)</td>
<td>15,750</td>
<td>15,750</td>
<td>15,750</td>
<td>14,300</td>
</tr>
<tr>
<td>Net return (Tk t⁻¹)</td>
<td>29,000</td>
<td>13,600</td>
<td>13,100</td>
<td>8,300</td>
</tr>
<tr>
<td>BCRa</td>
<td>1.84</td>
<td>0.86</td>
<td>0.83</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Yield and growth duration of transplanted aman varieties and new genotype BR6110 in tidal non-saline areas is presented in Figure 2.
Figure 2. Yield and growth duration of transplanted aman varieties and new genotype BR6110 in tidal non-saline areas.

Constraints to Adoption

Like any other new varieties, the availability of quality seeds is a constraint. A sufficient amount of seed must therefore be produced. In addition, these seeds should be made known and available to farmers in order to encourage them to grow this variety. Besides engaging in other commercial activities, farmer groups could be trained to produce quality seeds.

This genotype produces straw with less palatability as cattle feed as compared with those obtained from local varieties. Participating farmers, however, indicated that over time, the cattle will get used to the straw and therefore, this does not seem to be a serious constraint to adoption.

Validation status

The promising genotype, BR6110-10-1-2, was tested along with a standard check in 18 test locations in Bangladesh involving 99 farmers in 2001 and 101 farmers in 2002. The test sites for this genotype included five sites in Barisal, three sites in Potuakhali, two sites in Pirojpur, two sites in Jhalokati, two sites in Faridpur, and one site each in Mymensingh, Gazipur, Jessore, and Bogura. The findings from this study validated the observation of yield stability since the 2000 transplanted aman season.

This genotype was also tested during boro season at different locations in Bangladesh. Findings from on-farm trials showed that BR6110-10-1-2 was very promising - - grain yield during boro was between 6.6 and 7.5 t ha⁻¹.

A participatory proposed variety adaptive research trial was done in 12 farmers' fields in different Upazilas of Barisal region. This was undertaken to provide the National Seed Board opportunities for field evaluation. The NSB field evaluation team has recommended BR6110-10-1-2 as an aman variety and its release is expected soon.

Conclusions

It is expected that with the introduction of BR6110-10-1-2, farmers will readily shift from local rice varieties to this genotype. The genotype will increase farmers’ options in looking for improved rice varieties that are suitable for their varying land types and household needs. This will enable them to attain food security at the household level and increase their farm income.

Date of release: August 2003

Sources of useful additional information and resource persons on the technology:

Dr. Musherraf Husain, Adaptive Research Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701, Bangladesh

Dr. M. Zainul Abedin, Social Sciences Division, International Rice Research Division, Los Baños, Laguna, Philippines
Summary

Nitrogen is a key factor in achieving optimum lowland rice yield. It is believed that the color of the leaf indicates chlorophyll content and the need for nitrogen of the rice crop. The International Rice Research Institute (IRRI) developed a leaf color chart (LCC) to help farmers determine the time and level of N application. The use of LCC promotes a need-based N application to rice crops that saves N and increases N use efficiency. Because of healthier plant growth due to timely application of N fertilizer, damages caused by insects were reported to have been reduced.

Technical details

Leaf color chart (LCC)

The LCC is a simple tool that could be used for better N management. It was improved by IRRI and collaborators in NARES as an alternative to the very expensive chlorophyll (SPAD) meter. It measures leaf color intensity, which is related to N status of the leaf. Compared with other conventional N application techniques, the use of LCC is a
need-based N management tool and it helps farmers determine the right time of applying N fertilizer. With this kind of technology, the amount of N applied is reduced, which then decreases the cost of inputs for rice production. In an on-farm study in West Bengal, total direct cost was lower by 4.6% in LCC plots than in farmers’ plots. The decrease in cost is attributed to less N fertilizer used by farmers adopting the LCC.

Moreover, LCC is an inexpensive tool, costing about US$1 or less a piece. Most of the Asian rice farmers can very well afford it. Further, one LCC could be shared by several neighbors, making it more economically attractive.

It is made of high-impact plastic developed from a Japanese prototype (Furuya 1987). It has six color shades -- from yellowish green (no. 1) to dark green (no. 6). This simple tool is effective, inexpensive, and easy to use (Figure 1).

![Figure 1. Leaf color chart showing different shades of green.](image)

**Guide on how to use the LCC**

The guidelines for using LCC (usually printed at the back of the chart) are as follows (see Figure 2):

1. Take LCC readings from 14 d after transplanting (DAT) for transplanted rice (TPR) or 21 days after seeding (DAS) for direct wet-seeded rice (D-WSR). The last reading is taken when the crop just starts to flower.

2. Take readings at the same time of the day (8-10 am or 2-4 pm) with the sun at your back to shade the leaf being measured. Preferably, the same person should take the leaf color measurements throughout the growth period.

3. Select at random at least 10 disease-free rice plants or hills in a field with uniform plant population.

4. Compare the color of the youngest fully expanded leaf of at least 10 randomly selected plants by placing its middle part on top of the color strips in the chart. Do not detach or destroy the leaf. The plants should be selected from different parts of the field.

5. If six or more leaves read below a set critical value, apply 23 kg N ha\(^{-1}\) (for wet season) or 35 kg N ha\(^{-1}\) (for dry season). One 50-kg bag of urea contains 23 kg N, whereas one 50-kg bag of ammonium sulfate contains 10 kg N. The suggested critical values are 4 for TPR and 3 for high-density D-WSR.

6. Repeat the process about every 10 d and apply N as needed.

![Figure 2. N content is monitored with the use of the LCC.](image)
**Amount of N to be applied**

The amount of N to be applied may vary accordingly to the rice variety grown, season, and method of crop establishment. More N is applied in the dry season than in the wet season. During the dry season, the amount of N applied is higher by around 12 kg N ha\(^{-1}\) than that of the wet season. The application of N fertilizer in the IRRI long-term experiment (in the Philippines) is shown in Tables 1 and 2.

The time of application of N fertilizer varies with the method of crop establishment. N application is earlier for TPR (Table 1) than in DSR (Table 2).

**Table 1. Time of interval and amount of N to be applied to transplanted rice by growth stage.**

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Time interval (DAT)</th>
<th>N application (kg N ha(^{-1}))</th>
<th>Dry season</th>
<th>Wet season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early growth</td>
<td>14-28</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Rapid growth</td>
<td>29-48</td>
<td>45</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Late growth</td>
<td>49 - flowering</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Time of interval and amount of N to be applied to direct-seeded rice by growth stage.**

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Time interval (DAT)</th>
<th>N application (kg N ha(^{-1}))</th>
<th>Dry season</th>
<th>Wet season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early growth</td>
<td>21-34</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Rapid growth</td>
<td>35-55</td>
<td>45</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Late growth</td>
<td>56 - flowering</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

**Critical values**

The critical or threshold value suggests when N fertilizer should be applied. These values differ with the method of crop establishment. For TPR, the critical value is 4. On the other hand, 3 is the threshold value for D-WSR. When six or more leaves read below the critical value, N fertilizer is applied accordingly.

The critical value also varies according to the type of rice. For light green aromatic foliage, the critical value is 3; the range is from 3.5 to 4.0 for semidwarf TPR. On the other hand, the critical value for direct-seeded or transplanted hybrid rice is 4 (Table 3).

**Table 3. Critical values, by rice type and crop establishment method.**

<table>
<thead>
<tr>
<th>Rice type</th>
<th>Direct seeded</th>
<th>Transplanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic</td>
<td>-</td>
<td>3.0</td>
</tr>
<tr>
<td>Semidwarf</td>
<td>3.0</td>
<td>3.5-4.0</td>
</tr>
<tr>
<td>Hybrid</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Researchers are still investigating if the critical values will be different for different varieties within a season and plant type.

**Alternatives**

At present, there are different ways of managing N fertilizers in rice.

1. Farmers’ practice of N application
2. Research-recommended N fertilizer rate
3. Soil test-based N application
4. Chlorophyll meter or SPAD (soil plant analysis development)
5. Leaf color chart (LCC)

**Farmers’ practice of N management**

Farmers generally follow fertilizer recommendations from research organizations, but often they apply N fertilizer on the basis of their perception of factors that contribute to higher yield. Many farmers believe that more nitrogen means more yield as higher dose N makes the rice plants very green, usually a sign of healthy crop. The financial condition of the farmers also influences the amount and time of N application.
This farmers’ practice of nutrient management could result in either overuse of N fertilizer, polluting the surface and groundwater, or underutilization, leading to low yields and income. Overuse of N does not necessarily increase crop yield and income. Also, many farmers do not know the recommended fertilizer rate and timings of application, which could lead to fertilizer wastage.

**Soil test-based N application**

Soil test-based N application involves determining the nutrient-supplying capacity of the soil. Proper collection and handling of the soil sample is a must to ensure a reliable test. However, this nutrient management technique is not widely adopted by rice farmers because of their lack of knowledge and skills on soil testing. This likewise requires a soil test kit or getting soil tested from a laboratory that most cannot afford.

**Research-recommended N use**

In this approach, farmers are advised to apply a particular amount of N based on variety and crop growth stage. For example, 120 kg N ha\(^{-1}\) is recommended for boro rice in West Bengal. Though this is based on a large number of trials, it does not consider the amount of N present in a particular plot and the recommended N is applied at a fixed rate and time, with the assumption that the crop’s need for N is constant. This practice, therefore, may result in overuse or underuse of N resource and may keep the crop starving for N for a long period of time.

**Chlorophyll meter or SPAD**

The chlorophyll meter is a simple, nondestructive tool used to monitor plant N status expressed in g/m\(^2\) (Figure 3). This is used by clamping the meter over the leaf and getting a reading after 2 seconds. Aside from saving time, the use of chlorophyll meter as a nutrient tool may reduce N fertilizer application by 13-25% as compared with that of farmers’ practice. Application of fertilizer is done when the SPAD value is less than the set critical value. Chlorophyll reading is affected by several factors such as variety differences, growth stages, environmental conditions (temperature, moisture, stress, sunlight, etc.), plant diseases, and nutrient deficiencies. Because of these factors influencing the chlorophyll reading, every chlorophyll meter must be calibrated according to field soil, variety, and environment.

**Expected impact**

The LCC is a technology that helps manage N without reducing yield. On-farm validation trials in West Bengal, India during boro season have indicated that the adoption of LCC resulted in about 30% decrease in N used by farmers without significant adverse
effects, if any, on grain yield. This resulted in a decrease in the cost of inputs, thereby increasing farmers’ income.

A similar result was also observed in an on-farm study during transplanted aman and boro seasons in Bangladesh. During the aman season, use of LCC (as against the recommended fertilizer rate) enabled farmers to save a significant amount (37%) of N fertilizer (about 26.0 kg N ha\(^{-1}\)) (Table 4). On an average, farmers could save about US$ 6-12 ha\(^{-1}\). A 9% decrease in rice crop sterility was also observed with the LCC-based N management and grain yield tended to increase.

Table 4. Comparison of grain yield and amount of fertilizer used between LCC and recommended fertilizer rate in Bangladesh, aman 2002.

<table>
<thead>
<tr>
<th>Item</th>
<th>LCC</th>
<th>Recommended rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. yield (t ha(^{-1}))</td>
<td>4.44</td>
<td>4.32</td>
</tr>
<tr>
<td>Panicles (no. m(^{-2}))</td>
<td>238.56</td>
<td>240.44</td>
</tr>
<tr>
<td>No. of grains per panicle</td>
<td>99.78</td>
<td>98.00</td>
</tr>
<tr>
<td>Sterility (%)</td>
<td>21.00</td>
<td>23.11</td>
</tr>
<tr>
<td>N-used (kg ha(^{-1}))</td>
<td>45.56</td>
<td>71.89</td>
</tr>
<tr>
<td>N-saved due to LCC (%)</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

Farmers and researchers also have reported that the LCC plots had lower insect damage as a result of a vigorous crop growth.

**Economic advantage**

The use of LCC was found more profitable than the farmers’ practice of N application. About 40-50 kg N ha\(^{-1}\) was used in LCC-based N application during aman season, while 70-80 kg N ha\(^{-1}\) was applied in farmer’s practice. An amount of US$ 8-12 ha\(^{-1}\) could be saved with the adoption of this technology.

The reported reduction in pest control also helped farmers save on pest control expenses making it more economically attractive. The additional farm income ensures an improved level of living of the poor rice farmers.

**Constraints to adoption**

Farmers’ perception on N fertilizer use and their lack of knowledge about appropriate timing of N application limits the adoption of LCC as a N management technique. To promote the effective use of LCC, farmers must be given technical know-how and proper training. Large-scale community-based demonstrations are needed to make the tool popular.

In addition, the LCC must be made available to farmers. Enough number of LCCs should be manufactured locally for distribution, taking care to maintain consistency in color grades and to ensure accurate readings.

**Validation status**

This technology was tested in farmers’ participatory demonstration trials in transplanted aman and boro during 2002 and 2003 seasons in Bangladesh and West Bengal, India.

Also, the use of LCC was tested in several locations in Vietnam’s. A significant decrease in the amount of N used (25.5%) was observed without any negative effect on grain yield. Similar results were also observed from on-farm studies in India and Philippines. In fact, a large number of farmers are already using LCC in some parts of these countries.

**Conclusions**

The LCC is an effective and inexpensive N management tool. With this, over-application of N fertilizer is avoided without any negative impact on grain yield. Adopting this technology could save poor farmers significant amounts of money. This will help
farmers, especially the resource-poor ones, increase their benefits and attain food security at the household level. The reduced application of N will also have a positive effect on the environment.

For further reading:


Date of release: September 2003

Sources of additional information:

Dr. Musherraf Husain, Adaptive Research Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur 1701, Bangladesh

Dr. B. Bagchi, Bidhan Chandra Krishi Viswavidyalaya Kalyani, Nadia, West Bengal, India

Dr. M. Zainul Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

The development of short-duration varieties with ability to tolerate cold at the seedling stage and with superior grain quality has facilitated the expansion of modern variety (MV) boro rice cultivation in Bihar. Technologies have also been developed to raise good-quality seedlings during the cold winter months. The dapog method of raising seedlings is gaining popularity. Raising a ratoon crop is also being recommended to have an additional yield of about 2.5-3.0 t ha\(^{-1}\) at very little cost.

Technical details

Boro rice, part of an ancient and pious system of rice cultivation in waterlogged low-lying areas in winter (Oct-Nov to May-Jun), has been mentioned as one of the offerings to God in the Shiv Puran. Traditionally, these weak-stemmed, low-yielding cultivars had been cultivated, providing subsistence to resource-poor farmers.

With the advent of early and mid early high-yielding varieties (HYVs) in the 1960s, the varietal scenario changed in areas where temperature during winter was favorable. First, it became popular in West Bengal and the area expanded enormously with significantly higher yield. This technology was consequently adopted in a few districts in the adjoining northeastern Bihar. Pusa-221, Jaya, and IR8 were grown and gave average yields of about 4-5 t ha\(^{-1}\). The winter climate was favorable. However, boro rice cultivation did not extend beyond this region to nearly 0.1 million ha of waterlogged chaur lands in Bihar, mainly...
because varieties that can tolerate cold at the seeding stage are not available. In such lands, neither wet-season nor dry-season rice had been successful due to excess water. Boro rice was still an ideal choice.

**Prospective boro areas in Bihar**

Deepwater chaur lands are spread over the entire north Bihar in Darbhanga, Samastipur, Vaishali, Muzaffarpur, Champaran, Siwan, and Gopalganj districts and also in areas around canal-irrigated systems that remain waterlogged for long periods in south Bihar. In these nontraditional boro regions, though favorable in terms of water availability, the low temperature during winter at seedling stage and the high temperature at anthesis in some parts, were the major constraints to boro rice cultivation.

**Development of boro varieties**

Rice is the preferred staple food of Bihar, but the state is a chronically rice-deficit state because of floods and/or droughts. Boro cultivation on a large scale is one option to increase productivity. With this consideration in view, a breeding program was initiated in the late 80’s at Pusa, which is a hot spot for screening cold-tolerant germplasm. Winter was harsh and varieties presently popular in the traditional region did not survive at Pusa. Thus, this center is excellent for screening.

All available locally developed early and mid early germplasm and also those available through IRRI were tested. Several entries were identified and included in multilocation state varietal trials. One of the mutants of Rasi, PSRM1-16-4B-11, was identified. Yielding more than 8 t ha⁻¹ in on-farm trials, it was subsequently released as Gautam. This dwarf variety has erect, dark green leaves and profuse tillering and is highly tolerant of cold at the seedling stage.

It was first included in front-line demonstrations in the nontraditional boro region and then on a large-scale trial in deepwater chaur lands, Dalnyara, Kasyam, Israin, Parapatru, Madhepur, Nirmala in Madhubani district. About 180 ha was brought under boro rice with the help of four non-government organizations. The average yield was 7.5 t ha⁻¹. It became instantly popular, making non-productive, waterlogged lands highly productive. It changed the economic well-being of resource-poor farmers. It virtually triggered the boro revolution in the region. The development and validation of boro technology was one of the components in the IRRI-supported IFAD project.

**Development of new varieties**

With the success of Gautam, the breeding program was further strengthened. Three varieties belonging to different maturity groups were subsequently developed:

- **Richharia**
  - dwarf
  - 100 d maturity during kharif
  - synchronized flowering in boro season
  - long and slender grains
  - yield potential (3.5-4.0 t ha⁻¹ [kharif] and 5.5-6.0 t ha⁻¹ [boro])
  - cold tolerant

- **Dhanlaxmi**
  - dwarf
  - 105 d maturity during kharif
  - long and slender grains
  - can grow in Zn-deficient lands (prevalent in north Bihar)
  - resistant to bacterial leaf blight, brown spots, and brown plant hoppers
  - yield potential of 6.0-6.5 t ha⁻¹ (boro)
• **Saroj**
  - semi-tall
  - 115-120 d maturity in kharif
  - long and slender grains
  - yield potential (5.0 - 5.5 t ha\(^{-1}\) [kharif] and 6.5 - 7.5 t ha\(^{-1}\) [boro])
  - good ratooning ability
  - very popular in traditional boro regions

In addition, early duration variety, Prabhat, released for the kharif season, also become popular in the boro season. Three cultivars -- PSRM 1-16-48-11, Boro 3-1B-8 and RAU 1346-4-1 -- have been identified. PSRM 1-16-48-11 has excellent ratooning ability. During the 2002-03 boro season, the seedlings faced extremely low temperatures (2.0 - 4.5°C) for a prolonged period. Four progenies, namely RAU 1417-2-5-7-3, RAU 1421-12-1-7-4, RAU 1401-28, RAU 1421-15-3-2-5, have been identified as highly cold-tolerant with a yield potential of 7 - 8 t ha\(^{-1}\).

**Crop management**

• **Time of seeding**
  - Oct 20-Nov 15

• **Nursery bed**
  - Beds should be in low-lying area where irrigation water is available, preferably in heavy soil. Add a sufficient amount of compost and for 0.1 ha, 2.5 kg urea, 6 kg single superphosphate, and 1 kg muriate of potash are required.

• **Raising of seedlings**
  - Seeds should be soaked in water overnight and then kept in a moistened gunny bag for a day or two to enable them to sprout. These pregerminated seeds should be uniformly spread over carefully puddled nursery beds. Seed treatment with Bavistin (at 1 g kg\(^{-1}\) seed) is recommended. To avoid cold injury, the growing seedlings may be covered by polythene sheets at night.

• **Hardening seedlings through ‘dapog’**
  - In this method, seedlings can be raised anywhere -- on floors, dagra, trays, etc. Pregerminated seeds should be placed on the selected surface (a thick layer of about an inch). Moist conditions must be maintained and a little pressure by hand over the growing seedlings for some days is necessary. This method is very useful when seedlings are expected to be severely damaged by cold.

• **Transplanting**
  - It should be done when temperature is favorable, some time from the last week of Jan to the first week of Feb. Two to three
seedlings per hill and 40-45 hills m$^{-2}$ are desirable. Shallow planting helps increase tillering. Gap filling may be required.

- **Fertilization**
  - 100 kg N ha$^{-1}$ (250 kg urea), 40 kg P ha$^{-1}$ (250 kg single superphosphate) and 20 kg K ha$^{-1}$ (80 kg muriate of potash) are recommended. At the time of puddling, half of the N and a full dose of others have to be applied in the field. Topdressing of the remaining urea should be done 25-30 days after transplanting and at panicle initiation (equal split).

- **Ratoon crop**
  - If water stagnation is present in the field after harvest, the plot should be cleaned and urea topdressed at 20 kg ha$^{-1}$. The ratoon crop, to be harvested in 4-5 wk, will give an additional yield of 2.5-3.0 t ha$^{-1}$.

- **Emerging new crop systems**
  - Early-maturing, cold-tolerant boro varieties have shown promise in irrigated medium lands in areas where groundwater level is high. In such areas, bamboo or clay pipe boring will be successful.

- **Contributors to higher yield**
  - Long sunshine hours, cool night, good water management, and application of N are responsible for high yields. However, cold conditioning of seedlings for a long period will help achieve higher yield.

**Constraints to adoption**

Unavailability of quality seeds is a major constraint to adoption, particularly those of the promising advanced lines. The variety release procedure is a lengthy one, which prevents seed growers from multiplying the seeds of non-released advanced lines, despite continuing farmer to farmer seed exchange.

**Validation status**

The boro crop is now accepted as an economically profitable crop in several parts of Bihar. Newer lines and varieties included in this report were tested by farmers in these areas and were identified as acceptable. Farmers adopt most of them, including the advanced lines obtained through farmer-to-farmer seed exchange.

**Conclusions**

The development of short-duration HYVs has not only increased production in existing boro rice areas but facilitated expansion of boro cultivation in new areas as well. Newer varieties with cold tolerance and finer grain quality are being tested and adopted by farmers. These have opened up opportunities to productive use of otherwise marginal land resources. Improving the crop management practices and developing more cold-tolerant varieties will greatly enhance both rice production and household-level food security.

**Date of release:** September 2003

**Sources of additional information:**

Dr. R. Thakur, Department of Plant Breeding, Rajendra Agricultural University, Pusa, Bihar, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

High-yielding, early-maturing rice varieties ideally suitable to the boro rice-growing season are a long felt need of farmers in Assam. Until recently when three varieties (Joymati, Jyotiprasad, and Bishnuprasad) were developed, farmers had to grow either the low-yielding traditional boro rice varieties or the high-yielding modern varieties (MV) not specifically suited to the season (i.e. tolerant of low temperature at the vegetative growth stage and ready for harvest latest by early part of May to escape early floods). Most of the traditional boro rice varieties, though tolerant of low temperature at the seedling and early vegetative stages, have poor yields ($2.0 - 3.0 \, \text{t ha}^{-1}$) and have long growth duration (Table 1). On the other hand, none of the predominantly grown MVs though high yielding ($4.0 - 7.0 \, \text{t ha}^{-1}$), are ideal for the boro season as they are susceptible to low temperature stress and are prone to damage by early floods because of late maturity (Tables 1 and 2).

Table 1. Yield of improved boro rice varieties in farmers’ fields in different districts of Assam.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mangiaon</th>
<th>Nalbari</th>
<th>Barpeta</th>
<th>Kamrup</th>
<th>Nagaon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jyotiprasad</td>
<td>6.5–7.1</td>
<td>6.1–6.2</td>
<td>6.7–7.1</td>
<td>6.1–8.0</td>
<td>4.5–5.5</td>
</tr>
<tr>
<td>Bishnuprasad</td>
<td>6.1–7.2</td>
<td>6.6–7.0</td>
<td>6.5–8.0</td>
<td>7.0–7.2</td>
<td>6.0–6.2</td>
</tr>
<tr>
<td>Joymati</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.2–5.5</td>
<td>5.2–5.6</td>
</tr>
<tr>
<td>Other varieties</td>
<td>4.0–4.4</td>
<td>3.8–4.5</td>
<td>4.2–5.5</td>
<td>4.0–4.2</td>
<td>4.1–4.3</td>
</tr>
</tbody>
</table>

This is an output of the project “Validation and Delivery of New Technologies for Increasing the Productivity of Flood-prone Ricelands of South and Southeast Asia” funded by the International Fund for Agricultural Development (IFAD) for the benefit of the rural poor. The views expressed are not necessarily those of IFAD.
Table 2. Yield and crop duration of traditional and modern rice varieties under different boro rice-growing situations in Assam.

<table>
<thead>
<tr>
<th>Growing situations</th>
<th>Varieties</th>
<th>Yield range (t ha(^{-1}))</th>
<th>Duration (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed swampy</td>
<td>Jagli boro</td>
<td>2.3-3.0</td>
<td>160-170</td>
</tr>
<tr>
<td></td>
<td>Mahsuri</td>
<td>4.3-5.7</td>
<td>180-200</td>
</tr>
<tr>
<td></td>
<td>Biplab</td>
<td>5.1-7.1</td>
<td>200-220</td>
</tr>
<tr>
<td>Irrigated</td>
<td>China</td>
<td>5.1-6.3</td>
<td>170-180</td>
</tr>
<tr>
<td></td>
<td>Jaya</td>
<td>5.1-6.3</td>
<td>180-190</td>
</tr>
<tr>
<td></td>
<td>IR8</td>
<td>5.1-6.0</td>
<td>180-190</td>
</tr>
<tr>
<td></td>
<td>Mahsuri</td>
<td>4.3-7.1</td>
<td>180-200</td>
</tr>
<tr>
<td></td>
<td>Biplab</td>
<td>5.1-7.1</td>
<td>200-220</td>
</tr>
<tr>
<td>Irrigated</td>
<td>Jyotiprasad</td>
<td>4.5-7.1</td>
<td>160-165</td>
</tr>
<tr>
<td></td>
<td>Bishnuprasad</td>
<td>6.0-8.0</td>
<td>160-165</td>
</tr>
<tr>
<td></td>
<td>Joymati</td>
<td>5.2-5.6</td>
<td>175-178</td>
</tr>
</tbody>
</table>

Technical details

The Assam Agricultural University has identified three promising MVs through on-station and on-farm trials: Joymati, Jyotiprasad, and Bishnuprasad. These relatively short-duration varieties are moderately tolerant of low temperature stress at the seedling and early vegetative stages of growth. They mature by early May. These characteristics have made these varieties suitable to the boro season of Assam (Table 3).

Table 3. Characteristics of new boro rice varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>Growth duration (d)</th>
<th>Effective tillers (%)</th>
<th>Spikelet fertility (%)</th>
<th>Grain yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joymati</td>
<td>110</td>
<td>175-178</td>
<td>78-80</td>
<td>85-90</td>
<td>6.7-7.0</td>
</tr>
<tr>
<td>Jyotiprasad</td>
<td>85</td>
<td>160-165</td>
<td>75-80</td>
<td>85-90</td>
<td>6.1-6.5</td>
</tr>
<tr>
<td>Bishnuprasad</td>
<td>85</td>
<td>160-165</td>
<td>75-80</td>
<td>85-90</td>
<td>6.0-6.5</td>
</tr>
</tbody>
</table>

The following practices are to be adopted to get optimum yield:

*Sowing time*: Nov/Dec  
*Planting time*: Jan/Feb  
*Age of seedling*: 40 d  
*Spacing*: 20 cm × 20 cm

Weed management: need-based manual weeding by lowland rice weeder (2-3 times)

Water management: 5 cm irrigation 3 d after disappearance of ponded water

Nutrient management: Application of N, P, and K at 60, 15, and 25 kg ha\(^{-1}\) is recommended. Nitrogen should be applied in three splits -- 1/3 as basal at final puddling, 1/3 as topdressing at 30 d after transplanting (DAT) and 1/3 as topdressing at 75 DAT.

Plant protection: need-based application of pesticides is recommended. However, adoption of certain cultural management practices is being emphasized as an integral component of the integrated pest management package currently being formulated.

Alternatives

Before the three new varieties were developed, farmers relied primarily on either low-yielding traditional boro rice varieties such as Jagli boro, Kola boro, Lahi boro, and Dola boro or existing MVs such as Biplab, Mala, Joy Bangla, IRRI (non-descript varieties named by farmers), Jaya, IR8, Pusa 2-21, and Mahsuri, which are not recommended for the boro season. The new varieties yield more than 5.00 t ha\(^{-1}\), whereas traditional varieties have less than 3 t ha\(^{-1}\) (Tables 1 and 2). These three varieties, though similar to other MVs in terms of grain yield, have several advantages over the MVs earlier grown by the farmers. Their most important advantage is growth duration. These three varieties are of significantly shorter duration than the other MVs. Thus, the likelihood of these varieties being damaged by flood is far less than the other varieties. Further, farmers can get more turnaround time for the next sali rice crop. This enables farmers to choose appropriate varieties for the sali (summer) crop after boro rice (Tables 1 and 3). The seedling height attained by these new...
varieties is greater than that of other MVs owing to their moderate level of low temperature tolerance at the seedling stage.

**Expected impact**

The three new varieties gave better yields than did traditional local or MVs. Because they are shorter in duration and they have a better chance to escape the early floods.

In irrigated boro rice, the cost of cultivation is very high because of irrigation expenses. It is thus essential that maximum yield per unit area and time and, more importantly, per unit volume of irrigation water is achieved. The short growth duration will reduce both the use and cost of irrigation water. This, in turn, will create a positive impact on the environment and on the household economy through increased net benefits.

Moreover, these varieties would allow the cultivation of sali rice in time without any problem and also transplanting of deepwater rice in low-lying areas.

**Constraints to adoption**

Irrigation, which is crucial for growing these varieties, is not available to all farmers and, wherever available, involves considerable investment. Availability of quality seeds is another major problem. The seedlings of these varieties, unlike those of traditional local varieties, remain short at the time of transplanting, causing difficulties in the transplanting operation in many areas. Further, the low market price of rice has encouraged farmers in many areas to grow other rabi crops.

**Validation status**

The varieties were evaluated for grain yield performance and other characters over several seasons in different research stations of Assam Agricultural University and other states of India. They have also been evaluated widely in the farmers’ fields in Assam under multilocation trials and on-farm testing to confirm the results obtained in the research stations. Front line block demonstrations are likewise being conducted.

**Conclusions**

The new varieties have clear superiority over the existing MVs in Assam. With short growth duration varieties, farmers can be assured of harvest by avoiding the risk of damage to maturing crop by flood. Efforts should be made to ensure that farmers grow these the three varieties. Moreover, new better varieties for the boro season need to be developed to augment rice production during this season, which is considered the most productive.

**Date of release:** September 2003

**Sources of additional information:**

Dr. T. Ahmed, Regional Agricultural Research Station, Titabar, Assam, India

Dr. P. K. Pathak, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. A. K. Pathak, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

Boro rice that grows in Assam is exposed to a long spell of cold stress, especially, at the seedling and early vegetative stages. The minimum temperature at night ranges from as low as 8° to 10° C in Dec-Jan, causing very slow seedling growth. This results in stunted seedling and longer growth duration. The new technology of raising boro rice seedlings under plastic tunnel is promising. A low-cost polythene-tunnel constructed over a nursery bed is able to significantly raise the temperature under the tunnel, allowing better seedling growth (Table 1).

Technical Summary

Pre-germinated seeds are sown in well-puddled soil in a standard nursery bed prepared in a sunny area. Immediately after sowing, the seedbeds are covered with a plastic tunnel. The frame for the tunnel is made of locally available low-cost materials such as jute stick, bamboo, cane, etc. Each tunnel is about 10.0 m long and 1.3 m wide with a height of 0.6 m at the center (Figure 1).

Figure 1. Polythene tunnel

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Above the frame, a colorless, transparent polythene sheet, 50-100 microns thick, is spread. To ensure that moisture and heat do not leak, mud lining is placed around the tunnel or the edge of polythene sheet is manually thrust gently in the mud. Proper care should be taken to keep the polythene cover in its original place so that it is not torn or blown away by wind. The plastic tunnel has to be kept undisturbed throughout the day and night for a period of 2-3 wks. However, light irrigation may be applied if the soil moisture inside the polythene tunnel is reduced. When the polythene tunnel-raised seedlings attain required height, ‘hardening’ of seedlings should be done for about 3-4 d by gradually raising the polythene cover in one end. Finally, the polythene cover is removed totally from the structure before seedlings are uprooted for transplanting.

Table 1. Seedling height inside and outside the low cost plastic tunnel during boro season

<table>
<thead>
<tr>
<th>Variety</th>
<th>Age (d)</th>
<th>Plant height (cm) Inside tunnel</th>
<th>Plant height (cm) Outside tunnel</th>
<th>Percent increase over 'outside tunnel'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern Joymati</td>
<td>20</td>
<td>11.74</td>
<td>5.94</td>
<td>97.6</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>14.04</td>
<td>7.50</td>
<td>87.2</td>
</tr>
<tr>
<td>Bishnuprasad</td>
<td>20</td>
<td>14.16</td>
<td>7.78</td>
<td>82.0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>16.50</td>
<td>9.33</td>
<td>76.8</td>
</tr>
<tr>
<td>Jyotiprasad</td>
<td>20</td>
<td>14.64</td>
<td>8.38</td>
<td>74.7</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>16.76</td>
<td>9.46</td>
<td>77.2</td>
</tr>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juglee boro</td>
<td>20</td>
<td>13.20</td>
<td>9.12</td>
<td>45.8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>30.02</td>
<td>19.82</td>
<td>51.46</td>
</tr>
<tr>
<td>Kola boro</td>
<td>20</td>
<td>25.50</td>
<td>8.62</td>
<td>195.8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>28.14</td>
<td>12.98</td>
<td>116.8</td>
</tr>
<tr>
<td>Dola boro</td>
<td>20</td>
<td>24.52</td>
<td>9.98</td>
<td>145.7</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>30.84</td>
<td>12.46</td>
<td>147.5</td>
</tr>
</tbody>
</table>

*Date of sowing: 19 Dec, minimum temperature: 10-13°C and 8-11°C inside and outside the tunnel, respectively; maximum temperature: 36-44°C and 22-28°C inside and outside the tunnel, respectively.

Field studies have shown that, by transplanting boro crop using healthy and vigorous seedlings grown under the plastic tunnel technology, crop duration is shortened by about 7-15 d, which is crucial in flood-affected situations.

The cost of a tunnel for a 10 m × 1.25 m seedbed is around Rs 300.00 (US$7.0) only. The same material may be used for several years, making the annual cost even less.

**Alternatives**

Traditionally, farmers in Assam sow boro seeds in the wet seedbed from late Oct-early Nov, when the temperature is still not very low. The aim is to achieve better germination and initial growth. Moreover, traditional boro rice varieties have the desired degree of tolerance for low temperature and can grow relatively well in the boro season. In the traditional boro rice-growing swampy lands, farmers start transplanting in Dec as the saucer-shaped land (bheel) becomes ready for rice transplanting. Transplanting is done gradually from the periphery. The boro rice crop is mainly non-irrigated and is the only crop grown. In recent years, the boro rice area has expanded rapidly with the installation of shallow tube wells. Modern rice varieties are being grown in the non-traditional boro rice-growing areas. In such a situation, early transplanting is not advisable in view of the high cost of irrigation water. Normally, seeds are sown in the seedbed during Nov-Dec, or even Jan. As temperature is very low, seedlings become stunted. To maximize yield, good-quality seedlings are very important. Raising seedlings under a plastic tunnel is a simple and cost-effective technology that can help produce seedlings with good vigor and health.

**Expected impact**

This new technology of raising boro seedlings allows farmers to have healthy
and vigorous seedlings, which in turn makes transplanting easy and timely. The use of these seedlings ensures a healthy crop and consequently, higher yield and production. The extra cost of raising the seedlings is negligible compared with the overall gains from getting healthy seedlings. Early harvesting will also save the maturing crop from damages caused by floods or excessive rain.

Constraints to adoption

There are few constraints to adoption of this technology. Little cost is involved in procuring the polythene sheet and construction materials. Large-scale demonstration and scaling up of on-farm validation will be necessary to bring the technology to a large number of farmers rapidly.

Validation status

A number of varieties were evaluated by raising seedlings under a plastic tunnel over the years at different research stations of the Assam Agricultural University.

Conclusions

Adoption of the technology, along with other recommended practices would provide several advantages such as ease in transplanting operation, advancement of transplanting by several days, early harvesting to escape flood damage, and increased productivity. Farmer participatory on-farm trials are needed to demonstrate and fine-tune this technology.

Date of release: September 2003

Sources of additional information:

Dr. B. Guha, Regional Agricultural Research Station, Assam Agricultural University, Shillongani 782 001, Naogaon, Assam

Dr. P. K. Pathak, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. A. K. Pathak, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. K. K. Sharma, Regional Agricultural Research Station, Titabar 785630, Assam, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

With the installation of shallow tube wells (STW) on a large scale in recent years, there has been a tremendous expansion in boro rice area in the state of Assam, India. With irrigation assured, the yield of boro rice has gone up to a satisfactory level. Farmers in Assam traditionally adopt the practice of keeping standing water continuously in the rice fields, which has implications on cost and environment degradation. It was necessary to study the effectiveness and efficiency of the traditional practice and recommend to farmers an optimum irrigation schedule for boro rice, considering the fact that the cost involved in irrigating boro rice crop constitutes the main part of cultivation cost. Results from the experiments showed that irrigation water requirements can be curtailed by about 50-60% without any reduction in yield by adopting an appropriate irrigation schedule and as such the expenditure incurred on irrigation can be reduced by about 50-60%. In other words, an additional area of about 50-60% can be brought under irrigation with the same amount of water currently used in boro cultivation (Figure 1).

![Figure 1. Pump irrigation.](image)
Technical details

Among different irrigation schedules tried, the application of 5 cm irrigation water 3 d after disappearance of ponded water (DADPW) was found to be the best. The yield was the same as that obtained from continuous submergence (farmers' practice). The total irrigation water used under farmers' practice (about 188.0 cm) was considerably higher than that under the irrigation management practice of applying 5 cm irrigation 3 DADPW (80.0 cm). The studies demonstrated that adopting the new irrigation schedules over the one traditionally practiced by farmers could save about 50-60% of irrigation water. Considerably higher water use efficiency (WUE) was obtained from irrigations at 3 DADPW (55.10 kg ha-1 cm-1), followed by irrigations at 1 DADPW (43.20 kg ha-cm-1) than farmers' practice of continuous submergence (22.66 kg ha-cm-1) (Figure 2, Figure 3, and Table 1).

<table>
<thead>
<tr>
<th>Irrigation regime</th>
<th>Irrigation (no.)</th>
<th>Total irrigation requirements (cm)</th>
<th>Grain yield (kg ha-1)</th>
<th>Irrigation water use efficiency (kg ha-cm-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 cm 1 DADPW</td>
<td>20</td>
<td>100.00</td>
<td>4,320</td>
<td>43.20</td>
</tr>
<tr>
<td>5 cm 3 DADPW</td>
<td>16</td>
<td>80</td>
<td>4,400</td>
<td>55.00</td>
</tr>
<tr>
<td>Continuous submergence</td>
<td>18</td>
<td>180</td>
<td>4,030</td>
<td>22.66</td>
</tr>
</tbody>
</table>

Alternatives

Rice farmers in Assam normally try to keep depth of standing water at 5-10 cm continuously. The experiments have shown that continuous submergence requires an average of 18 irrigations (10 cm depth each), while only about 16 irrigations of 5 cm depth each were sufficient when the recommended practice of 5 cm irrigation 3 DADPW was adopted. Thus, farmers who spend about Rs 5,400 (US$118) ha-1 with the traditional practice will need only about Rs 2,400 (US$52) with the recommended practice.

Expected impact

The new irrigation schedule would reduce the cost of cultivation of boro rice by about Rs 3,000 (US$66) per ha over the traditional practice. Such savings will have a substantial impact on resource-poor farmers and also on the state economy. The savings could be used to meet other household needs or to irrigate additional boro rice areas.

Savings in terms of quantity of water pumped will have beneficial effects on groundwater resources in the long run, though it may not be seen as a problem in Assam now.
In addition, the cyclic submergence and drying (i.e., disappearance of ponded water) will reduce methane emission to the environment and reduce the iron toxicity problems.

On the other hand, reduction in pumping water will also have beneficial effects on the amount of fossil fuel burned and lubrication used. A simple decrease in number of hours of pump operation will reduce wear and tear, and therefore, expenses on repair and maintenance.

However, water saved would most likely be used for irrigating more rice areas. This will increase overall production of rice. This also means an increase in the command area of each irrigation unit, which would further reduce the cost of irrigation per unit of land.

**Constraints to adoption**

Lack of knowledge and inadequate training and community action are the major constraints to adoption of the new technology. Large-scale demonstrations and technology validation work are needed to reach a large number of farmers quickly.

**Validation status**

Research on irrigation scheduling has been conducted for several years in research stations as well as in farmers’ fields before making final recommendation to farmers.

**Conclusions**

The adoption of the new irrigation schedule (5 cm irrigation water 3 DADPW) will significantly reduce cost of cultivation for boro rice by about US$66. This will result to an increase in farm income which could be used for other household needs or irrigating additional area for boro cultivation.

**Date of release:** September 2003

**Sources of additional information:**

Dr. N. N. Sarmah, Water Management, Assam Agricultural University, Jorhat, Assam, India

Dr. P. K. Pathak, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. A. K. Pathak, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Division, Los Baños, Laguna, Philippines
Damage caused by insect pests is one of the major constraints to boro rice production in Assam, India. Stem borers, case worms, and leaf folders are important pests of boro rice. Of these, yellow stem borers (YSB) (*Scirpophaga incertulas*) walkers are the most common (Figure 1). Emergence of the first generation of YSB moths coincides with the reproductive stage of boro rice. Damage resulting from feeding of larvae of this generation causes significant yield loss. Most farmers apply insecticides and some indigenous technical know-how to control this and other insect pests, but such an approach was often found ineffective. Therefore, an integrated approach for managing these pests, especially stem borers is advocated.

**Summary**

Insect pests in boro rice cause significant damage, especially during the reproductive stage of the crop, which coincides with the emergence of the first generation of stem borers after hibernation during winter.
In view of the many problems associated with the use of inorganic pesticides, an integrated approach for the management of insect pests is considered the best possible option. The integrated pest management (IPM) technology for boro rice includes the following:

1. Use of appropriate variety
2. Timely planting
3. Optimum plant population
4. Balanced fertilizer application
5. Split application of nitrogenous fertilizer
6. Regular pest monitoring using pheromone traps for YSB (to reduce pest population)
7. Use of Trichogramma egg parasitoids for YSB and leaffolders
8. Need-based application of pesticides
9. Use of indigenous technical knowledge such as use of bamboo perches

Studies in Assam have shown that the integrated approach minimizes application of insecticides and is economically profitable and environmentally sustainable.

 Alternatives

The alternative option to control insect pests is application of pesticides and/or adoption of some indigenous practices such as the use of bamboo perches, planting of *Eupatorium odoratum* twigs, etc. However, these practices alone are often ineffective and data indicate that application of pesticide alone also is not economical and not environment-friendly.

Results showed that IPM has increased rice yield by about 33% than that of farmers’ practice (3.97 t ha$^{-1}$) and the benefit-cost ratio has doubled. IPM also helped increase the beneficial predator population as against the application of pesticides. Trials with biological control techniques significantly reduced incidence of stem borers as against farmer practice (Tables 1, 2, and 3).

### Table 1. Effect of IPM on insect pest incidence and yield of boro rice, Assam, India.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem borer incidence</th>
<th>Yield (kg ha$^{-1}$)</th>
<th>BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DH (%)</td>
<td>WE (%)</td>
<td>LFDL (%)</td>
</tr>
<tr>
<td>IPM</td>
<td>5.20</td>
<td>4.28</td>
<td>3.24</td>
</tr>
<tr>
<td>Pesticide alone</td>
<td>5.57</td>
<td>4.71</td>
<td>3.88</td>
</tr>
<tr>
<td>Farmers' practice</td>
<td>10.37</td>
<td>8.01</td>
<td>5.66</td>
</tr>
</tbody>
</table>

DH = deadheart, WE = white earhead, LFDL = leaffolder-damaged leaf, BCR = benefit-cost ratio, IPM = Integrated pest management

### Table 2. Effect of different treatments on predator population (mean population per hill), Assam, India.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spiders</th>
<th>Coccinelids</th>
<th>Drascenty</th>
<th>Ground beetles</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPM</td>
<td>16.60</td>
<td>21.60</td>
<td>13.08</td>
<td>13.90</td>
</tr>
<tr>
<td>Pesticide alone</td>
<td>9.10</td>
<td>6.10</td>
<td>9.74</td>
<td>10.10</td>
</tr>
<tr>
<td>Farmers’ practice</td>
<td>20.60</td>
<td>18.00</td>
<td>13.30</td>
<td>22.80</td>
</tr>
</tbody>
</table>

IPM = Integrated pest management

### Table 3. Effect of biological control agents on stem borer and leaffolder incidence in sali rice.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem borers incidence</th>
<th>LFDL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DH (%)</td>
<td>WE (%)</td>
</tr>
<tr>
<td>Biological control agents</td>
<td>3.5</td>
<td>4.69</td>
</tr>
<tr>
<td>Farmers’ practice</td>
<td>10.31</td>
<td>11.58</td>
</tr>
</tbody>
</table>

LFDL = leaffolder-damaged leaf

### Expected impact

Experiments conducted in farmers’ fields demonstrated that the IPM treatment gave significantly higher yields and recorded higher benefit-cost ratio (2.86) than pesticide application alone (2.25) or farmers’ practice (1.52).

Adoption of IPM will improve the economic well-being of farmers through increased production and increased net benefits. This will also reduce application of pesticides and will therefore have a beneficial effect on the environment.
Constraints to adoption

Lack of knowledge and access to biological control agents are serious impediments in the way of farmers adopting the IPM strategy. Training of farmers and large-scale validation through community action will be necessary for rapid transfer and adoption of the technology. Involving pesticide dealers early on would be beneficial to ensure the supply of biological control agents.

Validation status

The IPM technology was tested in farmers’ fields in rainfed sali (summer) rice season (Jun/Jul-Nov/Dec) 2001 and 2002. The trials were conducted by farmers in five villages (two replication each village) under the guidance of researchers and also at the research station of the university. Besides this, the efficacy of the biological control agents has been tried in the research stations as well as on farmers’ fields. However, the technology needs to be extrapolated to boro rice with some modifications. More work will have to be done, as the pest scenario in boro rice is slightly different from that in sali rice.

Conclusions

The adoption of IPM to boro rice cultivation will increase yield by about 33% without the adverse effect on the environment. This practice will help promote boro rice productivity and sustain the crop environment.

Date of release: September 2003

Sources of additional information:

Dr. D. K. Bora, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

Dr. P. K. Pathak, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat-785013, Assam, India

Dr. A. K. Pathak, Assam Agricultural University, Jorhat-785013, Assam, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines
Summary

Chemical fertilizers are considered hazardous because they degrade soil health and create environmental pollution. Moreover, its cost is too prohibitive for resource-poor farmers. In this context, use of biofertilizers in sali (summer) rice was found to be an attractive alternative to farmers. The biofertilizers-based integrated nutrient management (BINM), which included biofertilizers Azospirillum and phosphate-solubilizing bacteria (PSB) as sources of N and P, compost, and K in the form of muriate of potash (MP) resulted in greater grain yield than that obtained from NPK application (60-30-30 kg ha\(^{-1}\)) in all demonstration sites.

The new technology offers Assam rice farmers a very effective alternative to achieve better nutrient management and increase grain yield and monetary benefits.

These combinations were found very effective in a cropping sequence such as sali rice–french bean–ahu rice: organic manure at 1-3 t ha\(^{-1}\), biofertilizers (Azospirillum and PSB) at 4 kg ha\(^{-1}\), 4.4 kg P ha\(^{-1}\) from rock phosphate, and 16.6 kg K ha\(^{-1}\) from MP.

Technical details

The BINM has emerged as the best strategy. BINM package has been formulated for rice in Assam. It comprises organic manure at 1-3 t ha\(^{-1}\), biofertilizers (Azospirillum and PSB) at 4 kg ha\(^{-1}\), 4.4 kg P ha\(^{-1}\) and 16.6 kg K ha\(^{-1}\). The BINM package

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This is an output of the project “Validation and Delivery of New Technologies for Increasing the Productivity of Flood-prone Ricelands of South and Southeast Asia” funded by the International Fund for Agricultural Development (IFAD) for the benefit of the rural poor. The views expressed are not necessarily those of IFAD.
may be applied following these steps:

- Prepare a triangular bund in a corner of the field.
- Apply 5 kg of dry organic manure powder and the total amount of rock phosphate (RP) and biofertilizers into the mud inside the bund and mix them properly to prepare a slurry.
- Wash the roots of the uprooted seedlings to remove the mud.
- Insert the roots of the uprooted seedlings into the slurry for 1-2 h.
- Gently remove the seedlings from the slurry without removing the slurry adhering to the roots.
- Transplant the seedlings into the field.
- Spread the excess amount of slurry in the field.
- Apply MP and rest of the organic manure as basal during final land preparation.

Alternatives

Based on years of experimentation, Assam farmers are given recommendations to apply fertilizers at 40 kg N, 20 kg P₂O₅, and 20 kg K₂O ha⁻¹ (sali rice) or 60 kg N, 30 kg P₂O₅, and 30 kg K₂O ha⁻¹ (boro rice). The farmers are also asked to apply N in three splits, first half as basal and the other half equally divided at maximum tillering and panicle initiation.

However, most of the farmers are reluctant to apply fertilizers as recommended because of several reasons. There is heavy rainfall during sali season and the risk of crop damage by flood is greater. They also lack capital and knowledge. It is to be noted that more than 80% of the total annual average rainfall in the state falls during sali season. As a result, N-fertilizers leach out from the light-textured Brahmaputra alluvial soils. N use efficiency in sali rice is hardly 20% in the state. The high activity of Al and Fe in the acid soils of Assam causes the fixation of soluble P-fertilizers (e.g., SSP). Also, a large majority of the farming community of the state cannot afford to buy chemical fertilizers and are not fully knowledgeable about the use of balanced fertilizers. The rate of fertilizer application is often based on farmers’ perception of factors that result in higher yield and their economic condition.

In general, farmers of the state use cow dung from their cattle shed. Some of them topdress urea at 20 kg N ha⁻¹ at maximum tillering. A few farmers apply DAP along with urea. Only a small group of farmers uses balanced fertilizers.

BINM technique is more relevant to small and marginal farmers who cannot adequately invest in fertilizer inputs. Here, Azospirillum is used to supply N. This is an associative N₂-fixer that cannot be removed from the root rhizosphere by leaching. Again, RP instead of SSP is used as a source of P. This is insoluble in water but becomes slowly available in acidic soil reaction. As soils in Assam are acidic, RP is more suitable. PSB can solubilize the insoluble forms of P in soil through secretion of organic acids. RP becomes easily available to the crop. Results of on-station and on-farm trials indicate that the new BINM package is far more remunerative and less costly than using inorganic fertilizers (Tables 1-4).

### Table 1. Effect of BINM on yield and income of sali rice farmers, Assam, India.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of inputs (Rs ha⁻¹)</th>
<th>Yield (t ha⁻¹)</th>
<th>Return (Rs ha⁻¹)</th>
<th>Return/unit input cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINM</td>
<td>726.00</td>
<td>3.16</td>
<td>15,775.00</td>
<td>21.73</td>
</tr>
<tr>
<td>NPK</td>
<td>1,345.00</td>
<td>2.96</td>
<td>14,798.00</td>
<td>11.00</td>
</tr>
</tbody>
</table>

*aOnly the cost of nutrient input is considered.

*bAv. of three consecutive sali crops.

*cReturns from grain considered with price taken as Rs 5,000 t⁻¹.
The cost of inputs in the biofertilized crop was reduced by about 46% and yield increased by about 13%. These increased the marginal rate of return by Rs 12.00 per rupee invested on nutrients. Results of trials with BINM on rice-legume-rice cropping pattern were similar (Table 3).

Table 2. Effect of BINM on yield and income of sali rice farmers, Assam, India.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of input (Rs ha⁻¹)</th>
<th>Yield (t ha⁻¹)a</th>
<th>Return (Rs ha⁻¹)</th>
<th>Return/unit input cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINM</td>
<td>726.00</td>
<td>3.61</td>
<td>18,055.00</td>
<td>24.87</td>
</tr>
<tr>
<td>NPK</td>
<td>1,345.00</td>
<td>3.21</td>
<td>16,035.00</td>
<td>11.92</td>
</tr>
</tbody>
</table>

aAverage of 15 demonstration sites

Figure 1. Comparison of cost of inputs between BINM and NPK plots, sali rice.

Table 3. Grain yield (t ha⁻¹) in rice-legume-rice cropping system under fertilizer and BINM treatments, Assam, India, 1999-2002a.

<table>
<thead>
<tr>
<th>Season</th>
<th>Crop</th>
<th>Treatment</th>
<th>Control</th>
<th>NPK</th>
<th>Organic Manure</th>
<th>BINM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999, Kharif</td>
<td>Sali rice</td>
<td>2.35</td>
<td>2.53</td>
<td>2.64</td>
<td>2.96</td>
<td></td>
</tr>
<tr>
<td>2000, Rabi</td>
<td>French bean</td>
<td>0.02</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>2000, Summer</td>
<td>Ahu rice</td>
<td>1.60</td>
<td>2.08</td>
<td>1.92</td>
<td>2.33</td>
<td></td>
</tr>
<tr>
<td>Total 1st year crop cycle</td>
<td>3.97</td>
<td>4.71</td>
<td>4.65</td>
<td>5.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000, Kharif</td>
<td>Sali rice</td>
<td>2.81</td>
<td>3.74</td>
<td>3.51</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>2001, Rabi</td>
<td>Pea</td>
<td>0.34</td>
<td>0.50</td>
<td>0.61</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>2001, Summer</td>
<td>Ahu rice</td>
<td>1.59</td>
<td>2.19</td>
<td>2.33</td>
<td>2.34</td>
<td></td>
</tr>
<tr>
<td>Total 2nd year crop cycle</td>
<td>47.40</td>
<td>6.43</td>
<td>6.45</td>
<td>6.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001, Kharif</td>
<td>Sali rice</td>
<td>2.39</td>
<td>2.67</td>
<td>2.78</td>
<td>2.82</td>
<td></td>
</tr>
<tr>
<td>2002, Rabi</td>
<td>Pea</td>
<td>0.15</td>
<td>1.21</td>
<td>1.16</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>2002, Summer</td>
<td>Ahu rice</td>
<td>2.35</td>
<td>2.44</td>
<td>2.53</td>
<td>3.21</td>
<td></td>
</tr>
<tr>
<td>Total 3rd year crop cycle</td>
<td>4.89</td>
<td>6.32</td>
<td>6.46</td>
<td>7.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aBasic soil parameters: Sandy loam (55% sand, 30% silt and 15% clay); bulk density=1.28 g cc⁻¹; water-holding capacity=37.23%; CEC=3.17 cmole (p⁺) kg⁻¹; base saturation=75.08%; pH=4.5; OC=0.88%; soil total N=2399.40 kg ha⁻¹; soil available P₂O₅= 44.3 kg ha⁻¹ and available K₂O= 119.00 kg ha⁻¹.

Table 4. Cost of BINM package and chemical fertilizers, Assam, India.

<table>
<thead>
<tr>
<th>Input</th>
<th>Amount required (kg ha⁻¹)</th>
<th>Price (Rs kg⁻¹)</th>
<th>Total (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical fertilizers only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>87</td>
<td>6.00</td>
<td>522.00</td>
</tr>
<tr>
<td>SSP</td>
<td>125</td>
<td>5.00</td>
<td>625.00</td>
</tr>
<tr>
<td>MP</td>
<td>33</td>
<td>6.00</td>
<td>198.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,345.00</td>
</tr>
<tr>
<td>BINM package</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic manure</td>
<td>1000</td>
<td>0.20</td>
<td>200.00</td>
</tr>
<tr>
<td>Biofertilizer (Azospirillum+PSB)</td>
<td>4</td>
<td>40.00</td>
<td>160.00</td>
</tr>
<tr>
<td>RP</td>
<td>56</td>
<td>3.00</td>
<td>168.00</td>
</tr>
<tr>
<td>MP</td>
<td>33</td>
<td>6.00</td>
<td>198.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>726.00</td>
</tr>
</tbody>
</table>

Expected impact

The new technology will provide better nutrient management strategy to produce more with less cost on a sustainable basis (Tables 1-4). The reduction in input cost will
enable poor farmers to obtain higher yield and greater net benefits (by about Rs 2,000 or US$43.6 ha<sup>-1</sup>). The BINM will also reduce NO<sub>3</sub> pollution in the environment. Adoption of the BINM does not require any specialized skills. Experiments conducted in research stations of Assam Agricultural University using the rice-legume-rice cropping pattern for 4 years showed that BINM has no hazardous effect on the soil environment.

**Constraints to adoption**

Lack of information and non-availability of the biofertilizer may be a problem for some time. However, several biofertilizer production units have been set up to make biofertilizers available in the state. The important production units operating in the region now are the following:

- Biofertilizer and Microbial Inoculant Production Unit, Assam Agro Industries Corporation Ltd., Guwahati
- Biofertilizer Production Center, Hindustan Fertilizer Corporation Ltd., Dibrugarh
- Biofertilizer Production Unit, Assam Agricultural University, Jorhat
- North East Green Tech Pvt. Ltd., Guwahati

The present facilities, however, can satisfy only about 10% of the total biofertilizer requirements of the entire rice crop of the state. The biofertilizer packets should be stored in cool shady places, preferably in cold storage units. The shelf-life of biofertilizers is about 6 months only. As biofertilizers are applied as a root dip treatment, the slurry should be allowed to firmly adhere to the roots. Care should also be taken to retain the adhered slurry in roots during transplanting. The right isolates of Azospirillum and PSB are to be used to ensure better crop productivity. It will also be necessary to train farmers on the use of biofertilizers, particularly in making the slurry and root dipping in the slurry.

**Validation status**

The technology is the result of extensive research work carried out in research fields as well as on farmers’ fields. However, the technology needs to be extrapolated to wider areas that grow boro and sali rice.

**Conclusions**

Use of BINM package in boro rice would provide resource-poor farmers a better and cheaper nutrient management strategy without adverse effects on the environment.

**Date of release:** September 2003

**Sources of additional information:**

Dr. N. C. Talukdar, Department of Soil Science, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. P. K. Pathak, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. A. K. Pathak, Assam Agricultural University, Jorhat 785013, Assam, India

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines
Summary

The rice-rice-upland crop cultivation is a new cropping pattern introduced in the coastal areas of Tra Vinh Province, Mekong Delta, Vietnam. With this cropping pattern, an upland crop is grown after two rice crops with partial irrigation. Farmers benefit from increased household income, farm productivity and seasonal crop diversity from improvement brought by the two rice and upland crop cultivation. Incorporation of an additional crop also generates additional employment opportunities directly or indirectly.

Technical details

Vietnam, world’s second largest rice exporter, has about 4.2 million ha of land used for rice cultivation. Mekong Delta has an area of about 3.97 million ha, which is about 12% of area of the country. Rice is the predominant crop with about 1.95 million ha. Since 1975, rice production has gained a great growth due to Doi Moi (renovation) policies in agriculture and rural development, improvement of irrigation systems and fast adoption of new technologies, especially the use of high yielding rice varieties with short duration, resistance to pests and good grain quality.
However, due to insufficient development of irrigation facilities, about 720,000 ha of land are still cultivated under rainfed, poorly irrigated or deepwater condition, mostly in the coastal areas.

The source of water for irrigating the rice field is a problem in the coastal areas. In some areas, manual irrigation is observed. Irrigation is made possible by digging shallow wells with a depth of 1.5-2.0 m.

The availability of irrigation and short duration HYVs in the coastal areas caused farmers to grow more than one rice crop per year. The major rice cropping patterns in Mekong Delta are the single rice crop and double rice crop. In the coastal areas, upland crops such as casaba melon (*Cucumis melo* L.), groundnut (*Arachis hypogaea* L.), maize (*Zea mays* L.), and watermelon (*Citrullus vulgaris* L.) are grown in rotation with rice. The new cropping pattern called ‘rice-rice-upland crop’ was found profitable and helped in promoting farm productivity and crop diversity.

In the ‘rice-rice-upland crop’ cropping pattern, the first crop is an upland crop grown during the month of Jan-Apr to avoid the low temperature during winter. On the other hand, the second crop is a high yielding variety (HYV) grown during May to Aug while the third crop may be an HYV or a traditional variety grown during the autumn-winter months (refer to Fig.1).

Very short duration rice varieties with growth duration of less than 90 d are grown by farmers to avoid the floods during the wet season and drought during the dry season. The use of early maturing rice varieties gives farmers more time for the cultivation of other crops.

Row seeding method with the use of the improved IRRI seeder is preferred by farmers as the method of crop establishment. This technology could save about 100-150 kg of seeds as compared to the broadcasting method.

**Alternatives**

Different cropping patterns were observed in the coastal areas of the Mekong Delta. These are as follows:

1. Single rice
2. Double rice
3. Rice-shrimp or rice-rice-shrimp
4. Upland crop-rice or upland crop-upland crop
5. Rice-rice-upland crop

**Single rice**

Single rice crop is observed in tidally inundated coastal areas. Low elevation and bad drainage characterize these areas. Rice is grown during the rainy season or Mua using traditional or local varieties. Farmers rely on rain for irrigation and grain yield is very low (1.8 t ha$^{-1}$) because of the unfavorable environment.

**Double rice**

The double rice cultivation is a dominant cropping pattern in the Mekong Delta provinces. Rice crops may be grown during the winter-spring and summer-autumn (DX-HT) or during the summer-autumn and rainy season (HT-Mua).

**Double rice (DX-HT)**

Double rice cropping pattern during DX-HT seasons is found in Ca Mau, Mekong Delta. High yielding varieties (HYV) are used for the two rice crops. Seeds are broadcasted at a range of 130-140 kg ha$^{-1}$, which is below the normal rate. The rice crops are irrigated using shallow tube well or pumps. Total grain yield for this cropping pattern is about 5.3 t ha$^{-1}$.
Double rice (HT-Mua)

This cropping pattern is commonly observed in the provinces of Mekong Delta. A modern variety (MV) is grown during the summer-autumn season and then followed by a traditional rice crop during the rainy season. The seeds of MV are broadcasted using about 157 kg ha$^{-1}$ while the amount of seeds used in transplanting of the traditional variety is only 25 kg ha$^{-1}$. The average total grain yield obtained for this cropping pattern is about 4.8 t ha$^{-1}$.

Rice-shrimp/rice-rice shrimp

Shrimp integration to rice cultivation is a practice observed in the Mekong Delta particularly in the province of Long An. With this practice, shrimp is raised with single or double rice crop. For the rice-shrimp pattern, MV is grown in the summer-autumn season and a local variety is grown during the rainy season. Two kinds of shrimps may be raised - - the freshwater shrimp or the saline water shrimp (tiger shrimp). In the area, tiger shrimps are usually raised during the dry season when saline water enters the field. Shrimps are grown at the same time with rice crops or before the first crop. A stock density of 7 post larva sq.m.$^{-1}$ is used.

Shrimp cultivation incurs high cost of production because of the high cost of field construction and feed costs. Only farmers having the financial resources can adopt this technology.

The average production for shrimp cultivation is low amounting to about 153 kg ha$^{-1}$. However, this practice still gives higher benefits than monoculture of one or two rice crops.

Upland crop-rice/upland crop-upland crop-rice

Rice-upland crop cropping pattern is a newly introduced technology in Dai An village. There are different combinations for the rice-upland crop cropping pattern. Their corresponding yields are given below (refer to Tables 1).

Watermelon seemed to be the best yielder among the upland crops with a rice equivalent of 6.85 t ha$^{-1}$. Next to this is casaba melon followed by groundnut with rice equivalent of 3.55 t ha$^{-1}$ and 2.90 t ha$^{-1}$ respectively.
Table 1. Grain yields of different crops for the rice-rice-upland crop, Tra Vinh, Vietnam.

<table>
<thead>
<tr>
<th>Cropping season Kind of crop</th>
<th>REa</th>
<th>Yield (t ha(^{-1})) Ave. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st crop (Spring-Summer) Maize</td>
<td>2.60</td>
<td>4.38</td>
</tr>
<tr>
<td>Ground nut</td>
<td>2.90</td>
<td>3.46</td>
</tr>
<tr>
<td>Water melon</td>
<td>6.85</td>
<td>13.35</td>
</tr>
<tr>
<td>Casaba melon</td>
<td>3.55</td>
<td>8.95</td>
</tr>
<tr>
<td>2nd crop (Summer-Autumn) Rice</td>
<td>-</td>
<td>3.34</td>
</tr>
<tr>
<td>High-yielding rice</td>
<td>-</td>
<td>3.13</td>
</tr>
<tr>
<td>3rd crop (Autumn-Winter) Traditional rice</td>
<td>-</td>
<td>2.84</td>
</tr>
</tbody>
</table>

Economic comparison of the different combination of rice-rice-upland cropping pattern is shown in Table 2. All combinations were found to be profitable since their BCRs are greater than 1.

This means that gross return is larger than the total cost incurred by the farmers resulting to a positive net return.

Among the combinations, rice-rice-watermelon was the most profitable combination with a 1.59 benefit-cost ratio and net return for this cropping pattern is around 12 million VND (US$ 770).

Farmers could benefit around 6.3 million VND (US$ 400) from rice-rice-casaba melon or rice-rice-maize cropping pattern and around 4.3 million VND (US$ 270) from rice-rice-groundnut.

The incremental costs of and returns from growing upland crops after two rice crops are shown in Table 3. Growing of either maize or casaba melon after the second rice crop would require an additional investment of about 6.1-6.8 million VND ha\(^{-1}\) (US$ 400-440) but could increase net returns by about 2.0 million VND ha\(^{-1}\) (US$ 130). On the other hand, farmers with enough financial resources could be encouraged to grow watermelon after the two rice crops, which would incur additional cost of around 12 million VND ha\(^{-1}\) (US$ 775) but would increase net returns by about 8.0 million VND ha\(^{-1}\) (US$ 520). The benefit-cost ratio from additional investment is about 1.63.

Table 2. Economic comparison of the different combinations of rice-rice-upland cropping pattern.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Rice - rice - maize</th>
<th>Rice - rice - groundnut</th>
<th>Rice - rice - watermelon</th>
<th>Rice - rice - casaba melon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total costs (VND ha(^{-1}))</td>
<td>14,583,356</td>
<td>17,100,408</td>
<td>20,094,210</td>
<td>13,942,622</td>
</tr>
<tr>
<td>Material cost</td>
<td>8,493,249</td>
<td>8,722,168</td>
<td>10,787,173</td>
<td>7,041,342</td>
</tr>
<tr>
<td>Labor cost</td>
<td>5,025,181</td>
<td>7,447,073</td>
<td>7,033,585</td>
<td>6,072,113</td>
</tr>
<tr>
<td>Others</td>
<td>1,064,926</td>
<td>931,167</td>
<td>2,273,452</td>
<td>829,167</td>
</tr>
<tr>
<td>Gross returns (VND ha(^{-1}))</td>
<td>20,720,876</td>
<td>21,351,953</td>
<td>31,982,906</td>
<td>21,602,232</td>
</tr>
<tr>
<td>Net returns (VND ha(^{-1}))</td>
<td>6,137,520</td>
<td>73,907</td>
<td>7,711,058</td>
<td>2,160,232</td>
</tr>
<tr>
<td>Benefit-cost ratio (BCR)</td>
<td>1.42</td>
<td>1.01</td>
<td>1.63</td>
<td>1.35</td>
</tr>
</tbody>
</table>

However, farmers should be very careful in choosing an upland crop. It is advisable for them to select upland crops not only based on the net returns but also based on the easiness and farmer’s knowledge on crop production and pest incidence of the upland crop. This is because some upland crops...
with high net returns such as watermelon and casaba melons are prone to diseases and require a lot of water (note: irrigation is poor in the coastal areas). In addition, high market price fluctuations are observed with these crops. Farmers should take into consideration a lot of factors in selecting an appropriate upland crop for the double rice and upland cropping pattern.

**Expected output**

With the double rice cropping pattern (see Table 4), farmers used to get about 4 million VND (US$ 260) but with the integration of upland crop cultivation in the double rice cropping pattern, an additional income could be obtained by farmers. The increase in income could be as high as 7.7 million VND (US$ 500) depending on the upland crop grown.

**Table 4. Benefit-cost analysis of the double rice cropping pattern.**

<table>
<thead>
<tr>
<th>Item</th>
<th>1st rice crop</th>
<th>2nd rice crop</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(VND ha⁻¹)</td>
<td>4,119,555</td>
<td>3,699,642</td>
<td>7,819,197</td>
</tr>
<tr>
<td>Material cost</td>
<td>2,181,236</td>
<td>1,898,076</td>
<td>4,079,312</td>
</tr>
<tr>
<td>Labor cost</td>
<td>1,601,593</td>
<td>1,556,531</td>
<td>3,158,124</td>
</tr>
<tr>
<td>Other</td>
<td>336,726</td>
<td>245,035</td>
<td>581,761</td>
</tr>
<tr>
<td>Gross returns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(VND ha⁻¹)</td>
<td>6,083,599</td>
<td>5,913,236</td>
<td>11,996,835</td>
</tr>
<tr>
<td>Net returns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(VND ha⁻¹)</td>
<td>1,964,044</td>
<td>2,213,594</td>
<td>4,177,638</td>
</tr>
<tr>
<td>BCR</td>
<td>1.48</td>
<td>1.60</td>
<td>1.53</td>
</tr>
</tbody>
</table>

In addition, this cropping pattern would promote crop diversification, which could improve the household’s eating pattern. It is expected that the household rice consumption would decrease because of the consumption of other agricultural products such as fruits and vegetables. The crop diversification could help address the household food and nutrition security.

**Constraints to adoption**

Aside from the flood and drought that occur during the wet and dry season, limited water availability, low labor supply, marketing of products, and high investment cost are the major constraints to adoption. Farmers adopting the double rice cultivation need about 6-12 million VND or US$ 400-800 (depending on the upland crop) for upland crop cultivation.

Credit and other financial assistance must be provided to farmers and marketing of farm products must be organized to encourage them to adopt this technology and promote crop diversification.

**Validation status**

An on-farm study on rice-rice-upland crop was found economically viable in Dai An village in Vietnam in 2002.

**Conclusions**

The two rice crops and upland crop cultivation was found feasible and beneficial to farmers. This cropping pattern would provide farmers higher incomes than monoculture of 1 or 2 rice crops and promote crop diversification that could lead to food and nutrition security at household levels.
Date of last revision: August 2003

Sources of useful additional information and resource persons on the technology:

Dr. Nguyen Ngoc De, Mekong Delta Farming Systems Research and Development Institute, Cantho University, Vietnam

Dr. Vo Tong Xuan, Angiang University, Vo Thi Sau Street, Long-Xuyen City, Angiang, Vietnam

Dr. M. Zainul Abedin, Social Sciences Division, International Rice Research Division, Los Baños, Laguna, Philippines
Summary

Rice production in Bangladesh is becoming economically less profitable than before because of rising costs and falling prices. The cost of production is increasing as a result of increases in cost of labor associated with raising of seedlings, transplanting using human labor, and other inputs. There is a growing concern about labor scarcity in agriculture in spite of the increase in area under modern varieties (MV), more alternative non-farm employment opportunities become available in both rural and urban areas.

Most of the boro rice crop is grown in areas usually prone to floods. The chances of early floods occurring often limit the cultivation of MVs during boro. Early harvesting of boro rice is important not only to protect the crop from flood but also to allow timely sowing/transplanting of the deepwater aman rice after boro, a practice farmers have recently started. Similarly, late-season drought also reduces the productivity in aman (rainy, summer season) rice. Early harvesting can ensure higher yield and possibly allow growing of a winter crop between aman and boro rice in many areas.

Direct seeding, whether manual or mechanical (using a seeder), is one of the methods of crop establishment that has potential to deal with these problems. Trials conducted on direct wet seeding of boro and aman rice crops in Bangladesh showed promising results.
Technical details

Crop establishment through direct seeding can be done either by manually broadcasting the seeds or by using seeders.

Manual direct seeding (broadcasting)

Manual broadcasting of sprouted seeds is done in the puddled main field on the same day that similar seeds are sown in traditional seedbeds. All crop management practices followed are the same as in transplanted crop, except that the irrigation schedules are different since direct seeded crop requires irrigation right from the beginning.

Direct seeding using drum seeder (DST)

The IRRI-designed drum seeder, improved by researchers and manufacturers in Vietnam, is of high-density plastic, which substantially reduced its weight and cost. The 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 diameter) on each side. Inside the drum, a device pushes the seeds toward the holes as the drum rotates. Figure 1 shows direct seeding using a drum seeder.

![Figure 1. Direct seeding with the use of a drum seeder.](image)

The land is leveled to avoid stagnation of water in pockets. Seeds are pregerminated using 24 h of soaking and 24 h of incubation. Direct seeding of sprouted seeds is done using a drum seeder in the puddled field on the similar day (between 4 and 21 Jul) that seeds are usually sown in traditional seedbeds.

All crop management practices are the same as in transplanted rice, except that the irrigation schedules used should be different. N management was done using a leaf color chart (LCC).

Alternatives

Transplanting

Transplanting is the traditional crop establishment method used by farmers. The number of farmers using transplanting is decreasing because of labor shortages and scarcity of other resources.

In a trial conducted in Bangladesh, transplanting and direct seeding were compared using the following treatments:

(i) Single thin row (with seed rate of about 18 kg ha\(^{-1}\)) using a drum seeder

(ii) Single thick row (with seed rate of about 38 kg ha\(^{-1}\)) using a drum seeder

(iii) Double rows (thin + thick, at about 56 kg seeds ha\(^{-1}\)) using a drum seeder

(iv) Conventional manual transplanting as (control)

Grain yields were adjusted at 14% moisture content. Ten farmers from each location were randomly chosen and interviewed to obtain data on crop production practices and input use with the view of making a comparative analysis of the treatments with the farmers’ own management practices.

Results

A. Manual wet broadcasting of boro rice from 1999 to 2003
(i) Results of the direct wet-seeded technology (Table 1) showed that direct wet-seeded rice was consistently superior to conventionally transplanted rice both in the research station and farmers’ field. The direct wet-seeded rice (broadcast) gave about 10% higher grain yield and matured about 10 d earlier than transplanted rice. The economic analysis showed that direct seeded crops reduced cost by about US$35 (Tk 2,000) compared with transplanted crops.

### Table 1. Grain yield and growth duration of boro rice grown under manual direct wet seeding and transplanting methods, 1999-2003.

<table>
<thead>
<tr>
<th>Cropping year</th>
<th>Yield (t ha(^{-1}))</th>
<th>Increase (%)</th>
<th>Growth duration (d)</th>
<th>Decrease (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS</td>
<td>TPR</td>
<td>DS</td>
<td>TPR</td>
</tr>
<tr>
<td>1999</td>
<td>6.08</td>
<td>5.35</td>
<td>14</td>
<td>141</td>
</tr>
<tr>
<td>2000</td>
<td>7.10</td>
<td>6.15</td>
<td>15</td>
<td>146</td>
</tr>
<tr>
<td>2001</td>
<td>6.88</td>
<td>6.40</td>
<td>7</td>
<td>151</td>
</tr>
<tr>
<td>2002</td>
<td>7.25</td>
<td>6.89</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>2003</td>
<td>5.78</td>
<td>5.36</td>
<td>8</td>
<td>145</td>
</tr>
<tr>
<td>Mean</td>
<td>6.62</td>
<td>6.03</td>
<td>10</td>
<td>146</td>
</tr>
</tbody>
</table>

B. Direct wet seeding using a drum seeder during aman 2003

It was expected that with the introduction of drum seeder, some of the problems associated with adoption of direct seeding would be solved. The use of a drum seeder could reduce the demand for labor and water, thereby reducing the cost of cultivation per unit of grain produced. It facilitates plant establishment in lines, which allows mechanical weeding. Seed rates and thus plant population can be controlled.

**Growth duration/maturity**

The crops in DST method matured about 10 days (122 d) earlier than did the transplanted rice (TPR) (132 d). In one location, the crops in DST matured about 16 d earlier. This was because the crops did not experience any transplanting shock.

Thus, direct seeding of aman rice would help release the land earlier to accommodate winter/rabi crops and help increase cropping intensity. Early harvest will enable the aman crop to avoid late-season drought during the maturity period.

**Grain yield**

Table 2 shows that the three DST treatments outyielded the TPR significantly in all five locations.

### Table 2. Effect of crop establishment methods using drum seeder on grain yield (t ha\(^{-1}\)), 2003 aman.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>BRRI Farm</th>
<th>Gazipur Sadar</th>
<th>Kaligonj</th>
<th>Kapasia</th>
<th>Sreepur</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>DST1</td>
<td>4.96 ab</td>
<td>4.95 b</td>
<td>4.20 b</td>
<td>4.86 b</td>
<td>4.27 a</td>
<td>4.65</td>
</tr>
<tr>
<td>DST2</td>
<td>5.27 a</td>
<td>5.49 a</td>
<td>4.44 ab</td>
<td>5.21 a</td>
<td>4.16 a</td>
<td>4.92</td>
</tr>
<tr>
<td>DST3</td>
<td>4.97 b</td>
<td>5.27 ab</td>
<td>4.68 a</td>
<td>5.30 a</td>
<td>4.34 a</td>
<td>4.91</td>
</tr>
<tr>
<td>TPR</td>
<td>4.67 bc</td>
<td>3.86 c</td>
<td>4.08 b</td>
<td>3.91 c</td>
<td>3.81 b</td>
<td>4.07</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.66</td>
<td>0.45</td>
<td>0.34</td>
<td>0.31</td>
<td>0.52</td>
<td>-</td>
</tr>
<tr>
<td>SE (x)</td>
<td>0.19</td>
<td>0.13</td>
<td>0.09</td>
<td>0.09</td>
<td>0.15</td>
<td>-</td>
</tr>
<tr>
<td>% Increase in yield (DST2 over TPR)</td>
<td>12.8</td>
<td>42</td>
<td>8.8</td>
<td>33</td>
<td>9.2</td>
<td>21</td>
</tr>
</tbody>
</table>

**Note:** Numbers followed by the same letter do not differ significantly.

DST1 - Direct seeding in single thin row
DST2 – Direct seeding in single thick row
DST3 – Direct seeding in double row
TPR – Transplanting (conventional)

On an average, seeding using single thick rows produced higher grain yield, by about 21% (4.92 t ha\(^{-1}\)), than TPR. The range of such an increase was from 8.8 to 42.0% The low response was moved at the BRRI farm (6%), where TPR method yielded 4.6 t ha\(^{-1}\) because of two supplemental irrigations given at the reproductive phase when rainfall was less than 100 mm during Oct-Nov.

Although the single-thick-row and double-row treatments gave similar grain yields, the former may be recommended because this treatment reduced seed rate and, therefore, costs. The increased grain yield was attributed to the increased number of grains m\(^{-2}\) in DST (Figure 2), which was the result of increasing the number of panicles m\(^{-2}\).
Figure 2. Number of grains m$^{-2}$ obtained in the DST and TPR methods in five locations, 2003 aman.

Costs and returns
The gross returns from DST rice plots in all locations were consistently higher than those from TPR plots, except in Sreepur where the crop was infested by tungro. It was evident that in all locations, production costs (variable costs) under DST method was lower than those under TPR method. This was due primarily to labor costs for crop establishment. The cost and return analysis (Table 3) showed that rice production using the drum seeder proved to be more profitable than the conventional TPR method. Farmers in Kaliganj obtained much higher profit by adopting DST (additional US$170 ha) compared with TPR.

Table 3. Differences in variable costs and returns from production under DST and TPR methods in different locations, 2003 aman.

<table>
<thead>
<tr>
<th>Location</th>
<th>Variable costs (US$ ha$^{-1}$)</th>
<th>Gross returns (US$ ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPR</td>
<td>DST</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>379.5</td>
<td>371.8</td>
</tr>
<tr>
<td>Sreepur</td>
<td>326.3</td>
<td>309.0</td>
</tr>
<tr>
<td>Rahapara</td>
<td>375.3</td>
<td>358.3</td>
</tr>
<tr>
<td>Kapasia</td>
<td>364.1</td>
<td>320.7</td>
</tr>
<tr>
<td>Average</td>
<td>361.3</td>
<td>340.0</td>
</tr>
</tbody>
</table>

These findings indicate that the increase in yield, savings in production costs, increase in net returns and earlier harvest were significant factors that encourage farmers to adopt the DST method. Table 4 shows the farmers' perceptions about the DST method.

Table 4. Farmers' perceptions on the DST method.

<table>
<thead>
<tr>
<th>Positive response</th>
<th>Negative response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers' statement</td>
<td>% of farmers</td>
</tr>
<tr>
<td>Less labor needed</td>
<td>62</td>
</tr>
<tr>
<td>Higher yield</td>
<td>50</td>
</tr>
<tr>
<td>Less expensive</td>
<td>75</td>
</tr>
<tr>
<td>Higher straw yield</td>
<td>37</td>
</tr>
<tr>
<td>No seedbed cost</td>
<td>62</td>
</tr>
<tr>
<td>Less seed needed and less costs</td>
<td>50</td>
</tr>
<tr>
<td>Early plant growth reduces risk of submergence</td>
<td>37</td>
</tr>
<tr>
<td>DST enables better plant vigor</td>
<td>50</td>
</tr>
<tr>
<td>No need to allocate land for seedbed</td>
<td>37</td>
</tr>
</tbody>
</table>

Expected output
The adoption of direct seeding using a drum seeder was found to be superior to the conventional transplanting method. Direct seeding not only reduces demand for labor but also requires less water. Also, direct-seeded crops mature about 10 days earlier than transplanted crops, allowing farmers to grow other crops after harvesting the aman rice crop.

Generally, it is expected that adoption of direct seeding would result in higher net
profits because of decreased cost and increased production.

**Constraints to adoption**

Despite the superiority of direct seeded rice to transplanted rice, farmers were not motivated enough to adopt the technology on a large scale because of some technical and some socioeconomic constraints:

(i) Heavy rainfall immediately after seeding can wash away the seeds, thereby causing poor stand.

(ii) Weed infestation was higher and it was difficult to weed in direct broadcast seeded rice.

(iii) Absence of community intervention to start irrigation equipment 30-40 d earlier than normal for transplanted rice (particularly in areas where t. aman rice is followed by boro rice).

(iv) Disease infestation was higher possibly due to dense population in direct seeding.

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 and local manufacture of seeders can take care of other concerns.

**Validation status**

During 1999-2003, manual direct wet seeding was tested in boro rice crops in several locations in Bangladesh with MVs such as BRRI dhan28, BRRI dhan29, and BRRI dhan36.

The drum seeder was tested and validated in the BRRI research farm, Gazipur Sadar Upazilla (Rahapara), Kapasia Upazilla, Sreepur Upazilla, and Kaligonj Upazilla in Bangladesh during the 2003 aman season, on medium high and high lands. The seeder is being tested by farmer groups in 25 upazillas in Bangladesh during the boro (winter) season of 2004.

**Conclusions**

The cultivation of boro rice by direct seeding using the drum seeder has created a sensation among farmers wherever it was tested. Farmers recognized the multiple benefits, of which cost reduction due to savings in labor was the most important. The technology is promising, particularly during the boro season in areas where the land becomes free before the middle of December or in traditional single boro areas where muddy soil after the flood recedes would further eliminate the cost of irrigation and puddling. Earlier harvest can result in another crop being accommodated. The choice of appropriate variety and cropping system would be important. However, a group approach in the irrigation command area during on-farm testing and demonstration stage would be essential. Farmers also need to be properly educated and trained on the need for proper land leveling to ensure success of the technology.

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**Sources of additional information:**

Dr. Musherraf Husain, Adaptive Research Division, Bangladesh Rice Research Institute, Regional Station, Bhanga, Faridpur, Bangladesh

Dr. M. Z. Abedin, Social Sciences Division, International Rice Research Division, Los Baños, Laguna, Philippines