Improved Production Technology for *Boro* Rice Cultivation in Eastern India

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Preface

Boro rice is an ancient system of rice cultivation in eastern India and Bangladesh. In India, *boro* rice has been traditionally grown from November-December to May-June in the deeply flooded areas of West Bengal, North-East Bihar, Eastern Uttar Pradesh and Assam. This system of rice cultivation is more productive than *kharif/aman*/winter rice (June-July to November-December) and *ahu/aus/zaid/ bhadai* rice (February-Mar to July-Augugst) owing to availability of good sunshine during growing season, less risk of crop failure (due to absence of flood), high input use efficiency, and less incidence of insect pests and diseases due to prevailing cool and dry season. With the advent of short duration, high yielding modern rice varieties and hybrids and creation of irrigation facilities through shallow tubewells, the cultivation of *boro* rice is fast spreading to non-traditional areas in eastern India. However, the main environmental factor limiting its cultivation is the cold stress. Traditional *boro* rice varieties are cold tolerant at early vegetative stage along with a combination of desired traits such as early maturity and high tillering ability. However, such varieties also possess undesired characteristics like short panicle, bold grain, red kernel, presence of awn, weak culm, tall plant stature, non-synchronous maturity and poor grain yield (2-3 t/ha). These characteristics make them unfit for intensive cultivation. An ideal *boro* rice variety should have semi-dwarf to semi-tall plant type with stout culm and moderate tillering ability (8-12 tillers/ hill), cold tolerance at early vegetative stage and high temperature tolerance at reproductive stage, early maturity, medium slender grain type, tolerance to major insect pests and diseases and high grain yield potential (8-10 t/ha). Initially, high yielding short (Pusa 2-21, Pusa 33 and Saket 4) and medium duration (Sita, Sujata, Jaya and IR 36) semi-dwarf varieties released for *kharif* season were introduced in the *boro* season. However, none of these varieties were found suitable for cultivation as *boro* rice. *Gautam* was the first *boro* rice variety released for cultivation in 1994. This was followed by the release of a number of *boro* rice varieties like *Chandrama*, *Chandan*, *Richharia*, *Dhanlaxmi*, *TRC Boro Dhan*, *Jaymati*, *Jyotiprasad*, and the like.

The authors of the present technical bulletin "Improved production technology for *boro* rice cultivation in eastern India" believe that it will serve as an invaluable resource for researchers, extension workers and farmers who are involved in promoting sustainable rice research and development in the waterlogged and deeply flooded areas of eastern India. We take this opportunity to extend our deep sense of gratitude and indebtedness to our Director General, Deputy Director General (NRM) and Deputy Director General (Crop Science), ICAR for encouraging and guiding us to carry out research and come up with a technical bulletin on *boro*

rice. The funding support received from ICAR is also gratefully acknowledged. Authors sincerely thank other supporting staffs of ICAR-Research Complex for Eastern Region who contributed directly or indirectly to our endeavor in giving final shape to this bulletin. Secretarial assistance rendered by Mr. Sarfaraj Ahmad is duly acknowledged.

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Introduction

Rice is the most important food crop of India covering about one-fourth of the total cropped area and providing food to about half of the Indian population. It is cultivated in about 44 million ha with production and productivity of 112.76 million tonnes and 2576 kg/ha, respectively (http://eands.dacnet.nic.in). Rice is grown in three seasons as *kharif*/*aman*/winter rice (June-July to November-December), *boro* or summer rice (Nov-Dec to May-June) and *ahu*/*aus*/*zaid*/*bhadai* rice (Feb-Mar to July-August). About 58% of rice is grown under irrigated condition and the remaining area is rainfed. Most of the rice area under rainfed condition lies in the eastern region of the country. Rice is the staple food of the people living in the eastern and the southern parts of the country, particularly in the areas having over 120-150 cm annual rainfall. In north-western parts of the country, it is grown only as a *kharif* crop during southwest Monsoon season.

'*Boro*' is a Bengali term, derived from the Sanskrit word '*BOROB*'. It denotes a special type of rice cultivation in lowland areas during the month of November to May. It takes advantage of the residual moisture in the field after *kharif* paddy, longer moisture holding capacity of the soil and water stored in the adjacent ditches. *Boro* rice is an ancient system of rice cultivation in Eastern India and Bangladesh. Apart from these, there is no equivalent of *boro* rice in any other country. However, the rice culture *Mayin* (winter rice) in Myanmar is closest to *boro* rice with similar cropping period. In India, *boro* rice has been traditionally grown during winter season (Nov-Dec to May-June) in the deeply flooded areas of West Bengal, North East Bihar, Eastern Uttar Pradesh and Assam. The flood-prone deep water areas are more vulnerable than the other rainfed rice ecosystems. The wet season rice crop in these areas is commonly damaged by floods and submergence at different crop growth stages. The rice crop also suffers from intermittent drought, especially during early stages of the same season. The farming situations around these areas comprise of flowing or standstill water conditions and flooding at different times. The situation varies greatly depending upon intensity of rainfall, drainage facility, onset of flooding, rate of water rise, etc. The rice production in this ecosystem is very poor and uneven. Due to change in environment with special reference to rainfall pattern and amount, the wet season rice crop faces the problems of submergence at early stage due to flood and drought at panicle initiation (PI) stage. Such extremely diverse situation compelled farmers to search an alternative for their sustenance and livelihood based on rice cultivation. The *boro* rice system of cultivation emerged out of this necessity, and now it has become a boon for natural vagaries prone area. There is an unlimited and annually rechargeable source of water under the earth in the vast area in flood prone rainfed lowland and

deep-water ecologies remaining fallow after harvest of monsoon rice in eastern India.

Boro rice is grown in low lying areas in the flood prone ecosystem during dry season. It takes advantage of the residual water in the field after harvest of *kharif* paddy. *Boro* is the most productive season for growing rice. It possesses an inherent high yield potential due to availability of good sunshine during growing season, good water control, less risk of crop failure (due to absence of flood), high input use and less incidence of insect pests and diseases due to prevailing cool and dry season. Farmers are encouraged to take up its cultivation in the season where ever irrigation facilities are available. However, the main environmental factor limiting *boro* rice cultivation is the cold stress. Cool water and air temperature affect the seedling growth, tillering ability, plant height and crop duration and cause yellowing of leaves and high sterility (Pathak *et. al.* 1990). Minimum temperature falling down as low as 6-10^{O}C, 15^{O}C, 15-20^{O}C, and 35-40^{O}C during seedling , vegetative, PI stage and harvesting, respectively are detrimental to realizing potential yield.

Boro rice is cultivated under three broad categories: rainfed flood-prone areas; irrigated flood-prone areas; and Irrigated flood free areas (Pathak et. al, 1999). Traditionally, *Boro* rice is grown in rainfed swampy areas, which are not under cultivation during rainy season due to chronic flood problem. These areas are generally saucer-shaped and have various levels of soil saturation and submergence. Old seedlings (2 months age) are transplanted initially in the periphery. Tillers are detached from the mother culm in this zone and are used in the lower zone for planting with reducing water level. In the event of sufficient winter rain, these low-lying areas get inundated, while in case of continuous dry spell, the crop in the upper ridges suffers from moisture stress. Therefore, traditional varieties with tolerance to both excess and deficit moisture predominate in this ecology. In irrigated flood-prone ecology, flash flood is a problem. However, cold spell of 2 to 3 months is the major problem in all the *boro* rice growing areas. It is very difficult to maintain the water level in uplands with light texture soils. Stem borers, case worm, brown plant hoper (BPH), leaf folders, rice bugs and rice hispa are the important insect pests, whereas brown spot, sheath blight, sheath rot, neck blast and stem rot are the major diseases affecting the *boro* crop.

Area, Production and Productivity

Boro rice cultivation is practised in the deeply flooded areas of North East Bihar, West Bengal, Assam and eastern UP in Eastern India, and in the Sylhet and Mymensingh districts and in the pockets of Pabna and Gopalganj in Faridpur districts

of Bangladesh (Singh *et al*., 2003). With the advent of short duration, high yielding modern rice varieties and hybrids and creation of irrigation facilities through shallow tube-wells, the cultivation of *boro* rice is fast spreading to non-traditional areas in Eastern India. Generally, the acreage under *boro* rice is more during the year in which the preceding wet season rice crop has suffered flood induced damage. This is practised by farmers to compensate the loss incurred in wet season rice by harvesting additional rice in *boro* season. Area under *boro* rice in different states of eastern India is summarised below.

Table 1. Major *boro* rice growing areas in Eastern India

States	*Boro* rice growing areas	Approximate area (m ha)	Reference
West Bengal	24-Paraganas, Burdwan, Nadia, Midnapur and Bankura districts	0.10	Chatterjee, 1996
Assam	Swampy *bheel* areas	0.18	Pathak, 1995
Bihar	Low lying belts of north eastern (Purnia, Katihar and Kishanganj) and north western (East and West Champaran) parts	0.10	Thakur, 1995
Eastern UP	Along river banks and vicinity of tanks in Basti, Gorakhpur, Deoria, Ballia, Mau, Ghazipur Varanasi and Mirzapur districts	0.039	Dwivedi *et al*., 2003
Odisha	Low lying areas of coastal belt (Balasore, Bhadrak, Kendrapara)	0.02	Mohanty *et al*., 1995

Table 2. Area, production and yield of *boro* (summer) rice in different states (Average of 2014-15 to 2018-19)

States	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)
Assam	406.15	1166.83	2873
Bihar	75.23	177.39	2358
Odisha	251.12	840.98	3349
Tripura	69.17	222.99	3198
Uttar Pradesh	27.20	76.24	2803
West Bengal	1284.58	4345.56	3390

Source: http://eands.dacnet.nic.in

Productivity of *boro* rice is much higher than that of *kharif* rice in the same ecology. Compared to the 2-3 t/ha yield level of traditional *boro* rice varieties the newly developed *boro* rice varieties can yield as high as 5-7 t/ha. Gautam, a *boro* rice variety developed by RAU, Pusa has recorded grain yields between 8-10 t/ha on farmers' field (Thakur *et al*., 1994). Under proper crop management, yield level as high as 10-12 t/ha can be achieved in *boro* rice with appropriate high yielding varieties and hybrids.

Table 3. District wise area, production and productivity of *boro* rice in Bihar

Districts	Area (ha)		Production (metric tonne)		Yield (kg/ha)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Nalanda	10	-	23	-	2300	-
Nawada	3	-	7	-	2333	-
Darbhanga	1710	1545	2925	2557	1711	1655
Madhubani	5542	6556	7052	9630	1272	1469
Samastipur	2148	3197	4273	5776	1989	1807
Munger	262	262	506	569	1931	2172
Khagaria	360	337	802	781	2228	2318
Saharsa	840	837	1828	1947	2176	2326
Supaul	2728	2723	5284	7658	1937	2812
Madhepura	1491	1803	3088	4556	2071	2527
Purnia	5488	417	12390	913	2258	2189
Kishanganj	13334	13343	29092	26828	2182	2011
Araria	8341	8019	13581	21191	1628	2643
Katihar	25608	21361	62981	53875	2459	2522
Total	67865	60400	143832	136281	2119	2256

Source: Directorate of Economics and Statistics, Department of Agriculture, Govt of Bihar

Production Technologies

Nursery management

Boro rice is grown during Nov-Dec to May-June. The crop growth stages like seed germination, emergence, seedling establishment and early vegetative growth are subject to low temperature stress during the winter months. In eastern India, minimum temperature goes below 10°C during mid December to mid January.

The critical temperature for different growth stages in rice crop is given below in Table 4.

Table 4. Response of the rice plant to varying temperatures at different growth stages*.

Growth Stage	Critical temperature (°C)		
	Low	High	Optimum
Germination	10	45	20-35
Seed emergence and establishment	12-13	35	25-30
Rooting	16	35	25-30
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordial	15	-	-
Panicle differentiation	15-20	38	-
Anthesis	22	35	30-33
Ripening	12-18	30	20-25

*Modified after Yoshida (1981)

As *indica* rice is primarily a warm season crop, low temperature affects seed germination and results in slow growth of the seedling. Therefore, *boro* rice deserves special care for nursery management.

1.1 Time of sowing

Seed sowing should be done from November to mid December. In some regions like Bihar, eastern Uttar Pradesh and Assam, nursery seeding is done in the last week of October to ensure good seed germination and seedling growth before the onset of cold period.

1.2 Seed rate

For high yielding varieties and hybrids, 40 kg seed and 20 kg seed per hectare, respectively is required.

1.3 Nursery area and seeding rate

For transplanting one hectare of the main field, 1000 m^2 area is required for raising nursery. Seed should be sown @ 50-60 g/m^2 and @20 g/m^2 for high yielding varieties and hybrids, respectively. A dense seeding helps minimize the effect of cold injury in the seedling.

1.4 Selection of land for nursery raising

Wet bed method of nursery raising is used for *boro* rice. Irrigated lowlands and low lying tract, where water table is high, is most suitable for nursery raising *in boro* rice. Seedlings raised near river bank on swampy lands or on the periphery of deepwater lands virtually remain green due to lower effect of cold injury. The microclimate of the sites near water bodies remain little warmer which facilitates normal root development in the seedlings.

1.5 Seed treatment

Fully developed and healthy seed should be used for nursery raising. Seed should be put in 2.5% solution of common salt. The floating seeds should be discarded and then washed in clean water to remove the salt. To protect the seedling from leaf blast and other diseases, the seeds should be treated with Carbendazim 50WP @ 1g/kg seed or Emisan-6 @ 2g/kg seed. Treated seed is soaked overnight in water and then incubated in wet gunny bag for 40-50 h for sprouting.

1.6 Manures and fertilizers

FYM or compost @ 2000 kg/ 1000 m^2 is applied during the first ploughing of nursery bed. $N:P_2O_5:K_2O$ @ 10:5:5 kg/1000 m^2 is applied in splits. The schedule of fertilizer application is 5:5:5 kg:: $N:P_2O_5:K_2O$ as basal, 2.5 kg N at 20 days after sowing and 2.5 kg N seven days before uprooting of seedlings.

1.7 Preparation of seed bed and seeding

Land should be thoroughly puddled and perfectly levelled to maintain a thin layer of water during seedling emergence. Nursery bed should be prepared of any convenient length with 1.0 or 1.25 m width and 10 cm height. Between two beds, a 20 cm wide channel is prepared. The sprouted seed is then evenly broadcast on the bed as per required seeding rate.

1.8 Insect pests and disease control

For areas endemic to rice tungro disease (RTD), Carbofuran 3G @5 kg/1000 m^2 or Phorate 10G @1.5 kg/1000 m^2 area is applied in the nursery bed three weeks after sowing. As a preventive measure against the stem borer infestation in the main field, Cartap 4G @ 1.8 kg or Carbofuran 3G @5 kg or Phorate10G @1.5 kg/1000 m^2 area is applied one week before uprooting of seedlings. Spraying of Carbendazim 50% WP @ 1 g/litre of water one week before uprooting of seedlings is done to control the blast disease.

1.9 Irrigation in the nursery

The nursery should be given light irrigation on regular basis for proper seedling growth and protection of the seedling from cold injury. The effect of cold injury is severe in dry beds. Therefore, the seedbed should not be allowed to become dry. With advancement of the seedling growth, 2.0-2.5 cm irrigation should be given in the nursery bed as and when needed.

Fig. 1. Cold injury in *boro* rice nursery

Raising healthy seedling for *boro* rice is a problem. Low temperature adversely affects seedling growth. The seedlings in nursery bed during winter period display slow growth rate, remain stunted, show burnt look, and many times seedlings are damaged severely (Fig 1). Initial effect of cold injury on seedling appears in stunting of growth and yellowing of leaves. With progress of cold period, leaves turn dark yellow to bronze in colour, and eventually die under severe cold condition. Cold injury in *boro* rice seedling can be minimized through proper nursery management tips like:

- Use of cold tolerant varieties.
- Raising seedling near river banks, swampy lands or in the periphery of *chaur* lands where warmer soil temperature ensures proper root growth.
- Regular irrigation in the nursery bed reduces the damage due to cold as water has high specific heat that prevents lowering of soil temperature near root zone.
- Application of FYM or compost in the nursery bed helps to maintain higher soil temperature and improves water holding capacity of the soil for seedling root growth and development.

- Application of N-fertilizer in optimum dose as the deficiency of nitrogen in leaves is disguised as cold injury.
- Periodical dusting of fuel wood ash, straw ash, cattle dung ash, etc on the seedling prevents cold injury.
- Removal of dew from the leaves' tips in the morning with the help of a bamboo stick or rope.

Polythene tunneling

Polythene tunneling or covering the nursery bed with polythene sheet during night time helps in maintaining higher temperature and thereby reduces the effect of cold (Fig. 2.). Polythene-tunnel constructed over the nursery bed significantly raises the temperature under the tunnel, allowing better seedling growth. 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 centre.

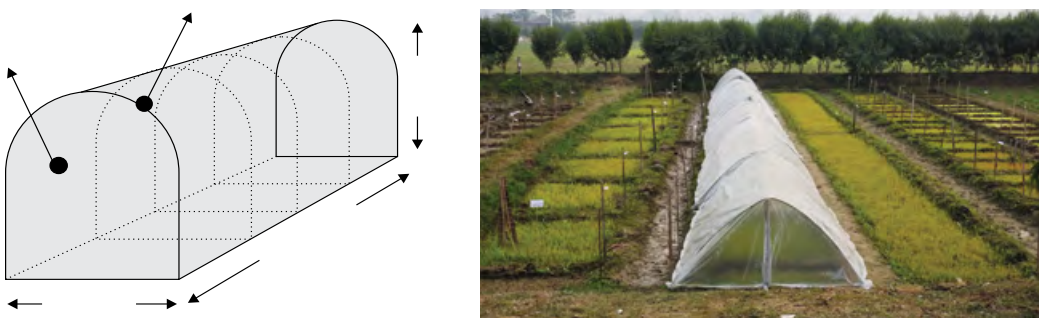


Fig. 2. Polythene tunnel for raising *boro* rice nursery

A colourless and transparent polythene sheet of 50-100 microns thick is spread over the frame. Mud lining is placed around the tunnel or the edge of polythene sheet is manually thrust gently in the mud to prevent any leakage of water and heat from the tunnel. 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 weeks. 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 rais-

ing the polythene cover in one end. Finally, the polythene cover is removed totally from the structure before seedlings are uprooted for transplanting.

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 only. The same material may be used for several years, making the annual cost even less.

Fig. 3. Preparation of raised seed bed

Dapog nursery

Dapog method of nursery raising is used when severe cold injury to seedling is expected.

Dapog method of nursery raising in *boro* rice is gaining popularity because it reduces the time required to produce seedlings; moreover, it uses less area per hectare to be planted compared to the wet bed method. In this method, 3 kg seeds are sown in 1 m^2 seedbed. It requires 15 to 25 m^2 seedbed for transplanting one hectare land. The seedbed must be 1-1.5 m wide for ease in management (Fig. 3). Nurseries can be located anywhere on a flat firm surface near the reliable source of water supply. The sprouted seeds are spread on plastic sheets or on banana leaves (Fig. 4&5). Seedlings could be grown under hut or in courtyard or even on roof. In this method, seedling raised in small container may cover a large area for transplanting, and it is very easy to carry the seedling from one place to other. There is saving of cost and time of uprooting of seedling.

Fig. 4. Sprouted seed

Fig. 5. Sowing of seeds on raised nursery bed

Fig. 6. Dapog or mat method of nursery raising

Field Preparation and Transplanting

Transplanting is the most common method of crop establishment for *boro* rice. Transplanting ensures a uniform plant stand and gives the rice crop a head start over emerging weeds. *Boro* rice is manually transplanted in puddled soils when the temperature starts rising from the middle of January onwards.

Selection of field for transplanting

Traditionally *boro* rice used to be transplanted in deep water ecosystem and on river banks where the availability of water is ensured for irrigating the crop. Low lying fields with high water table are suitable for *boro* rice cultivation. The *boro* rice grown in light textured soils requires frequent irrigation which in turn increases the overall cost of production. Therefore, fields with medium to heavy textured soils, having good water holding capacity and with irrigation source available in the vicinity are preferred for *boro* rice.

Time of transplanting

Date of transplanting plays an important role in the *boro* rice phenology (Mahmood, 1997). The rice seedling remains dormant during winter when the temperature is below 10° C. Transplanting should be done when the temperature rises from 12-13°C which generally comes from middle of January to middle of February. In multiple cropped areas, late planting up to first fortnight of March can be practised with early maturing varieties, although there is reduction in grain yield.

Land preparation

Land preparation is an important factor that influences the yield in rice crop. Proper land preparation promotes good physical, chemical and biological conditions of the soil for optimal crop growth. In deep water areas, water starts receding from the periphery. Here transplanting starts after puddling the areas in the periphery from where the water starts receding, and progressing towards the centre. In other areas, the land should be initially ploughed 3-4 times followed by laddering in presence of water. After one week, the field should be again ploughed 2-3 times followed by laddering in presence of water to produce puddle. During laddering, the field should be properly levelled to ensure uniform distribution of irrigation water. The depth of ploughing should be 10-15 cm. The basal dose of fertilizer should be applied before final puddling.

Fig. 7. Transplanting in puddled field

Transplanting

Transplanting of *boro* rice is done after second week of January when temperature starts increasing above 10° C. Due to low temperature, growth of seedling is stunted. A two month seedling of *boro* rice may attain a height of 12-15 cm with 4-6 leaves depending on varieties.

Transplanting is done in rows with spacing of 15 cm × 15 cm using 2-3 seedlings/ hill in puddled soil at a depth of 2-3 cm. Due to prevailing low temperature, mortality of seedlings occurs after transplanting. Therefore, gap filling should be done after 8-10 days to maintain the optimum plant population in the field.

Varieties and their Characteristics

Traditional *boro* rice varieties have very good cold tolerance at early vegetative stage, early maturity and high tillering ability which are highly desired traits; however, such varieties also possess undesired characteristics like short panicle, bold grain, red kernel, presence of awn, weak culm, tall plant stature, non- synchronous maturity and poor grain yield (2-3 t/ha). These are not suitable for intensive crop cultivation.

An ideal *boro* rice variety should have semi-dwarf to semi-tall plant type with stout culm and moderate tillering ability (8-12 tillers/ hill), cold tolerance at early vegetative stage and high temperature tolerance at reproductive stage, early maturity, medium slender grain type, tolerance to major insect pests and diseases and high grain yield potential (8-10 t/ha). Rice variety with such characteristics can be able to fully exploit the relatively risk free crop growing environment with abundant sunshine available in *boro* season.

Initially, high yielding short duration dwarf varieties released for *kharif* season like Pusa2-21, Pusa 33 and Saket 4 were introduced in the *boro* season. Later, medium duration varieties like Sita, Sujata, Jaya, IR 36, etc were also adopted for this season. None of these varieties were released for cultivation as *boro* rice. All these varieties have been adopted in *boro* season only due to varying degree of cold tolerance. Gautam was the first *boro* rice variety which was developed by Rajendra Agricultural University, Pusa, Bihar and released for cultivation in 1994. This was followed by other *boro* rice varieties like Chandrama, Chandan, IR64, TRC *Boro* Dhan, Jaymati. Jyotiprasad, Bishnunuprasad, and the like. Development of the ideal *boro* rice variety is still under progress. Characteristics features of some popular varieties of *boro* rice are given below**:**

Gautam

It is the first *Boro* rice variety released in 1994. It is a mutant of Rasi. It flowers in 165 days and matures in 195 days in *boro* season; however, it matures in 125-130 days during *kharif* season. It has high level of cold tolerance. On 0-9 scale, it has shown an average score of 1-3 across different years. The average plant height is 70 cm. It has displayed very good number of productive tillers per hill and high establishment ability of transplanted seedling. Panicle length is about 25-28 cm with

180-200 numbers of grains per panicle. The harvest index of this variety is 0.48 to 0.52 with yield potential up to 10 t/ha in Bihar, and may be suitable for other states as well.

IR 64

This variety was notified in 1991 and recommended for all India cultivation under irrigated ecology. It is semi-dwarf (100 cm) in stature with long slender grains. This variety matures in about 115-120 days in *kharif* season. In *boro* it takes 155-160 days to 50% flowering and 185-195 days to maturity. It has cold tolerance at seedling stage. This variety is tolerant to blast, bacterial leaf blight, rice tungro virus, brown plant hopper, green leaf hopper, white backed plant hopper and gall midge. The average yield potential has been recorded as 5.5-6.0 t/ha in *boro* season.

Rajendra Bhagwati

This rice variety was released by Rajendra Agricultural University (RAU), Pusa (Bihar) in 2010 and recommended for Bihar. This variety matures in 115-120 days in *kharif*; however, in *boro* it takes 145-150 days to 50% flowering and 175-185 days to maturity. This variety has low temperature tolerance at seedling stage. It has shown profuse productive tillering and high establishment ability of transplanted seedling. It has yield potential of 4.5-5.0 t/ha in *kharif* and 5.5-6.0 t/ha in *boro* season.

Gautam

IR64

Rajendra Bhagawati

Naveen

Naveen

This is a mid early maturing variety with average plant of 105 cm. It was released for cultivation in Odissa and Tripura in 2006 for irrigated condition. It has medium bold grain and it is tolerant to stem borer. It is suitable for *boro* season and performs well with SRI. It takes 170 days in boro with grain yield of 5-5.5 t/ha.

Prabhat

This is an old rice variety released by RAU, Pusa (Bihar) in 1978 for cultivation in the state of Bihar. It has dwarf stature and synchronized flowering during *boro* season. It has long slender grain.This variety matures in 95-100 days in *kharif*, whereas it takes 125-130 days to 50% flowering and matures in 155-160 days during *boro* season. It is tolerant to low temperature at seedling stage. Its yield potential is 3.5-4.0 t/ha in *kharif* and 5.5-6.0 t/ha in *boro* season.

Richharia

This rice variety was also developed by RAU, Pusa, Bihar for cultivation in Bihar. It is semi-tall with long slender grain and synchronized flowering during *boro* season. This variety matures in 100-110 days in *kharif* season. In *boro* season, it takes 130-135 days to 50% flowering and 160-170 days to maturity. It is tolerant to low temperature at seedling stage. Its yield potential is around 3.5-4.0 t/ha in *kharif* and 5.5-6.0 t/ha in *boro* season.

Dhanlaxmi

It has semi-dwarf plant height with synchronized flowering in *boro* season. It possesses long slender grain and matures in 95-100 days in *kharif* season, whereas in *boro* it takes 125-130 days to 50% flowering and 155-160 days to maturity. It is moderately tolerant to low temperature stress at seedling stage. It can grow in Zn deficient land (prevalent in north Bihar). It is tolerant to bacterial leaf blight, leaf blight and brown plant hopper. It has grain yield potential of around 3.5-4.0 t/ha in *kharif* and 5.5-6.0 t/ha in *boro* season.

Saroj

It is a semi-tall variety with long slender grain, and is recommended for irrigated condition. It has synchronized flowering in *boro* season. It matures in 115-120 days in *kharif* season, whereas in *boro* it takes 145-150 days to 50% flowering and 175-180 days to maturity. This variety is resistant to low temperature at seedling stage. Its yield potential is 5.0-5.5 t/ha in *kharif* and 6.5-7.5 t/ha in *boro* season. It has good ratooning ability, and it is popular in traditional *boro* rice growing region.

Chandan

It is a medium early duration (125 days) variety released and notified (2008) for cultivation in Odisha in *boro* season. It has medium slender grains and has an average productivity of 5.5-6.0 t/ha. This variety is tolerant to yellow stem borer, blast, bacterial leaf blight and sheath blight.

Jaymati

Jaymati is a medium-tall (130 cm) rice variety developed from the cross Jaya×Mahsuri followed by the pedigree method of breeding. It is suitable for growing in *boro* season. It has well-exerted panicles with brownish husk. Grains are awnless and medium in size. The variety has a 1,000-grain weight of 20.2 g. Jaymati is moderately resistant to bacterial blight, gall midge and stem borer. It matures in 170 days in *boro* season. It is recommended for *boro* rice growing areas of Assam. It has grain yield potential of 5.5-6.0 t/ha.

Chandrama

Chandrama **(**CR386-2-10), developed from the cross ARC6650× CR 94-721-3, was released by SVRC Assam in 2007 for cultivation during *boro* season. It is semi-tall with moderate cold tolerance at seedling stage. It is moderately tolerant to stem borer, gall midge, brown plant hopper and white backed plant hopper. It is resistant to leaf and neck blast and moderately tolerant to bacterial leaf blight, rice tungro virus, and sheath blight. It takes 155 days to 50% flowering and 185 days to maturity *boro* season. It has grain yield potential of around 6.5-7.0 t/ha.

Chandrama

Kshitish (IET4094)

This is an early duration (120 days) semi-dwarf variety released in 1982 for irrigated condition in West Bengal. It has been found suitable for *boro* season and it is popularly grown in West Bengal and north eastern Bihar as *boro* rice. It has moderate cold tolerance at seedling stage. It has long slender grain and it has moderate resistance to blast, bacterial leaf blight and rice tungro virus. It takes 150 days to maturity in boro and gives 5.5 t/ha grain yield.

Kshitish

CR Dhan 601

CR Dhan 601 has been derived from the cross Jaya×IR64. It was released by CVRC in 2010 for cultivation in Assam, West Bengal and Odisha. It is semi-dwarf with moderate tillering ability and good cold tolerance at seedling stage (score 3 on 0-9 scale). It is tolerant to diseases such as leaf blast, bacterial leaf blight and rice tungro disease and insect pests *viz*. yellow stem borer, green leaf hopper and leaf folder. It has medium slender grain. It matures in 185 days in *boro* season and it has grain yield potential of 7.0 t/ha.

Ajay (CRHR-5)

Ajay is a F_1 hybrid (CRMS31A× IR42266-29-3R) developed through three line system of hybrid rice breeding. This hybrid is based on an indigenous CMS system. Ajay is a medium statured (110 cm) having moderate tillering habit with high spikelet fertility (>85%). It has long slender grain with good milling, cooking and eating qualities. It is resistant to leaf blast, moderately resistant to rice tungro disease, bacterial leaf blight and field

Ajay

tolerance to stem borer, and white backed plant hopper. It matures in 125-130 days in *kharif* and 170 days in *boro* season. It has a yield potential of 6.5 t/ha in *kharif* and 7.0 t/ha in *boro* season.

Arize 6444

It is also an F_1 hybrid rice with high grain yield potential (5.5 t/ha). It is medium statured (100 cm) having high tillering ability, dense root and vigorous growth. It is popular hybrid of *kharif* season under irrigated condition. It is also grown during *boro* season following nursery management practice for low temperature stress. The grain yield potential in *boro* season is 7.0 t/ha.

Arize 6444

Pusa 2-21

It is short duration dwarf high yielding variety released for irrigated upland condition for *kharif* and summer season. But it has been adapted to *boro* season also. In *kharif*, it matures in 100-105 days with plant height of 80-90 cm. It has moderate degree of cold tolerance. It takes 158 days to mature in *boro* season. Its average plant height, panicle length and number of grains per panicle are 65 cm, 18-20 cm and 100-120, respectively. The average yield potential in *boro* season is 5.4 t/ha.

IR 36

It is a medium duration variety released for irrigated mid-land situation. In *kharif* season, it matures in 125-130 days, while it takes 170 days to 50% flowering and 200 days to mature in *boro* season. Its average plant height, panicle length, number of grains and yield potential during *Boro* season are 65 cm, 23 cm, 115 and 3.5 t/ha, respectively.

Jaya

It is also a medium duration variety which matures in 125-130 days in *kharif* season. When it is grown in *boro* season, it takes 180 days to flower (50%) and 205 days to mature. It attains average plant height of 70 cm in *boro* season; the panicle length and number of grains per panicle are 21 cm and 90, respectively. The aver-

age yield potential of Jaya during *boro* season has been recorded as much as 5.5 t/ha.

Mahsuri

It is a rainfed lowland rice variety which matures in about 140-145 days in *kharif* season. Due to its moderate cold tolerance at seedling stage, it has been adopted for *boro* season also. It flowers in 180 days and matures in 215 days in *boro* season. Its average plant height is 105 cm; panicle length is 24 cm and number of grains per panicle is 195.The average yield has been recorded around 4.5-5.0 t/ha.

Sujata

This variety matures in 130-135 days when grown in *kharif* season. In *boro* season, it takes 184 days to flower (50%) and 209 days to mature. Its average plant height is 75 cm; panicle length is 25 cm and number of grains per panicle is 160. The yield potential of Sujata has been recorded as high as 5.0 t/ha in *boro* season.

Water Management

Depending on the soil type, the total water requirement of *boro* rice may vary; however, typically it is around 2000 mm of which 50% is needed during the reproductive period of growth. As *boro* rice is cultivated in dry season, there is very little or no rainfall during the crop season. Therefore, assured irrigation is a prerequisite for successful cultivation of *boro* rice. Crop should be irrigated utilizing the available water sources like ground water, canal or low lying ditches. Irrigation in *boro* rice should be scheduled in such a way that there is adequate water in the field at critical crop growth stages, i.e., active tillering, panicle initiation, flowering and grain filling. After transplanting, there should be 2-3 cm standing water in the field up to 30 days after transplanting. It helps in proper seedling establishment and also mitigates the effect of low temperature stress on the crop. During this period (30-40 days after transplanting), water level of 4-5 cm should be maintained. Thereafter, the field should be kept at saturation (to check the growth of unproductive tillers). From panicle initiation to heading, 3.0 cm water should be maintained. After heading, 2-3 cm irrigation should be given after a gap of 2 days. This should be maintained up to20 days after heading. Heavy to medium textured soils are preferred for *boro* rice cultivation. These types of soils require less irrigation compared to light textured soil because heavy soils have high water holding capacity.

Nutrient Management

Organic manure should be applied @ 5 t/ha in the form of FYM or compost or azolla at the time first ploughing. Application of optimum dose of fertilizer at appropriate crop growth stage is important for harvesting high grain yield in *boro* rice. Inorganic fertilizers should be applied based on the soil test. For high yielding varieties of *boro* rice, the general fertilizer recommendation is 100:50:30 kg N:P:K /ha. Full dose of phosphorus and 75% dose of potash and 25% dose of nitrogen should be applied as the basal application. The remaining nitrogen should be applied in two splits, i.e., 50% at active tillering stage, and the last 25% at panicle initiation stage. The remaining 25% dose of potash should also be applied at panicle initiation stage. Micronutrients are also applied in deficient soils on the basis of soil tests to increase productivity. In saline and sodic soil, to ameliorate the zinc deficiency, $ZnSO_4$ $7H_2O$ is applied @ 25 kg/ha. In calcarious or alkaline soil, $FeSO_4$ $7H_2O$ is applied @50 kg/ha to correct deficiency of iron in the soil.

Weed Management

Weeds in the field compete with *boro* rice crop for water, nutrients, sunlight and space, thereby reducing the grain yield. Yield losses due to weeds may go up to 97%. Besides this, weeds also act as alternate hosts for insect pests and diseases. Therefore, it is important to keep the *boro* rice field free from weeds. During the early vegetative period, the crop growth is slow due to prevailing low temperature, and seasonal weeds grow at fast speed owing to wider adaptation and rapid vigour.

Major weed flora in *boro* rice field consists annual grasses like barnyard grass (*Echinochloa crus-gally),* Shama grass or jungle rice (*Echinichloa colonum* (L.) Link); annual broad leaf weeds like Goose weed (*Monochoria vaginalis and Sphenoclea zeylanika*); annual sedges like umbrella plant (*Cyperus deformis* and *Cyperus irria*), perennial grass like knot grass (*Paspalum distichum* L.), doob grass (*Cynodon dactylon*) and perennial sedge Chechra (*Scirpus maritimus*). (Fig. 8).

Hand weeding twice at 20 days and 40 days after transplanting is effective in controlling weed growth in *boro* rice. In case of shortage of manpower, herbicides like Butachlor (Machete) 5 % granule @ 30 kg/ha in 3-4 cm standing water within 2-4 days after transplanting (DAT) is applied to control grassy weeds. If herbicide granules are not available, Butachlor in liquid form may be applied @ 1.5 kg a.i./ ha mixed with 400 liter water or Benthiocarb (Saturn) @ 1.5 kg a. i. ha^{-1} just after 48 h of transplanting in 3-5 cm standing water or Pendimethalin @ 1.0 kg a.i./ha in 400 litre water. Their application helps in controlling weed and increasing nutrient

Rice sedge *(Cyperus deformis)*

Flat sedge *(Cyperus iria)*

Barn grass

Gooseweed *(Sphenoclea zeylanica)*

Water spinach *(Ipomea aquatic)*

Pondweed *(Monochoria vaginalis)*

Water clover *(Marsellia quadrifolia)*

Knotgrass *(Paspalum dis*tichum)

Bulrush *(Scirpus maritimus)*

Jungle rice

Fig. 8. Major weeds associated with *boro* rice

availability also. Bhattacharya *et al.* (2000) revealed that although hand weeding twice at 20 and 40 DAT gave the best level of weed control, this treatment was efficacious with quinclorac Sc 15 at 0.12 kg a.i ha^{-1} combined with one hand weeding at 40 DAT.

Cono-weeder can also be used for weeding by running the weeder in between the rows. Use of cono-weeder requires less manpower than manual weeding. It also helps in simultaneous incorporation of weed biomass into the soil and im-

proves soil aeration and root respiration. Line transplanting using a spacing of at least 20 cm between rows is prerequisite for using mechanical weeder.

Table 5. Recommended dose and application time of Herbicides for weed control in rice

S.N	Herbicides	Recommended dose (Kg a.i. ha-1)	Application time
1	Butachlor	1.5	Pre-emergence
2	Fluchloralin	0.65	Pre-emergence
3	Pendimethalin	1.5	Pre-emergence
4	Pretilachlor	1.0	Pre and early emergence
5	Pyrazosulfuronethyl	40 g	Pre and early post emergence
6	Oxyflurofen	1.5	Pre-emergence
7	Anilofos	0.2-0.4	Pre-emergence
8	Trifluralin	1.5	Pre-planting
9	2,4-D	1.0-1.5	Post emergence
10	Thiobencarb	1.0-1.5	Post emergence
11	Propanil	2-3	Post emergence
12	Bentazone	2.0	Post emergence

Insect Pests and Disease Control Measures

Disease management

In comparison to *kharif* rice, incidence of diseases is less observed in *boro* rice due to prevalent cool and dry weather. Major disease affecting the *boro* rice are leaf blast, neck blast, Helminthosporium leaf spot, narrow brown leaf spot, sheath rot and sheath blight. Proper management of diseases is essential to maintain healthy crop growth and high grain production. An integrated approach covering all aspects of disease management should be followed in order to grow a healthy crop. This includes seed treatment with fungicide, growing disease resistant varieties, adoption of proper agronomic practices, strict surveillance over appearance of disease symptoms and application of need based chemical control measures.

Table 6. Common diseases and control measures in *boro* rice.

Disease/ Symptoms	Control measure	Figure depicting symptom
Leaf blast: Initial symptoms appear as white to grey-green lesions or spots, with dark green borders. Older lesions on the leaves are elliptical or spindle-shaped and whitish to gray centers with red to brownish or necrotic border	Seed treatment with carbendazim @ 1.5 g kg seed. Spray Carbendazim 50WP @ 500g/ha (or) spray Trycyclozole 75 WP @ 600 g/ha	 Leaf blast
Neck blast: Lesions on the node are blackish to grayish brown and occur in banded pattern. Lesions on the neck are grayish brown and can cause girdling, making the neck and the panicle fall over. If infection of the neck occurs before milky stage, no grain is formed, but if infection occurs later, poor quality grains are formed.	Spray Carbendazim 50WP @ 500g/ha (or) spray Trycyclozole 75 WP @ 600 g/ha	 Neck blast
Helminthosporium leaf spot: Isolated brown, round to oval (resemble sesame seed) spots appear on leaf Spots measures 0.5 to 2.0 mm in breadth - coalesce to form large patches. Seed also infected (black or brown spots on glumes spots are covered by olivaceous velvety growth) Infection also occurs on panicle neck with brown colour appearance 50% yield reduction in severe cases	Treat seeds with hot water (53–54°C) for 10–12 minutes before sowing, to control primary infection at the seedling stage. To increase effectiveness of treatment, pre-soak seeds in cold water for eight hours. Spray Metominostrobin @ 500ml/ha or Propiconazole 25EC 500ml/ha	 Brown spots on leaves  Brown spots on grains

Sheath blight: Irregular lesions usually found on the leaf sheaths (initially water-soaked to greenish gray and later becomes grayish white with brown margin). Discoloration begins from leaf tip and extends down to the blade or the lower leaf portion. Delayed flowering, - panicles small and not completely exerted. Panicles remain sterile or grain filling is partial.	Seed treatment with carbendazim @ 1 g/ kg seed. Foliar spray of Neem oil 3% (15 l/ha) on appearance of symptom or spray Hexaconazole 75% WG @ 100 mg/ lit (1st spray at the time of disease appearance and 2nd spray 15 days later)	  Sheath blight
Sheath rot: Irregular spots or lesions, with dark reddish brown margins and gray center. Discoloration in the flag leaf sheath. Lesions enlarge and often coalesce and may cover the entire leaf sheath. Severe infection causes entire or parts of young panicles to remain within the sheath. Infected panicles sterile, shrivelled, or with partially filled grain.	Apply Gypsum @ 500 kg/ ha at two equal splits once basally and another at active tillering stage. Foliar spray of Neem oil 3% (15 l/ha) on appearance of symptom. Or, Spray Hexaconazole 75% WG @ 100 mg/ lit 1st spray at the time of disease appearance and 2nd spray 15 days later	 Sheath rot

Insect Pest Management

Boro rice has witnessed less insect pests pressure in comparison to *kharif* or *autumn* rice due to prevailing cool and dry weather condition. However, stem borer, gundhi bug, rice hispa, leaf folder, paddy grass hopper and rice mealy bug are major insect pests of *boro* rice crop. Proper pest management technique should be followed to reduce the insect pest infestation for increasing the grain yield. The insect pests of *boro* rice are presented below:

Table 7. Common insect pests of *boro* rice.

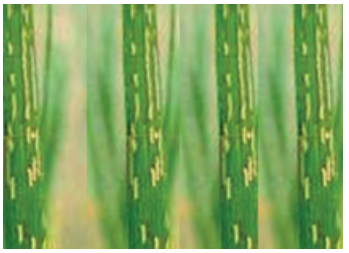
Insect pest name	Nature of damage	Management
Stem borer ***(Scirpophaga incertulas)***	Stem borers destroy rice plant at any stage from seedling to maturity. They feed upon tillers and cause "dead hearts" or drying of the central tiller, during vegetative stage; and causes "white-heads" at reproductive stage. Affected tillers or panicles can be easily pulled by hand.	• Before transplanting, cut the leaf top of seedlings to reduce carry-over of eggs from seed bed to main field. • At ATL release egg parasitoid, *Trichogramma japonicum* • Foliar spray of Azadirachtin 0.03% 1000 ml/ha , or Phosalone 35 EC 1500 ml/ha, Chlorpyriphos 20% EC 1.25 l/ha or apply Carbofuran 3% CG 25 kg/ha.
Rice hispa (*Dicladispa armigera*)	Adult insect feeds on chlorophyll by scraping and causing white parallel streaks on the leaves Grubs mine into the leaves and make blister near leaf tips. Damaged leaves fall down At severe infestation, field looks like burnt appearance.	• Spray the infested crop withChlorpyriphos 20% EC 1250ml/ha, or Malathion 50%EC 1150 ml/ha, or Triazophos 40% EC 625-1250 ml/ha
Gundhi bug (*Leptocorisa acuta* Thunberg)	Gundhi bugs cause damage by sucking out the contents of developing rice grains from pre-flowering spikelets to soft dough stage, thereby causing unfilled or chaffy grains and grain discoloration. Both immature as well as adult rice bugs feed on rice grains.	• Spray Malathion 50 EC 500 ml/ha or Neem seed kernel extract 5% 25 kg/ha twice: first at flowering and the second after one week when there are 5 bugs/100 earheads at flowering and 16 bugs/100 earheads from milky stage to grain maturity. • Or dust Quinalphos 1.5 D twice as above
Leaf folder ***(Cnaphalocrocis medinalis)***	longitudinal and transparent whitish streaks on damaged leaves, tubular folded leaves, leaf tips sometimes fastened to the basal part of leaf. Larva scrapes the green tissues of the leaves which becomes white and dry. During severe infestation the whole field exhibits scorched appearance with many folded leaves	• When 10% leaf damage at vegetative phase and 5% of flag leaf damage at flowering are observed spray the crop with Azadirachtin 0.03% 1000 ml/ha or Phosalone 35 EC 1500 ml/ha, or Chlorpyriphos 20 EC 1250 ml/ha or Carbaryl 50 WP 1.0 kg/ha. • Or release *Trichogramma chilonis* @5 cc (1,00,000/ha) thrice at 37, 44 and 51 days.
Grasshopper (*Hieroglyphus banian*), Short horned grasshopper *(Oxya nitidula)*	Insect feeds on seedlings and leaf blade in irregular manner. It cuts the stem at panicle stage. Sometimes it completely defoliates the plants leaving only the mid ribs	• Spray the crop with chlorpyriphos 20 EC 1250 ml/ha.

Grass hopper

Rice hispa

Leaf folder

Irregular feeding by grasshopper



Foliage damage by rice hispa

Foliage damage by leaf folder

Stem borer

Dead hearts

White ear heads

Rice gundhi bug

Rice gundhi bug

Fig. 9. Major insect-pests of *boro* rice

Harvesting and Threshing

Harvesting of the crop at the appropriate maturity stage is very important. Pre-mature harvesting of the crop might result in loss of yield with poor quality grains. If harvesting is delayed, grain may be lost due to damage by rats, birds, insects, shattering and lodging. Timely harvesting ensures better yield, good quality of grains, consumer acceptance and less breakage when milled. The right stage for harvesting is when panicles turn golden yellow with grains containing about 20 percent moisture.

Water in the field should be drained out 10-12 days before the expected date of harvesting. It hastens maturity and improves field conditions for harvesting. Matured crop is harvested manually using serrated edged sickles or paddy harvester. Threshing is done by is trampling by bullocks or lifting the bundles and striking them on the raised wooden platform or by using pedal threshers or power operated threshers.

Research on *Boro* Rice Conducted at ICAR-RCER, Patna

During *boro* season of 2015-15 to 2017-18 research work at ICAR-RCER, Patna was carried out on varietal evaluation, screening of rice genotypes for cold tolerance at seedling stage, nursery management practices and scoring of disease severity in *boro* rice. The salient findings of the work are presented below.

Varietal evaluation

Ten elite rice genotypes were evaluated at research farm of ICAR-RCER, Patna during *boro* 2015-16 and 2016-17 to assess their suitability as *boro* crop. Performance of these genotypes is presented in Table 10.

Fig.10. Cold tolerant rice TP30752 (IRTON103) and Cold susceptible rice TP20692 (IRTON 204)

All the genotype, except Kshitish and Silky, were significantly superior in terms of grain yield in comparison to the check variety Gautam (5.87 t/ha). An elite culture, RCPR31 produced the highest grain yield (8.17 t/ha) followed by IR64 (7.10 t/ha) and Naveen (6.90 t/ha). IR64, Kshitish, Ram and Silky are popularly grown as boro rice in north eastern Bihar.

Table 10. Performance of promising rice varieties in *boro* season

Rice genotypes	Days to 50% flowering	Ear bearing tillers/sq.m.	Plant height (cm)	Fertile grains/ panicle	Spikelet fertility (%)	Panicle length (cm)	Harvest index (%)	Grain yield (t/ha)
Kshitish	144	357	101.4	222	84.7	24.1	40.3	5.47
Chandrama	149	363	107.3	156	81.0	27.6	49.3	6.30
IR64	149	353	106.7	126	77.3	26.3	46.0	7.10
Ram	146	405	105.6	170	85.3	26.1	42.7	6.10
Naveen	151	318	109.0	180	90.0	28.1	46.3	6.90
Silky	153	350	97.6	197	78.0	27.3	42.3	5.47
RCPR31	149	384	97.7	142	86.3	26.5	48.3	8.17
CRL193	145	359	107.3	169	81.0	26.8	40.3	6.10
Rajendra Bhagwati	145	332	101.9	134	79.3	28.3	46.3	6.37
Gautam (check)	142	355	101.3	167	92.0	25.5	45.7	5.87
SE(m)	*1.1*	*11.9*	*1.4*	*6.2*	*3.0*	*0.7*	*1.6*	*0.24*
$CD_{0.05}$	*3.2*	*35.6*	*4.2*	*18.7*	*8.9*	*2.0*	*4.7*	*0.71*

Screening of rice genotypes for cold tolerance

A number of rice varieties grown in boro season along with 16 genotypes under IRTON-2017 Set No. 1 obtained from IRRI, Philippines were screened for cold tolerance at seedling stage during 2017-18 *boro*. Observations on seedling height, number of leaves per seedling and leaf colour were recorded after 40 and 60 days after seeding. The numerical values for seedling colour were assigned in the scale of 1-9 (1-seedlings dark green, 3-seedlings light green, 5- seedlings yellow, 7-seedlings brown and 9-seedlings dead) based on Standard Evaluation System for Rice (SES) of IRRI-2002. Out of these only TP30752 (IRTON 103) was found to be highly cold tolerant at seedling stage with score (3). Rice varieties Kshitish and IR 64 showed moderate level of tolerance to cold stress at seedling stage with score (5). Other genotypes showed high (Score 7) to very high (score 9) susceptibility to cold stress at seedling stage.

Nursery management in *boro* rice

In order to manage the adverse effect of low temperature in *boro* rice seedling, nursery of three rice verities namely Rajendra Bhagawati, Prabhat and IR 64 were established under three management practices: (1) Mulching with vermi-compost, (2) Poly-Tunneling and (3) farmers' practice as control . In mulching with vermicompost, vermicompost @ 2.0kg /m^2 was applied in the bed after seed sowing. In poly-tunneling, the nursery bed was covered with white polythene sheets on bamboo frame during night period. The farmer's practice of nursery raising in open without application of vermi-compost was used as control. Observations on seedling height, number of leaves per seedling and leaf colour were recorded after 40 and 60 days after seeding based on Standard Evaluation System for Rice (SES) of IRRI-2002. The effect of these three management practices was found to be significant among all three varieties.

Table 11. Effect of different management practices in boro rice nursery

Treatments	Seedling height (cm)		Number of leaf/ seedling		Seedling Colour	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Use of Polytunnel	15.51	19.97	3.5	4.60	3.00	8.33
Mulching with vermi-compost	16.42	21.01	3.7	5.27	3.80	3.00
Control (Open)	15.25	19.42	4.0	4.60	4.67	5.00
C.D.	NS	NS	0.23	0.40	0.80	NS
SE(m)	0.33	0.48	0.07	0.12	0.24	1.93
Rajendra Bhagawati	17.85	23.06	4.00	5.20	3.67	4.33
Prabhat	14.91	18.87	3.67	4.60	3.80	7.67
IR 64	14.42	18.48	3.60	4.67	4.00	4.33
C.D.	1.28	1.64	0.23	0.52	NS	NS
SE (m)	0.44	0.56	0.08	0.18	0.21	1.93

Among the three management practices, mulching with vermi-compost was most effective in overcoming the affect of low temperature stress as evident by better seedling vigour. Among the varieties Rajendra Bhagawati is most cold tolerant followed by IR 64 and Prabhat.

Incidence of disease and disease severity in *boro* rice

Susceptibility of *boro* rice to major field diseases like brown spot, sheath blight and bacterial leaf blight was evaluated during boro 2015-16. The disease incidence and disease severity were recorded at flowering, milk and maturity stages in 30 genotypes of *boro* rice (Bhakta *et al*. 2017).

Diseases	Disease incidence (%)			Disease severity (%)		
	Flowering stage	Milk stage	Maturity stage	Flowering stage	Milk stage	Maturity stage
Brown spot	8.9 to 17.8	16.7 to 25.7	18.3 to 28.3	5.1 to10.3	9.3 to 20.0	11.6 to 22.7
Sheath blight	4.0 to 8.6	8.3 to 13.9	18.3 to 34.3	4.0 to 8.6	8.3 to 13.9	18.3 to 34.3
Bacterial leaf blight	5.0 to 14.0	11.4 to 21.0	17.0 to 34.0	2.0 to 8.0	6.3 to 12.0	14.5 to 20.2

All the 30 genotypes were susceptible to brown spot, sheath blight and bacterial leaf blight. Highest incidence and severity of brown spot was observed in Rajendra Bhagawati in all the three growth stages where as the lowest incidence and severity was observed in 27P31. For sheath blight, highest incidence and severity was recorded in Samba Mahsuri and the lowest in CRL193. Similarly for sheath blight, the highest incidence and severity was observed in Kranti and lowest incidence and severity was observed in CRL193. It was also observed that minimum incidence and severity of diseases resulted in maximum grain yield. There was a gradual increase in disease incidence and severity from flowering to Maturity.

Issues in *Boro* Rice

Cold injury in seedling

Boro rice suffers from cold injury due to low ambient temperature during the early vegetative growth stage. This is the main constraint in *boro* rice area expansion. The term "Cold tolerance" in case of rice refers to the capacity of plants to withstand temperature in the range of 15-20°C (Chung 1979). In December, seedling faces severe cold, and sometimes temperature goes down below 8°C. Seedlings show high rate of mortality. Due to cold, at first, leaf turns yellow and ultimately plant dies. The effect on seedling can be seen in term of leaf rolling, leaf chlorosis and seedling death (Xu and Shen, 1988), rooting ability, and the like (Shahi and Khus, 1985).

Hot weather during ripening stage

The ambient temperature becomes high (>40°C) at ripening stage. Hot weather causes grain sterility and drought in absence of irrigation facilities.

Long crop duration

From seedling (October/November) to harvest (first to second week of May), crop takes about 190-200 days. Due to long duration, it needs more care and increases the total cost of cultivation. This calls for breeding and development early maturing (150-160 days), high-yielding rice varieties suitable for cultivation in the *boro* season.

Maintenance of seedlings

Seedling remains in nursery for 90 to 120 days. Because of its longer period, seedlings are vulnerable to grazing and require much attention and care, which add additional cost to nursery management.

Stunted growth of seedling

Due to long interval (9-10 days) for leaf emergence in seedling of *boro* rice, the average leaf number in 45 days after emergence remains only 4-5. During winter, the seedling growth is virtually stopped. With stunted seedling (10-12 cm), transplanting becomes difficult in deeper landscape. This calls for raising nursery in polyhouse where temperature may be regulated.

High seed rate

High seed rate (70-80 kg/ha) is used by farmers for transplanting more seedling/hill and also for gap filling after transplanting to maintain optimum plant population in the crop field.

Unsynchronized tillering

In *boro* rice, tillering is continued beyond 60 days after transplanting. Panicles on the main culm and primary tillers mature much earlier than secondary and tertiary tillers, making harvesting a bit difficult.

Conclusion

Boro rice produces more yields (5-7 t/ha) than the *kharif* rice (2-3 t/ha).The productivity of *boro* rice is high owing mainly to favourable soil-water-climatic

conditions such as bright sunshine during entire crop growth period, assured irrigation, low incidence of pests and diseases and use of high fertilizer responsive modern varieties. However, one of the major constraints associated with *boro* rice cultivation is low temperature during middle of November to middle of February which adversely affects the physiological and biochemical processes of the crop at seedling and early crop establishment stage. Use of polytunnel with thin bamboo sticks to cover nursery during night, removal of dew drops from the tips of seedling in the morning, dusting of ashes and frequent irrigation helps in reducing cold injury to rice seedling. Addition of compost /FYM improves seed germination and seedling vigour.

Due to long crop duration and increased requirement for irrigation, the cost of cultivation of *boro* rice is high as compared to *kharif* rice. Nevertheless, *boro* rice cultivation is still profitable in deeply flooded areas.

There is about 9 m ha of flood-prone, waterlogged and deep water areas in eastern India with unstable productivity of rice. Rice productivity in these areas can be improved through *boro* rice cultivation by providing assured irrigation through shallow tube well or surface irrigation. There is a need of rice varieties and hybrids with cold tolerance at seedling stage, heat stress tolerance at reproductive stage, high grain yield, resistance to insect pests and diseases along with good grain quality. *Boro* rice has the potential to produce grain yield upto 10 t/ha with use of high yielding varieties/hybrids and integrated crop management practices.

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