INFLUENCE OF DIFFERENT CULTIVATION METHODS ON GROWTH AND YIELD OF HYBRID AND INBRED RICE

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CERTIFICATE

This is to certify that thesis entitled, **"INFLUENCE OF DIFFERENT CULTIVATION METHODS ON GROWTH AND YIELD OF HYBRID AND INBRED RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY,** embodies the result of a piece of bona fide research work carried out by **QUAZI NASIM AHMED**, Registration No. **00490** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

(Dr. Parimal Kanti Biswas)
Supervisor

Dedicated

To

Those Who:

Work for humanity

Struggle against poverty

Fight against superstitions

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ABSTRACT

A field experiment was carried out at Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2005 to May 2006 to study the influence of different cultivation methods on hybrid and inbred rice in boro season. The experiment consisted of two level of treatments viz. variety and cultivation method. The experiment was laid out in split-plot design with four replications. Experimental results showed that variety had significant effect on all the agronomic parameters except panicle length, total grains panicle^{-1}, straw yield and biological yield. The highest grain yield (8.26 t ha^{-1}) with lowest straw yield (7.25 t ha^{-1}) was obtained from Sonarbangla-1 and BRRI dhan 29 gave the lowest grain yield (7.53 t ha^{-1}) with highest straw yield (9.58 t ha^{-1}). Cultivation method also significantly influenced all the growth and yield attributes except unfilled grains panicle^{-1}, 1000-grains weight and straw yield. The results revealed that nursery seedlings showed the best performance compared to other cultivation method. The highest grain yield (8.73 t ha^{-1}) and straw yield (9.21 t ha^{-1}) was obtained from the nursery seedlings and the lowest grain yield (7.23 t ha^{-1}) and straw yield (7.19 t ha^{-1}) was obtained from the SRI. Maximum harvest index 52.47 was calculated in the SRI and minimum harvest index 46.22 was found in the sprouted seeds broadcast. Tillers hill^{-1} of SRI was the highest among the treatments, however, it failed to perform well in terms of effective tillers m^{-2}, though sprouted seeds sown in line and broadcast showed opposite trends. The plants from sprouted seeds and SRI matured early compared to the nursery seedlings and clonal tillers. Sprouted seeds of the hybrid variety sown in line required 113 days, which is 33 days less than the required time for the traditional method of the inbred rice variety.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AWD	Alternate Wet-Dry
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CARE	Co-operations for American Relief Everywhere
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAE	Department of Agricultural Extension
DAS	Days After Sowing
DAT	Days After Transplanting
et al.	And others
e.g.	*exempli gratia* (L), for example
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram (s)
HI	Harvest Index
i.e.	*id est* (L), that is
IRRI	International Rice Research Institute
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter squares
Maund	One maund is equal to 37.5 kg
M.S.	Master of Science
NGO	Non Governmental Organization
No.	Number
NS	Non significant
PETRRA	Poverty Elimination Through Rice Research Assistance
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource and Development Institute
SRI	System of Rice Intensification
var.	Variety
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
°C	Degree Centigrade
%	Percentage

CHAPTER 1

INTRODUCTION

Rice is a semi-aquatic annual grass plant and is the most important cereal crop in the developing world. Ninety percent of all rice is grown and consumed in Asia (Anon., 1997; Luh, 1991). Rice feeds more than half the people in the world (David, 1989) but not well and may not do so for much longer. As the population rises, so does the demand for rice. Yet, yields of the crop are levelling out. How the current level of annual rice production of around 545 million tons can be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 using less water and less land is indeed the great challenge in Asia (Dawe, 2003). A study showed that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management inputs (Beinroth et al., 2001).

Densely populated and threatened by floods and storms – Bangladesh is one of the poorer countries of the world. About 75% of the total cropped area and more than 80% of the total irrigated area is planted to rice (Hossain and Deb, 2003). Almost all of the 13 million farm families grow rice. It provides nearly 40% of national employment (48% of rural employment), about 70-76% of total calorie supply and 66% of protein intakes of an average person in the country (Anon., 2004a; Hossain and Deb, 2003; Greenfield and Dowling, 1998; Dey et al., 1996). Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (Hossain, 2002). Thus, rice plays a vital role in the livelihood of the people.

The country is now producing about 42.3 million tons of clean rice @ 3.78 t ha^{-1} in 11.2 million ha of land (Appendix XI, XII and XIII). A conservative statistics given by Bhuiyan et al. (2002) indicates that about 21% higher amount of rice than the production of 2000 have to be produced to feed the population by the year 2025. There is no opportunity to increase rice area consequently; much of the additional rice required will have to come from higher average yield on existing land. Clearly, it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. (Wang et al., 2002).

Rice cultivation in Bangladesh is predominantly practiced in transplanting method that involves raising, uprooting and transplanting of seedlings. This is rather a resource and cost intensive method since, preparation of seedbed, raising of seedling and transplanting are labor and time intensive operations. Labor involvement for these operations consists nearly one third of the total cost of production in Bangladesh. Moreover, rice cultivation is largely depended on the climate. To avoid these difficulties several rice cultivation methods have been developed so far. Among those SRI (System of Rice Intensification), drum seeder technique and clonal tillers are gaining acceptance by the growers day by day.

SRI is a technique that is a set of practices and a set of principles rather than as a "technology package" (Uphoff, 2004a). SRI is not a technology like the seed of high-yielding varieties or like a chemical fertilizer or insecticide. It is a system for managing plants, soil, water or nutrient together in mutually beneficial ways, creating synergies (Laulanié, 1993). With SRI, management practices control or modify the microenvironment so that existing genetic potentials can be more fully expressed and realized.

The most obvious advantage from SRI appears to be the yield increase in farmers' field without any new seeds or chemical and mechanical inputs (Stoop et al., 2002) and that is reported to be from 50% to 200% (Uphoff, 2005; Deichert and Yang, 2002; Wang et al., 2002). According to proponents, SRI encompasses a set of principles, each of them fairly simple, but working synergistically with the others in order to achieve higher grain yield (Uphoff et al., 2002; Anon., 1992; Vallois, 1996).

Since optimum number of tillers per unit area is a prerequisite for obtaining maximum yield from a rice cultivar and hence removal of excess tillers from the mother hill may (Reddy and Ghosh, 1987) or may not (Biswas and Salokhe, 2002; 2001; Biswas, 2001) create any adverse effect on mother crop. However, it makes room for further development of the remaining tillers and detached tillers can be used as seedlings during scarcity of the same caused by flood/natural hazards but also substitute the local varieties. Thus, it could be an important aspect to know the strength of minimum number of tillers to be transplanted per unit area and hill for optimizing yield. However, sometimes price of seeds may be high, for instance seeds of hybrid rice. Clonal tillers reduce the seeding rate and thus save the cost of seed. In post-flood situations, planting area could be increased by about 300% by detaching tillers from the mother hills and replanting in separate plots (Roy et al., 1990).

The transplanting of rice seedlings being a high labor-intensive and expensive operation needs to be substituted by direct seeding which could reduce labor needs by more than 20 percent in terms of working hours (Pradhan, 1969; Fujimoto, 1991; Santhi et al., 1998.). With the advent of improved agricultural machinery coupled with shortage of farm labor, mechanization is becoming inevitable and as such we must strive to take advantage of those. Drum seeder is an appropriate technology to combat low profitability of rice cultivation caused by increasing production costs, lower yield per unit area and shortage of farm labor at planting time.

Direct wet-seeding is an alternative method of growing rice instead of conventional transplanting (Coxhead, 1984). In this method, sprouted (pre-germinated) seeds are sown on well prepared puddled land (Can and Xuan, 2002). Direct seeding can be done either by hand broadcasting or by using a drum seeder.

Many Southeast Asian countries are now increasingly shifting to direct wet-seeded method of growing rice (Moody and Cordova, 1985; Erguiza et al., 1990; Pandey et al., 2002). However, the practice of direct wet-seeded rice is very negligible in Bangladesh, although research results have clearly shown the superiority of direct seeded rice to conventional transplanting (Khan et al., 1992; Sattar et al., 1996; Husain et al., 2002). In Bangladesh, direct seeded rice produced about 2-12% higher grain yield than transplanting (Husain et al., 2003a). Sattar and Khan (1994) reported that direct wet-seeded rice required about 20% less water compared with transplanted rice. Isvilanonda (2002) reported that direct seeded rice reduced 2-6% production cost and increased net return by 37%, in dry season. Direct seeding eliminates the need for seedbed preparation, seedling uprooting and transplanting and the associated costs and energy. In addition, direct seeded rice matures about 8-10 days earlier (Husain et al., 2003a; Khan et al., 1992) because direct seeded rice may escape transplanting shock and injury (Sattar et al., 1996) and gives about 10-15% higher yield than transplanted rice (Ding et al., 1999).

Because of these variable information about the effect of cultivation methods of inbred and hybrid rice varieties on yield, a detailed study was under taken with the following objectives:

- to compare the performance of BRRI dhan 29 (inbred) and Sonarbangla-1 (hybrid), and
- to find out the effect of cultivation method for optimum growth and yield of boro rice,
- to predict the perfect cultivation method for optimum growth and yield of boro rice.

CHAPTER 2

REVIEW OF LITERATURE

New technologies are available now and received much attention to the researchers throughout Bangladesh to develop its suitable production technologies for rice areas. Although this idea is not a recent one but research findings in this regard is scanty. Some of the pertinent works on these technologies have been reviewed in this chapter.

2.1 Effect on growth parameters

2.1.1 Plant height

Nissanka and Bandara (2004) evaluated the productivity of System of Rice Intensification (SRI) method with conventional rice farming systems in Sri Lanka. Average plant height growth and leaf chlorophyll content during the growing stages were also similar among the treatments.

Sarkar et al. (2003) reported that compared with transplanting, the crops from anaerobic direct sowing had greater plant height.

Sarkar et al. (2002) investigated the effect of row arrangement, time of tiller separation on growth of transplant aman rice (cv. BR23). The experiment comprised of three row arrangement viz., single, double and triple row; two times of tiller separation viz., 25 days after transplanting (DAT) and 35 DAT; and three levels of number of tillers kept hill^{-1} viz., 2,4 and intact hills. The tallest plant was recorded in single row, intact hills and when row and intact hills.

Goel and Verma (2000) investigated the effects of 2 sowing methods, direct sowing and transplanting, on the yield and yield components of 2 rice cultivars, and observed plant height (104.8 cm) was higher in transplanting. No significant interactions were observed between cultivars and sowing methods.

Rahman (2001) observed that the tallest plant was found in the intact crop. Paul (1999) reported that the maximum plant height at harvest was found when tillers were separated at 25 DAT whereas, separated at 35 DAT was minimum in respect of above character. Mamin et al. (1999) observed that plant height was greatest in intact mother hills (105-106 cm), while the height of split and replanted tillers ranged from 95-101 cm. Sharma (1994a) reported that clonal tillers were taller (90 cm) compared with nursery seedlings (50-80 cm). Mollah et al. (1992) observed that removal of greater numbers of tillers from the mother hill reduced plant height significantly. Richharia et al. (1964) observed that the plant height was more in tiller plants than those in seed plants.

Reddy et al. (1987) conducted an experiment in India in which rice cv. Tellahamsa seedling were transplanted in lines or at random. They found that plant height (78.1-78.01 cm) did not differ significantly for the planting methods.

2.1.2 Number of tillers hill^{-1}

Akbar (2004) reported that Sonarbangla-1 ranked first in respect of total tillers hill^{-1} among the varieties studied. Sarkar et al. (2002) investigated the effect of row arrangement, time of tiller separation on growth of transplant aman rice (cv. BR23). Experimental result showed that in single row tillers could be separated at 25 DAT without hampering tiller reduction hill^{-1}.

Saina (2001) reported in SRI practice fifty tillers per plant were easily obtained, and farmers who had mastered the methods and understand the principles had been able to get over 100 tillers from single tiny seedling. Garcia et al. (1995) found that uninhibited growth of direct seeded rice during the vegetative stage led to superior tiller number at maturity to that of transplanted rice.

2.1.3 Leaf area index

Sarkar et al. (2002) investigated the effect of row arrangement, time of tiller separation on growth of transplant aman rice (cv. BR23). Growing of transplant aman rice in triple rows with intact hills appears as the promising practice in respect of highest leaf area index.

Hoon and Kim (1997) compared the physiological and ecological characteristics of rice cv. Whasungbyeo in direct sown and transplanted crops in Japan. The specific leaf area was higher in mechanically transplanted crop (MTC) than in direct sown crop (DSC) from the tillering stage to 15 days before heading, and was lower in MTC from the heading stage to 15 days after heading.

2.1.4 Dry matter production

Nissanka and Bandara (2004) evaluated the productivity of System of Rice Intensification (SRI) method with conventional rice farming systems in Sri Lanka. Dry weights of stems, leaves, and roots and the total dry weights, leaf area and total root length per hill during the growing period and the tiller number per plant at heading were significantly higher in SRI compared to other treatments. However, all these parameters, when expressed per unit area basis, were not significantly different.

Paul et al. (2003) investigated leaf production, leaf and culm dry matter yield of transplant aman rice as affected by row arrangement and tiller separation in this study. The maximum culm dry matter yield was recorded in triple row (4.14 t ha^{-1}, 85 DAT), when tiller separation was done at 35 DAT (4.01 t ha^{-1}, 85 DAT) and intact hills (4.10 t ha^{-1}, 85 DAT) which was statistically identical to 4 tillers kept hill^{-1} (3.97 t ha^{-1}, 85 DAT). But the lowest dry matter of culm was recorded in single row (0.42 t ha^{-1} 25

DAT), when tiller separation was done at 25 DAT (0.50 t ha^{-1}, 25 DAT) and 2 tillers kept $hill^{-1}$ (0.49 t ha^{-1}, 25 DAT). Closer row spacing significantly reduced the leaf production ability $hill^{-1}$ but increase leaf and culm production per unit area and hence, dry matter yield increased. To enhance leaf production $hill^{-1}$, transplant aman rice cv. BR 23 (Dishari) could be grown in single row but to increase dry matter yield it could be grown in triple or double row arrangement. Tillers could be separated at 25 or 35 DAT keeping 4 tillers $hill^{-1}$.

Sarkar et al. (2003) conducted an experiment at Cuttack, Orissa, India where seeds of 6 rice cultivars (Tulasi, FR 13A, T 1471, Sabita, Kolasali and CH 19) were sown in moistened soil and maintained after 5 days under 5 cm of water were compared with 30-day-old seedlings transplanted in the normal way. Compared with transplanting, the crops from anaerobic direct sowing had greater above-ground dry matter.

Longxing et al. (2002) studied the physiological effects of different rice crop management systems by comparing the results associated with traditional methods of flooded rice irrigation to non-flooded rice farming with young seedlings and wider spacing (SRI). In SRI, they observed, forms high biomass by large individual plants, and dry matter accumulation after heading accounted for 40% of the total dry matter. More than 45% of the material from stem and sheath was contributed to grain yield in SRI. At the same time, SRI facilitates a heavier and deeper root system.

Sarkar et al. (2002) investigated the effect of row arrangement, time of tiller separation on growth of transplant aman rice (cv. BR23). Growing of transplant aman rice in triple rows with intact hills appears as the promising practice in respect of highest total dry matter production. Sharma (1994a) reported that clonal tillers had more dry weight (1.78 g) compared with nursery seedlings (0.25-0.91 g).

Naklana et al. (1996) reported that direct sowing produced more total dry matter than transplanting. Root dry matter growth was small after panicle initiation under all conditions and was greatest in direct sowing than transplanting in low land conditions.

Naklang et al. (1996) reported that rainfed rice crops were grown under both upland and lowland conditions. While upland crops were almost always direct sown, both transplanting and direct sowing were commonly practiced for lowland crops in Asia. Direct sowing, particularly broadcasting, produced more total dry matter than transplanting. Root dry-matter growth was small after panicle initiation under all conditions, and was greater in direct sowing than transplanting in lowland conditions. Root growth occurred mostly in the top 10 or 15 cm soil layer in both upland and lowland crops. Root mass below 30 cm depth exceeded 10% of the total root mass at maturity in only one crop in which seeds were dibbled under upland conditions.

2.1.5 Days to flowering and maturity

Ali et al. (2006) mentioned that shortage of labor and water are forcing farmers to explore the alternatives of transplanting. He further concluded that direct-seeded rice had shorter crop duration. Anon. (2004b) reported that the cultivation of boro rice by direct seeding using the drum seeder had created a sensation among farmers wherever it was tested. Earlier harvest could result in another crop being accommodated. The choice of appropriate variety and cropping system would be important.

Karmakar et al. (2004) conducted two experiments in Boro 2002 and 2003 at the Bangladesh Rice Research Station, Rajshahi, Bangladesh to validate the SRI practice through spacing, seedling age and water movement comparing with conventional practice and bed planting on BRRI dhan 29. In general, growth duration increased by 7-10 days in the treatments where wider spacing and younger seedlings were used.

Valarmathi and Leenakumary (1998) carried out a field experiment in Kerala, India to evaluate the suitability of aman rice cultivars under direct sown conditions because of scarcity of labor for transplanting. Shorter duration in time to maturity was observed in all the cultivars under direct sowing, upland situation than under lowland transplanted conditions.

Bo and Min (1995) noticed that transplanted rice was most costly and it delayed flowering by 20 days and yielded lower than the direct wet-seeded rice. Sattar and Khan (1992) reported that direct wet-seeded rice was harvested 16 days earlier than transplanted rice.

Mollah et al. (1992) observed that removal of greater numbers of tillers from the mother hill prolonged growth duration. This had, however, no influence on the grain yield and yield components as compared to the intact mother hill.

De Datta and Nantasomsaran (1991) reported that direct wet-seeding contributed to early establishment of the first crop and contributed to increase cropping intensity because it eliminated the time for seedling raising.

2.2 Effect on yield contributing characters

2.2.1 Number of effective tillers m^{-2}

Akbar (2004) reported that inbred variety BRRI dhan 41 performed the best in respect of number of bearing tillers $hill^{-1}$ in comparison with hybrid variety Sonarbangla-1. Paul et al. (2002) studied the effect of row arrangement, time of tiller separation and number of tillers kept $hill^{-1}$ on the yield of transplant aman rice (cv. BR23). The highest number of effective tillers $hill^{-1}$ was obtained when 2 tillers were kept $hill^{-1}$. The highest number of effective tillers $hill^{-1}$ was obtained when tillers were separated at 35 DAT and 4 tillers kept $hill^{-1}$, which was similar to tiller separation at 25 DAT keeping 2 tillers $hill^{-1}$. Paul (1999) obtained the highest number of effective tillers $hill^{-1}$ when 2 tillers were kept $hill^{-1}$.

Aziz and Hasan (2000) reported that in SRI practice, the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103, respectively in Parija variety at Rajshahi. The highest number of effective tillers m^{-2} (531) was found with 35cm×35cm spacing in Department of Agricultural Extension trials at Kishoregonj. But with the same spacing the number was 342 m^{-2} in Locally Intensified Farming Enterprises trials at Kishoregonj. On the other hand, in farmers practice the average number of effective tillers m^{-2} was 290 and 393 with 20cm×20cm and 20cm×15cm, respectively.

Maqsood et al. (1997) grown rice cv. Basmati-385 grown at Faisalabad during 1994 and 1995 established by transplanting or direct sowing. Number of productive tillers hill^{-1} was significantly higher from transplanting than direct sowing for both the years.

2.2.2 Total number of grains panicle^{-1}

Akbar (2004) reported that inbred variety BRRI dhan 41 produced the highest number of grains panicle^{-1} than the hybrid variety Sonarbangla-1. Paul et al. (2002) studied the effect of row arrangement, time of tiller separation and number of tillers kept hill^{-1} on the yield of transplant aman rice (cv. BR23). The highest number of grains panicle^{-1} was obtained when 2 tillers were kept hill^{-1}. Biswas and Salokhe (2001) observed that grains panicle^{-1} showed better responses with early transplanting of the photo periodically sensitive KDML 105 in the mother crop and vegetative tillers. Rahman (2001) observed that the maximum number of grains panicle^{-1} was found in the intact crop. Paul (1999) obtained the highest number of grains panicle^{-1} when 2 tillers were kept hill^{-1}. Biswas et al. (1989) conducted an experiment on number of splitted tillers hill^{-1} needed for replanting with BR 11 (Mukta) and suggested that splitted tillers of 35 DAT replanted at 3 tillers hill^{-1} gave the highest grains panicle^{-1}.

2.2.3 Filled grains panicle^{-1}

Biswas and Salokhe (2001) observed that percent filled grains showed better responses with early transplanting of the photo periodically sensitive KDML 105 in the mother crop and vegetative tillers. Rahman (2001) observed that the maximum number of filled grains panicle^{-1} was found in the intact crop.

Aziz and Hasan (2000) reported that in SRI practice, at Kishoregonj the average number of filled grains panicle^{-1} with 35cm×35cm spacing was found more promising, which was 173 panicle^{-1} and unfilled grains was 42 panicle^{-1}. At Rajshahi the average number of filled grains panicle^{-1} was 106 in case of SRI practice and 70 in case of farmers practice.

2.2.4 Weight of 1000-grains

Akbar (2004) reported that Sonarbangla-1 ranked first in respect of 1000-grain weight among the varieties studied. Biswas and Salokhe (2001) observed that weight of 1000-grains showed better responses with early transplanting of the photo periodically sensitive KDML 105 in the mother crop and vegetative tillers.

Aziz and Hasan (2000) reported that in SRI practice, the grain weight was found 12% higher with SRI practice over farmers practice. The weight of 1000-grains was the lowest (18.75g) with 20cm×15cm spacing in case of farmers practice and the highest (28g) with 40cm×40cm spacing in case of SRI.

Goel and Verma (2000) investigated the effects of 2 sowing methods, direct sowing and transplanting, on the yield and yield components of 2 rice cultivars, and observed weight of 1000-grains (25.0 g) was higher in direct sowing.

Biswas et al. (1989) conducted an experiment on number of splitted tillers hill^{-1} needed for replanting with BR 11 (Mukta). They suggested that splitted tillers of 35 DAT replanted at 3 tillers hill^{-1} gave the higher 1000-grains weight. Richharia et al. (1964) observed that weight of grain plant^{-1} was more in tiller plant than those in seed plants.

2.2.5 Grain yield

Ali et al. (2006) mentioned that crop-establishment method did not influence grain yield during the wet or dry seasons, indicating the potential of the three variants of direct seeding as alternative methods of establishing lowland rice.

Sato (2006) reported that comparison trials had given an average SRI yield of 7.23 t ha^{-1} compared to 3.92 t ha^{-1} with conventional methods, an 84% increase. Devarajan (2005) reported that SRI (System of Rice Intensification) method produced rice yields of 7 to 8 t ha^{-1} against the normal 3 to 4 tons. Reddy (2005) conducted a field experiment where SRI was compared with existing traditional cultivation methodology. In both systems (traditional and SRI), it was found that SRI could produce similar yield with less inputs.

Anon. (2005) summarized the speech of a workshop on drum seeding held at Bangladesh Rice Research Institute (BRRI) in Gazipur on June 20, that it was possible to produce 10-20 percent higher yield than the traditional transplanting method. Latif et al. (2005) reported that in comparison of short- and long-duration varieties, the long-duration variety BRRI dhan29 yielded highest with SRI practices.

McDonald et al. (2005) assembled 40 site-years of SRI versus best management practices (BMP) comparisons into a common database for analysis. Indeed, none of the 35 other experimental records demonstrated yield increases that exceeded BMP by more than 22%. Excluding the Madagascar examples, the typical SRI outcome was negative, with 24 of 35 site-years demonstrating inferior yields to best management and a mean performance of -11%.

Paris and Chi (2005) reported that the promotion of plastic row/drum seeder technology was on the yield increase in Vietnam, particularly in the southern part of the country, and in other Southeast Asian countries due to its advantages over the traditional transplanting or broadcast method of rice production.

Uphoff et al. (2005) reported that System of Rice Intensification (SRI) had 1.6-2.5 t ha^{-1} yield advantage over more input-intensive rice-growing practices.

Anon. (2004c) embarked on trialing SRI in the project target area in the Districts of Kralanh and Angkor Chum in Siem Province in Cambodia. Harvest of the trials was conducted in December 2002, which showed average yield increases of 148% and 85% respectively or 3.24 t ha^{-1} and 2.3 t ha^{-1}. Results from the 2003 season showed 130% and 92% increase or 2.94 t ha^{-1} and 2.16 t ha^{-1} this showed a consistent higher yield. Reduced results in 2003 were due to poor rainfall in the area, many families were unable to grow any rice which had resulted in food shortages and reinforces the need to improve methodologies to increase rice yields.

The highest grain yield of rice obtained from transplanting method than the grain yield obtained from direct seeding method Anon. (2004d). While the grain yields of seedling throwing methods were not significantly different from transplanting method.

In an experiment in Boro season with the planting methods of transplanting, seedling throwing/broadcasting with normal seedlings, direct seeding and seedling throwing with young seedling, the highest grain yield (5.4 t ha^{-1}) of BRRI dhan 29 was obtained from transplanting method and direct seeding method gave the lowest grain yield (4.73 t ha^{-1}). Seedling throwing method gave little bit lower yield than transplanting method but higher than direct seeding method (Anon., 2004e). Bari (2004) reported the grain yield from direct wet seeded line sowing method was significantly higher than those from transplanted method.

Horie (2004) reported some of the ways to increase yields might include components of the system of rice intensification (SRI). The extremely high yields in SRI were incredible but its elements, which had been studied and practiced in Japan for the past 50 years, might lead to yield increases. The practice of transplanting one or two young seedlings hill^{-1} had advantages in reducing transplanting injury and increasing tiller and root numbers on lower nodes. Such advantages could be realized under direct-seeding systems, where they were applicable.

Karmakar et al. (2004) reported that, conventional practice (25cm×15cm spacing with 15 days old seedling) gave higher yield than the SRI practices with wider spacings. Number of tillers and panicle per unit area were higher in closer spacing that contributed to obtain higher yield.

Nissanka and Bandara (2004) evaluated the productivity of System of Rice Intensification (SRI) method with conventional rice farming systems in Sri Lanka. Grain yield was 7.6 t ha^{-1} in the SRI and it was 9%, 20% and 12% greater than the conventional transplanting, and normal and high density broadcasting.

Rajkhowa and Gogoi (2004) conducted a field experiment at Jorhat, Assam, India, during the 1999 and 2000 in summer seasons to determine the effect of planting methods on transplanted summer rice cv. Luit. The treatments comprised 3 planting methods, namely closer (10×10 cm), normal (15×15 cm) and farmers' practice (haphazard planting). Normal planting showed significantly higher yield than the other planting methods in 1999, while closer planting recorded the highest grain yield in 2000.

Sheehy et al. (2004) reported that the combination of natural resources, genes, weather and management systems largely determines maximum crop yields. Recently, one of those elements was portrayed as the key to releasing hitherto unrecognized, but significant, untapped growth potential in rice. That element, the system of rice intensification (SRI), was an unconventional management system developed in Madagascar, where it was reported to increase rice yields to 'fantastic' levels. They further reported that the SRI had no inherent advantage over the conventional system and that the original reports of extraordinary high yields were likely to be the consequence of error.

Uphoff (2004b) reported that SRI offer unprecedented opportunities for improving rice production in a variety of situations around the world, not just by increments but even by multiples. SRI sounds 'too good to be true,' but increasing evidence from research and its spreading adoption by farmers were showing that SRI was as productive and as beneficial as reported by its proponents, initially Association Tefy Saina, an indigenous NGO in Madagascar. Less than five years ago, SRI was known and practiced only in Madagascar. Today there were confirming results from 18 additional countries ranging from China to Peru, with average yields from SRI in the 7-8 t ha^{-1} range, and with yields over 15 t ha^{-1} reported from at least four countries beyond Madagascar.

Zheng et al. (2004) mentioned that the features of the SRI were: transplanting of young seedlings singly in a square pattern with wide spacing, using organic fertilizers and hand weeding, and keeping the paddy soil moist during the vegetative growth phase. Significant phenotypic changes occur in plant structure and function and in yield and yield components under SRI cultivation. The production increased could be notable. With these modifications, grain yield exceeded 12 t ha^{-1}, 46% greater than in control using field comparison.

Akanda (2003) presented results of 232 SRI demonstration plots from Aman 2003 season, conducted in 15 districts under DAE, and the results of 386 demonstration plots of Boro 2002-2003 season conducted in 8 districts. In most of the cases, the result showed a significant yield increase in SRI practice.

Chowhan (2003) reported that farmers were able to achieve on average, 30% higher production from SRI practice than traditional practice (SRI = 75.75 Mds $acre^{-1}$, traditional practice = 58.04 Mds $acre^{-1}$).

Das (2003) reported that the System of Rice Intensification (SRI) gave more rice yield compared to the farmers' practice (FP). The farmers from their SRI plots received 19% higher yield compared to their FP plot during the Boro season in 2003.

Hossain et al. (2003) conducted an experiment at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh from July to December, 2001 to study the performance of BRRI Dhan 32 in SRI and conventional methods and their technology mixes. The highest grain yield of SRI planting method was mostly the outcome of higher total number of tillers $hill^{-1}$, highest panicle length and highest number of grains $panicle^{-1}$.

Husain et al. (2003a) conducted SRI trial in two Upazilas of Noakhali district. The farmers practiced both SRI and conventional cultivation at the same time to compare the results regarding production cost, yield, and net return. SRI practices permitted soil aeration, better root development, more effective tillering and more panicles, which ultimately increase the yield in SRI method. During the Boro season 2002-2003, SRI farmers got 43% more yield than with conventional methods.

Mazid et al. (2003) found that conventional practice of rice cultivation gave significantly higher grain yield compared to the SRI method of crop establishment. SRI method with 30×30 cm and 40×40 cm spacing and younger seedlings increased number of panicles hill^{-1} but total number of panicles per unit area was found to be low. They further concluded that, the SRI practice was not necessary for growing rice near the yield potential, and the conventional method of crop establishment was recommended for rice cultivation.

Biswas and Salokhe (2002) reported that separation of more than 4 tillers hill^{-1} had an adverse effect on the mother crop. The clonal tillers produced higher yield than the nursery seedlings, and transplanting 2 clonal tillers hill^{-1} resulted in almost the same yield as 3 clonal tillers and 4 clonal tillers^{-1}. A single clonal tillers had the capacity to produce 4.5 t ha^{-1} grain yield.

Deichert and Yang (2002) discussed the experiences of 400 Cambodian farmers in adapting on how many elements of SRI were applied. The majority of farmers obtained yields from 3 to 6 t ha^{-1} and the overall yields showed an increase from 50 to more than 200% over the national average. So far these achievements result mainly from small plot sizes, but importantly also with traditional crop varieties and without chemical fertilizers.

Johnkutty et al. (2002) studied the effects of crop establishment (transplanting, broadcasting or line sowing) along with manual (plots were kept weed-free up to the maximum tillering stage) control treatments on the yield of aman rice cv. Jyothi in Pattambi, Kerala, India during the rabi season of 1996/97, 1997/98 and 1998/99. In 1998/99, direct sowing of sprouted seeds by DRR wet seeder was also evaluated. Line sowing was conducted at a spacing of 15×10 cm. A seed rate of 80 kg ha^{-1} was used for broadcasting. In 1996/97 and 1997/98, the grain yield did not significantly vary among the treatments. In 1998/99, the highest yields were obtained with random planting with hand weeding.

McHugh et al. (2002) reported that SRI was associated with a significantly higher grain yield of 6.4 t ha^{-1} compared with 3.4 t ha^{-1} from conventional practices. On SRI plots, grain yields were 6.7 t ha^{-1} for AWD irrigation, 5.9 t ha^{-1} with nonflooded irrigation, and 5.9 t ha^{-1} for continuously flooded. The results of the study suggested that, by combining AWD irrigation with SRI cultivation practices, farmers could increase grain yields while reducing irrigation water demand.

Nagappa and Biradar (2002) conducted an economic analysis on employing drum seeding and transplanting of 2 rice varieties (BPT-5204 and ES-18) at a farmer's field in Siruguppa, Karnataka, India. A substantial difference in yield was noted between the two methods of planting during summer 1999-2000. During 2000-2001, similar yields were noted between drum seeding and transplanting during kharif and marginally higher yield was observed in drum seeding during summer. The yield obtained suggested that drum seeder sowing gave yields similar to those achieved with transplanting. These results suggest that drum seeding would help improve the profitability of rice farming in the Tungabhadra project area.

Ogura (2002) conducted an experiment using direct sowing in plots without ploughing and with fertilizer applied in the slots or by transplanting from long mats of seedlings grown hydroponically. Yields with transplanting were 470 g m^{-2} compared with 451 g m^{-2} with direct sowing.

Paul et al. (2002) reported that tillers can be separated at 25 or 35 DAT without hampering the grain yield. Paul (1999) obtained the highest grain yield when 2 tillers were kept $hill^{-1}$.

Subbaiah et al. (2002) conducted an experiment during wet seasons in 1996 and 1997 at Nizamabad district, Andhra Pradesh, India to evaluate the performance of a drum seeder in farmers' fields. Rice crops established using a drum seeder had a higher mean grain yield (4.63 t ha^{-1}) which was at par with transplanting (4.25 t ha^{-1}) and superior over broadcasting (3.34 t ha^{1}).

Venkatachalapathy and Veerabadran (2002) conducted a field experiment at the Agricultural College and Research Institute, Killikulam, Tamil Nadu, India during 1996 on wet-seeded rice cv. ADT-36. The highest yield was recorded in drum seeding with 2 cm intrarow spacing. However, the net return per rupee invested was higher with drill seeding at 2 cm. Direct seeding an effective alternative technology to transplanting, since it gave more gain without extra expenditure.

Changes to rice transplanting through SRI increased yield by 50%. For instance, in Bangladesh, the SRI increased yield from 4 to 6 t ha^{-1} and reduced seed requirement for planting by 80% (Anon., 2001a).

Biswas (2001) reported that vegetative propagation using clonal tillers separated from the previously established transplanted crop was beneficial for restoration of a damaged crop of rice. Separation of four vegetative tillers $hill^{-1}$ helped maintaining the grain yield of the mother crop and double area could be transplanted with two clonal tillers $hill^{-1}$. Transplanting two or more clonal tillers $hill^{-1}$ showed no difference in grain yield when compared to usual transplanted crops using nursery seedlings.

Biswas and Salokhe (2001) observed that vegetative tillers gave higher yield than nursery seedlings transplanted on the same date. The result suggested that in some flood prone lowland, where the transplant crop was damaged by natural hazards, vegetative propagation using tillers separated (max. of 4 $hill^{-1}$) from the previously established transplanted crop was beneficial for higher productivity. Rahman (2001) observed that the highest grain yield was found in the intact crop. Mamin et al. (1999) observed that intact mother hills produced the highest yield (5.0 t ha^{-1}), when retaining 4 tillers with mother plant produced the lowest yield (4.46 t ha^{-1}).

Bruno (2001) conducted on-farm experiments in the high plateau of Madagascar to evaluate the critical variables of SRI. Results showed that a minimum grain yield was about 8 t ha^{-1} if the main factors were used under the optimal conditions which had been identified through the experiment.

Budhar and Tamilselvan (2001) conducted an experiment to evaluate the feasibility of different stand establishment techniques in lowland irrigated rice (cv. ADT43). The stand establishment techniques were transplanting, seedling throwing, direct sowing by manual broadcasting and wet sowing by a drum seeder. The various stand establishment techniques showed no significant difference in grain yield in both seasons. In a pooled analysis of 2 seasons, grain yield was highest in wet sowing by manual broadcasting followed by direct sowing using a drum seeder and traditional transplanting.

Anbumani et al. (2000) reported that line planting of aman rice cv. ADT-38 revealed higher rice grain yield compared to direct sowing or random transplanting in Tamil Nadu, India, during August 1995-April 1996. The different planting methods did not influence the yield of aman rice.

Aziz and Hasan (2000) reported that in SRI practice, 35cm×35cm spacing showed better performance both at Locally Intensified Farming Enterprises and Department of Agricultural Extension trials at Kishoregonj where the average yield was 7.5 and 8.9 t ha^{-1}, respectively. On the other hand, in case of farmers practice the average yields were 5.2 and 4.7 t ha^{-1} with 20cm×15cm and 20cm×20cm spacings, respectively.

Ganajaxi and Rajkumara (2000) studied the performance of various methods of sowing with different agronomic practices for growing direct seeded rice an experiment conducted in Karnataka, India during the wet season of 1999. They reported that seeding with 8 row DRR drum seeder had significantly higher yield than broadcasting of sprouted seeds (3083 and 2433 kg ha^{-1}, respectively).

Goel and Verma (2000) investigated the effects of 2 sowing methods, direct sowing and transplanting, on the yield and yield components of 2 rice cultivars, Pusa-33 and HKR-120/HKR-126, during the kharif seasons of 1992, 1993, 1994 and 1996, at Karnal, Haryana, India. Grain yields in both sowing methods were at par during 1992 and 1993, but were 15.2 and 9.1% less in direct sowing than transplanting, respectively, during 1994 and 1996. This reduction in yield was attributed to the heavy infestation of weeds in direct sowing in subsequent years and the delay in first manual weeding beyond 20 days after sowing. Mean grain yield was higher in transplanting than in direct sowing, with values of 54.60 and 51.60 q ha^{-1}, respectively.

Hirsch (2000) reported that on the rice sector in Madagascar SRI yields in the Antsirable and Amhositra areas ranged between 6.7 and 10.2 t ha^{-1} and 7.7 and 11.2 t ha^{-1}, respectively.

Rajaonarison (2000) conducted an experiment to assess SRI practices during the 2000 minor season on the West Coast of Madagascar and found that SRI practices produced 6.83 t ha^{-1} grain yield where standard practices produced 2.84 t ha^{-1}.

Islam (1999) stated that in the SRI method plant spacing of 25cm×25cm or 20cm×20cm, yields were about the same (9.5 t ha^{-1} and 9.2 t ha^{-1}, respectively) but with spacing of 30cm×30cm, the yield increased up to 10.5 t ha^{-1}.

Uphoff (1999) reported that a system of plant, soil, water and nutrient management for irrigated rice developed in Madagascar had been yielding 5, 10, even 15 t ha^{-1} on farmers' fields where previous yields averaged around 2 t ha^{-1}.

Miyagawa et al. (1998) investigated rice grain yield and its components in Northeast Thailand in 24 direct-sown and 45 transplanted plots for 1994, and 41 direct-sown and 62 plots transplanted for 1995. Mean yield of direct-sown plots was lower than that of transplanted plots in the drought year of 1994 while this was not observed in 1995, a year with abundant precipitation. In irrigated fields, yield of direct-sown rice was not significantly different from that of transplanted rice in both years. In the rain-fed paddy fields of A type (most vulnerable to drought) and B type (less vulnerable to drought and flood), mean yield of direct-sown rice was lower than that of transplanted rice when yield values of both types were pooled in 1994, because of the smaller number of spikelets panicle^{-1} and spikelets m^{-2}. Grain yield in direct-sown rice showed a significant positive correlation with straw weight and culm length. It was concluded that more profuse vegetative growth and a larger number of spikelets panicle^{-1} obtained by supplemental irrigation, fertilizer application, early planting and appropriate breeding were necessary to improve direct-sown rice cultivation.

Sharma and Ghosh (1998) reported that stand establishment of rice either by direct sowing or transplanting with clonal tillers gave best results under semi-deep water condition.

Sorour et al. (1998) observed in field experiments in 1993-94 at Kafr El-Sheikh, Egypt, the short duration rice cultivar Giza 177 and the traditional cultivar Giza 176 were planted using the following methods: traditional transplanting (TT, no fixed number of hills or seedlings hill^{-1}), hand transplanting (HT) in hills at a spacing of 20×20 or 15×15 cm, mechanical transplanting (MT) in hills at a spacing of 30×14 or 30×12 cm, broadcasting (B), mechanical drilling (MD), or planted in puddled soil (D) in hills at a spacing of 20×20 or 15×15 cm. D 15×15 cm, HT 15×15 cm and MT 30×12 cm gave significantly better results than TT as regards dry matter production, LAI, crop growth rate, plant height, number of panicles m^{-2} and grain yield/feddan.

Valarmathi and Leenakumary (1998) carried out a field experiment in Kerala, India to evaluate the suitability of aman rice cultivars under direct sown conditions because of scarcity of labor for transplanting. Yield increases were dependent on an increase in the number of productive tillers plant^{-1}.

Maqsood et al. (1997) grown rice cv. Basmati-385 grown at Faisalabad during 1994 and 1995 established by transplanting or direct sowing. Yield was not significantly affected by establishment method in 1994, but in 1995 lower yield (3.58 t ha^{-1}) from direct sowing and higher yield (4.43 t ha^{-1}) from transplanting.

Naklang et al. (1997) reported that with the use of appropriate crop management, direct sowing could increase grain yield and reduce the cost and risk associated with transplanting in rainfed lowland areas.

Roknuzzaman (1997) conducted an experiment with rice cultivar BR11 where seedlings transplanted in haphazard and row arrangements. Haphazard planting produced the highest grain yield which was statistically similar to that produced by row method of planting.

Ye and Ye (1997) established rice cultivars with low, intermediate or strong tillering characteristics by direct sowing, by broadcasting seedlings or by hand transplanting. With low and intermediate tillering cultivars, yields were highest with broadcasting seedlings but with the strongly tillering cultivar they were highest with direct sowing. In all cultivars yields were lowest with hand transplanting.

Dwivedi et al. (1996) conducted a field experiment during the rainy seasons of 1991 and 1992 at RRS, Agwanpur, Saharsa (Bihar) to study the effect of different methods of planting on rice yield under mid upland situations. Transplanting rice (15×15 cm with 2 seedlings hill^{-1}) produced significantly higher yield attributes, yield and net returns. Random transplanting, spreading of seedlings, random transplanting of single seedlings and row transplanting of single seedlings hill^{-1} also resulted higher yield attributes, yield and net returns than direct sowing of seeds.

Naklang et al. (1996) reported that rainfed rice crops were grown under both upland and lowland conditions. While upland crops were almost always direct sown, both transplanting and direct sowing were commonly practiced for lowland crops in Asia. Under lowland conditions, direct-sown crops yielded more than transplanted crops in one year, slightly less in another when establishment was a problem in direct sowing, and similar between the two methods in the other.

Po (1996) stated that in a trial at Andapa in the north of Madagascar achieved average yields of 6.2 t ha^{-1}, while 27 farmers using SRI techniques in the same area averaged 10.2 t ha^{-1}.

Sharma (1996) conducted a field experiment in 1992-93 at Cuttack, Orissa, where rice cv. Gayatri (dwarf) and Matangini (tall), were either direct sown in dry soil after premonsoon showers by early June using 400 or 600 seeds m^{-2} or transplanted after accumulation of water in the field in July-Aug., using conventional nursery-grown seedlings and tillers uprooted from the direct-sown crop. Direct-sown crops showed better initial establishment and gave higher grain yield (3.23-3.53 t ha^{-1}) than transplanted crops (1.75-1.99 t ha^{-1}) which were flooded at or soon after transplanting. Transplanted crops grown from vegetative tillers yielded more (2.38 t) than those from nursery seedlings (1.36 t). It was concluded that in some flood-prone lowlands, where direct sowing could not be done earlier in the season, vegetative propagation using tall, vigorous tillers uprooted from the previously established direct-sown crops was beneficial for greater productivity.

Talukder (1996) stated that higher grain yield was obtained in direct wet seeded rice (2.75 t ha^{-1}) over transplanted one (2.56 t ha^{-1}) in late aman season.

Elahi et al. (1995) reported that method of planting has a profound effect on the yield performance of rice crops in Bangladesh, when rice is planted late in the aman season, direct wet-seeding yields was higher than the transplanting method mainly because of higher plant population and early flowering. Garcia et al. (1995) found that uninhibited growth of direct seeded rice during the vegetative stage led to equal grain yield to that of transplanted rice.

Park et al. (1995) analyzed the labor saving and cost reduction effects resulting from the adoption of direct sowing in rice cultivation in the Korea Republic. Data were collected from 125 dry sowing farms and 125 wet sowing farms. The average yield was 4.5% lower for direct sown rice than for transplanted rice (5% lower for dry sowing and 4% less for wet sowing).

Sattar and Khan (1995) carried out a number of studies on direct wet-seeded rice to recognizing the importance of direct wet-seeding method under different Agro-Ecological Zones of Bangladesh to determine its yield and economic performance compared to transplanted rice. In Aman season at Thakurgaon, direct wet-seeded rice gave 835 kg ha^{-1} higher yield than transplanted rice with same management practices. In boro season at BRRI, Joydebpur, Gazipur an average yield benefit of 319 kg ha^{-1} was obtained in direct wet-seeded rice over the transplanted one.

Supaad and Cheong (1995) observed that the production difference between direct seeding and transplanting have been obvious, generally up to 1 t ha^{-1}. In aman season at Thakurgaon, wet seeded rice gave 835 kg ha^{-1} higher yield than transplanted and an average of 319 kg ha^{-1} yield benefit was obtained over transplanted in the Bangladesh Rice Research Institute.

Kundu et al. (1993) recorded a higher grain yield in direct wet-seeded rice than the transplanted one; however, the yield difference was not significant. They recorded 4.5 t ha^{-1} and 4.2 t ha^{-1} of mean grain yield of direct seeding and transplanting methods, respectively.

Bautista and Gagelonia (1994) reported that the seeder facilitates chemical-free weeding methods (both manual and mechanical), which minimize environmental pollution and hazardous chemical contamination of both humans and animals. It might also allow additional sources of income for farmers engaging in a custom-seeding scheme. Pilot testing gave an av. increase in yield of 425 and 750 kg ha^{-1} compared with manual broadcasting and transplanting, respectively.

Mallick (1994) reported that removal of tillers from the mother shoot and double transplanting increased panicle formation by about 10% in both the varieties studied. Tiller removal increased grain yield $panicle^{-1}$ by 27% in Nizersail and 21% in BR 22. Sharma (1994a) reported that the highest yield was obtained from the crop planted with clonal tillers followed by that raised with fertilized and unfertilized nursery seedlings.

Sharma (1994b) compared the performance of intermediate rice under direct seeded and transplanted condition at Cuttack, India. The direct seeded crop with the higher seedling rate was thinned by uprooting some of the plants, including clonal tillers (100-120 m^{-2}), which were transplanted and reported that clonal tillers performed better than the others and could acclimatized more easily to flooded conditions. Clonal propagation was superior to nursery-grown seedlings and yield did not decreased with the removal of clonal tillers.

Bhattacharya (1993) conducted an experiment during June to December, 1989 at the Agronomy field Laboratory, Bangladesh Agricultural University, Mymensingh with three spacings viz. 25cm×15cm, 20rm×12.5cm and 15cm×10cm and three levels of tillers transplantation @ 3, 6 and 9 $hill^{-1}$ along with two ages of tillers viz. 30 and 40 days to find out their effect in transplant aman rice cv. BR11. Significant variations due to number of tillers transplanted $hill^{-1}$ were found in character like plant height, grains $panicle^{-1}$, panicle length, sterility, grain and straw yield and field duration. Three tillers transplanted $hill^{-1}$ gave significantly higher yield (4.23 t ha^{-1}) than that of 9 tillers transplanted $hill^{-1}$ (3.85 t ha^{-1}) but statistically identical with 6 tillers transplanted $hill^{-1}$ (4.14 t ha^{-1}). Effect of age of tillers was found statistically identical for yield and yield attributes. Older tillers significantly reduced the field duration than younger ones. The interaction between number of tillers transplanted $hill^{-1}$ and age of tillers were not found significant for yield and yield attributes. Similarly no variation due to interaction between spacing and age of tillers was observed with respect to any character.

Matsuo and Hoshikawa (1993) observed in an experiment that the main stem of a rice plant produced a large number of tillers, reaching around 50 or more at the 'maximum tiller number stage'. The tillers that developed in an early growing stage of a plant usually grow vigorously, produce panicles at the tips of the stem and finally contributed to the yield as productive tillers. The number of panicles in a yield component depends largely on the number of tillers. The development of tillers during the tiller stage, therefore was important for the yield or rice.

Rajput and Yadav (1993) observed in a field trial at Bilaspur, Madhya Pradesh in the 1982-83 kharif [monsoon] seasons where the improved biasi (broadcasting + biasi + challai) method of establishing rice gave the highest rice yield and net profit. Transplanting gave yields not significantly different from the improved biasi method, while all establishment methods tested were superior to the local method.

Varughese et al. (1993) observed in a field experiment at Kerala, India that rice cv. Ptb 20 and Jaya seedlings broadcasted (haphazardly) gave slightly higher grain yield compared with transplanted seedlings.

Hong and Park (1992) reported that since 1991, the Rural Development Administration had operated a demonstration farm project for direct sowing in rice production. Average rice yield was reported 4.267 kg ha^{-1} for the direct sowing method, 7% lower than for transplanting.

Sharma (1992) reported that there was no decrease in the yield of aman rice crop when clonal tillers were removed after 60 days to transplant either the equivalent of or double the uproot plot area. The loss due to decrease in panicles m^{-2} with the removal of clonal tillers was compensated for by the resulting increase in panicle weight. The crop planted from clonal tillers produced a significantly higher grain yield than planted from seedlings of equivalent age raised in a nursery seedbed with or without fertilizer application.

Anon. (1990) stated that splitting of tillers ranging from 1 to 5 at 30 DAT or 40 DAT produced satisfactory grain yield without significant loss of the mother crop. This trend was observed in both aus and transplant aman crop. It was concluded that retransplantation of splitted tillers from mother crop was a unique way to boost productivity during seedling scarcity.

Roy et al. (1990) reported that up to three clonal tillers $hill^{-1}$ could be separated without hampering the main crop yield but the removal of higher number of tiller $hill^{-1}$ significantly reduced the mother crop yield. As compared with over aged nursery seedlings, the clonal tillers performed better to the grain yield. They further concluded that, in post-flood situations, planting area could be increased by about 300% by detaching tillers from the mother hills and replanting in separate plots.

Anon. (1989) reported that splitting tillers up to 3 $hill^{-1}$ did not affect yield of the main crop in aus while in aman, splitting tillers up to 5 did not reduce yield. It appeared that tillers could be separated from 30 day old mother plants and any delay reduce yield when 3 or more tillers were separated.

Biswas et al. (1989) conducted an experiment on number of splitted tillers $hill^{-1}$ needed for replanting with BR 11 (Mukta), a transplant aman rice variety for an economic yield. They suggested that splitted tillers of 35 DAT replanted at 3 tillers $hill^{-1}$ gave the highest yield.

Park et al. (1989) conducted field trials at Milyang in 1987, where rice cv. Palgongbyeo and Gayabyeo were direct sown into wet fields by broadcasting or subsurface drilling or into upland fields by drilling. Grain yields after direct sowing averaged 4.82-4.93 t ha^{-1} for cv. Palgongbyeo compared with 5.77-5.70 t ha^{-1} for hand transplanting and 5.11-5.64 t ha^{-1} for cv. Gayabyeo compared with 5.64-8.12 t ha^{-1} for hand transplanting. There was little difference in grain yields between direct drilled and broadcast sown treatments.

Shahidullah et al. (1989) conducted an experiment on retransplantation with 5 different transplanting dates and 5 transplant aman varieties. The fifty percent of each plot were disturbed by separating 50% of the total tillers $hill^{-1}$ and subsequently retranslated on mid-September in the field with 40 cm lower elevation (considered as flood affected field) than that of main field. The yield of 50% tillers kept in the main field. They suggested that the total production might be increased through tiller separation and replanting and thereby the flood damaged transplant aman field could be recovered successfully.

Ullah (1989) showed that splitting tiller(s) ranging from l to 5 at 35 DAT with BRl1 did not reduce the yield of the main crop significantly. He also suggested that 4-6 severed tillers hill^{-1} could be planted for higher grain yield.

Reddy et al. (1987) conducted an experiment in India in which rice cv. Tellahamsa seedling were transplanted in lines or at random. They found that grain yields (3.05-3.25 t ha^{-1}) did not differ significantly for the planting methods.

Reddy and Ghosh (1987) noted that uprooting of clonal tillers up to 40 days of growth from a transplanted crop and up to 82 days from direct sown crop caused no adverse effect on mother crop. They also obtained higher grain yield from a clonally propagated transplanted crop than that raised from conventional Nursery seedlings under intermediate low and flood prone condition.

Ding et al. (1982) observed that the establishments of rice crop by tiller transplanting in place of seedling transplanting reduce the amount of seeds. They also recorded 4-10% higher yield with tiller transplanting than that obtained with seedlings.

2.2.6 Straw yield

Das (2003) reported that the System of Rice Intensification (SRI) gave more rice yield compared to the farmers' practice (FP). The SRI plots also produced more straw (12%) compared to the hay produced in the FP plot. Hossain et al. (2003) conducted an experiment to study the performance of BRRI Dhan 32 in SRI and conventional methods and their technology mixes and reported that conventional planting method produced the lowest straw yield (4.29 t ha^{-1}). Husain et al. (2003a) conducted SRI trial in two Upazilas of Noakhali district and found 39% higher straw yield in SRI compared to traditional methods. Mamin et al. (1999) observed that straw yields were markedly higher in intact mother hills (5.04-5.87 t ha^{-1}) than those of split replanted tillers (3.98-4.67 t ha^{-1}).

Budhar and Tamilselvan (2001) conducted an experiment to evaluate the feasibility of different stand establishment techniques such as transplanting, seedling throwing, direct sowing by manual broadcasting and wet sowing by a drum seeder. The various stand establishment techniques showed no significant difference in straw yield in both seasons. Ganajaxi and Rajkumara (2000) studied the performance of various methods of sowing with different agronomic practices for growing direct seeded rice an experiment conducted in Karnataka, India during wet season of 1999. They reported that fodder yield was highest in transplanting (farmer's practice; 5483 kg ha^{-1}).

Roknuzzaman (1997) conducted an experiment with rice cultivar BR11 where seedlings transplanted in haphazard and row arrangements and observed that straw yield was highest in row planting.

Mollah et al. (1992) observed that late tiller separation at 40 DAT significantly reduced straw yield compared to an early tiller separation at 30 DAT because of the removal of greater numbers of tillers from the mother hill. This had, however, no influence on the grain yield and yield components as compared to the intact mother hill.

Reddy et al. (1987) conducted an experiment in India in which rice cv. Tellahamsa seedling were transplanted in lines or at random. They found that straw yield (4.04-4.14 t ha^{-1}) did not differ significantly for the planting methods.

2.2.7 Biological yield

Bari (2004) reported that all the yield contributing characters studied were significantly affected by method of planting except panicle length, 1000-grains weight and straw yield. The biological yield from direct wet seeded line sowing method was significantly higher than those from transplanted method. Rahman (2001) observed that the highest biological yield was found in the intact crop. Garcia et al. (1995) found that uninhibited growth of direct seeded rice during the vegetative stage led to superior biological yield than that of transplanted rice.

2.2.8 Harvest index

Hoon and Kim (1997) compared the physiological and ecological characteristics of rice cv. Whasungbyeo in direct sown and transplanted crops in Japan. The harvest index was higher in direct sown crop (DSC) than in mechanically transplanted crop (MTC).

Roknuzzaman (1997) conducted an experiment with rice cultivar BR11, where seedlings transplanted in haphazard and row arrangements and observed that the harvest index was highest in haphazard planting.

Rao (1990) conducted an experiment with plant derived from primary, secondary and tertiary tillers and transplanted at 20×10 cm spacing produced harvest index which were 45.3, 45.3, 9.1 and 45.1% for plants derived from primary, secondary and tertiary tillers and control plants respectively. Biswas et al. (1989) conducted an experiment on number of splitted tillers hill^{-1} needed for replanting with BR 11 (Mukta) and suggested that splitted tillers of 35 DAT replanted at 3 tillers hill^{-1} gave the highest harvest index.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field Laboratory, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December, 2005 to May, 2006.

3.1 Site Description

3.1.1 Geographical Location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004e).

3.1.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area has sub tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period were presented in Appendix III.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.1-6.3 and had organic matter 1.29%. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The physico-chemical properties of the soil are presented in Appendix IV.

3.2 Details of the Experiment

3.2.1 Treatments

Two sets of treatments included in the experiment were as follows:

A. Variety (2):

1. BRRI dhan 29 (inbred)
2. Sonarbangla-1 (hybrid)

B. Cultivation method (5):

1. Sprouted seeds in line (P_1)
2. Sprouted seeds broadcast (P_2)
3. Nursery seedlings (P_3)
4. SRI (P_4) and
5. Clonal tillers (P_5)

3.2.2 Experimental Design

The experiment was laid out in a split-plot design with four replications having varieties in the main plots and cultivation methods in the sub-plots. There were 10 treatment combinations. The total numbers of unit plots were 40. The size of unit plot was 4.0 m by 3.0 m. The distances between plot to plot and replication to replication were 1 m and 1.5 m, respectively. The layout of the experiment has been shown in Appendix II.

3.3 Crop/Planting Material

Two rice varieties (BRRI dhan 29 and Sonarbangla-1) were used as plant material.

3.3.1 Description of Variety: BRRI Dhan 29

BRRI dhan 29, a high yielding variety of boro season was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. The pedigree line (BR802-118-4-2) of the variety was derived from a cross (BG902/BR51-46-5) and was released in 1994. It takes about 155 to 160 days to mature. It attains at a plant height of 95-100 cm and at maturity the flag leaf remains green and erect. The grains are medium slender with light golden husks and kernels are white in color. This genotype is known for its bold grains, with a 1000-grains weight of about 29 g, grain length of 5.9 mm, and grain width of 2.5 mm. The cultivar gives an average grain yield of 7.5 t ha^{-1}. The milled rice is medium fine and white. It is resistant to damping off and moderately resistant to blast (Pyricularia oryzae) and bacterial blight (Xanthomonas oryzae) in terms of yield, this is the best variety so far released by BRRI (Anon., 2003; Anon., 1991).

3.3.2 Description of Variety: Sonarbangla-1

Sonarbangla-1 (CNSGC-6), a hybrid rice variety which produce higher yield than modern varieties, was imported and marketed in Bangladesh by the Mallika Seed Company (MSC), 145, Siddique Bazar, Dhaka-1000, Bangladesh from Hefei Fengle Seed Co. Ltd., China. The variety is photoperiod insensitive and could be cultivated in aus, aman and boro seasons. This variety has a yield potential of 36 to 45% over the conventional HYV. The variety matures within 120 to 130 days in boro season. It attains at a height of 90 to 100 cm with 10 to 15 or more tillers hill^{-1}. Its panicle length is larger than the HYV and local verities and each panicle contains about 120 to 150 grains. The weight of 1000-grains weight of this variety 27 to 29 g and gives an average yield of 8.30 to 9.68 ha^{-1}.

3.4 Crop Management

3.4.1 Seedling Raising

3.4.1.1 Seed Collection

Seeds of BRRI dhan 29 were collected from Genetic Resource and Seed Division, BRRI, Joydebpur, Gazipur, Bangladesh and the hybrid rice seed, Sonarbangla-1 was collected from the Mallika Seed Company.

3.4.1.2 Seed Sprouting

Seeds were selected by following specific gravity method. Seeds were immersed into water in a bucket for 24 hours. These were then taken out of water and kept tightly in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.4.1.3 Preparation of Seedling Nursery

A common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. No fertilizer was used in the nursery bed.

For SRI, sprouted seeds were sown as broadcast in two portable trays containing soil and cowdung each for BRRI dhan 29 and Sonarbangla-1. Thin plastic sheets were placed at the base of the trays to protect water loss. The moisture of the trays was controlled accurately by applying water everyday, which ensured proper growth of all the seedlings in the trays. These trays were kept inside a room at night to protect the seedlings from freezing temperature of the season and kept in sunlight at daytime for proper development of seedlings.

3.4.1.4 Seed Sowing

Seeds were sown in the seedbed on December 07, 2005 for raising nursery seedlings and clonal tillers treatments. For SRI, seeds were sown in the portable trays on January 02, 2006. The sprouted seeds were sown as uniformly as possible.

3.4.2 Collection and Preparation of Initial Soil Sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.4.3 Preparation of Experimental Land

The experimental field was first ploughed on January 01, 2006 with the help of a tractor drawn disc plough, later on January 13, 2006 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on January 14, 2006 according to experimental specification. Individual plots were cleaned and finally leveled with the help of wooden plank so that no water pocket could remain in the puddled field.

3.4.4 Fertilizer Application

The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} of N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate, respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at final land preparation. Urea was top-dressed in three equal installments i.e., after seedling recovery, during the vegetation stage and at 7 days before panicle initiation.

3.4.5 Direct Seed Sowing, Uprooting and Transplanting of Seedlings

For nursery seedlings and clonal tillers treatments, 40 days old seedlings were uprooted carefully on January 15, 2006 and were kept in soft mud in shade. The seedbeds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted with 25 cm × 15 cm spacing on the well-puddled plots. In each plot, there were 12 rows, each row contains 26 hills of rice seedlings.

In case of SRI treatment, 14 days old seedlings were uprooted from the trays and transplanted on January 15, 2006. The trays were brought to the main field and seedlings were planted in the prepared plot just after uprooting and this process was completed within one minute.

Sprouted seeds were sown on January 15, 2006 continuously in line with 25 cm row to row distance. For the treatment of sprouted seeds broadcast, sprouted seeds were randomly broadcasted.

3.4.6 Clonal Tiller Separation and Transplanting

On February 14, 2006 clonal tillers were separated at 30 DAT from the mother crop and retransplanted on the same plot. The clonal tillers were collected from the plot adjacent to the experimental area, which were also prepared on the same day of seedling transplanting on the main field. During tiller separation, 11 tillers hill^{-1} were obtained in BRRI dhan 29 and 13 tillers hill^{-1} in Sonarbangla-1.

3.4.7 Intercultural Operations

3.4.7.1 Thinning and Gap Filling

After one week of direct seed sowing thinning was done to maintain the constant population number. After transplanting the nursery and SRI seedlings and clonal tillers, gap filling was done whenever it was necessary using the seedling or separated clonal tillers from the previous source.

3.4.7.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weedings were done for every method, first weeding was done at 15 days after direct sowing or transplanting followed by second weeding at 15 days after first weeding. In SRI plots, weeds were removed mechanically with the help of a Japanese rice weeder.

3.4.7.3 Application of Irrigation Water

Irrigation water was added to each plot according to the treatments. All the plots were kept irrigated as per treatment and dried before harvesting.

Water management was the most complicated variable in SRI method. The logic was to supply the plant as much water as it needs to meet physiological requirements, not any excess. With SRI, rice crops kept unflooded during vegetative growth. Partial amount of water was applied to keep the soil moist, and it was even allowed to dry out for 2 to 4 days during tillering. This was done to keep the soil well aerated, to allow better root growth. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Again water was drained from the plots during ripening stage.

3.4.7.4 Plant Protection Measures

Plants were infested with rice stem borer (Scirphophaga incertolus) and leaf hopper (Nephotettix nigropictus) to some extent which were successfully controlled by applying Diazinone @ 10 ml/10 liter of water for 5 decimal lands on February 03 and by Ripcord @ 10 ml/10 liter of water for 5 decimal lands on February 20 and March 25, 2006. Crop was protected from birds and rats during the grain filling period. Field trap and foxtoxin poisonous bait was used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.7.5 Harvesting and Post Harvest Operation

Maturity of crop was determined when 80-90% of the grains become golden yellow in color. The harvesting of Sonarbangla-1 was done on April 23; April 26; May 02; May 06 and May 08, 2006 for nursery seedlings; clonal tillers; SRI; sprouted seeds sown in line and sprouted seeds broadcast, respectively. The harvesting of BRRI dhan 29 was done on May 10; May 14; May 19; May 21 and May 28, 2006 for nursery seedlings; clonal tillers; sprouted seeds in line; sprouted seeds broadcast and SRI, respectively. Ten pre-selected hills per plot from which different data were collected and 6 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were determined and converted to ton ha^{-1}.

3.4.8 Recording of Data

Experimental data were determined from 30 days of growth duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of hills at different dates from the inner rows leaving border rows and harvest area for grain. The followings data were determined during the experiment.

A. Crop Growth Characters

- i. Plant height (cm) at 20 days interval
- ii. Number of tillers $hill^{-1}$ at 20 days interval
- iii. Leaf area index at 20 days interval
- iv. Dry weight of plant at 20 days interval
- v. Time of flowering and maturity

B. Yield and Yield Components

i. Number of effective tillers $hill^{-1}$

ii. Number of ineffective tillers $hill^{-1}$

iii. Length of panicle (cm)

iv. Number of fertile spikelets $panicle^{-1}$

v. Number of sterile spikelets $panicle^{-1}$

vi. Number of total spikelets $panicle^{-1}$

vii. Weight of 1000-grains (g)

viii. Grain yield (t ha^{-1})

ix. Straw yield (t ha^{-1})

x. Biological yield (t ha^{-1})

xi. Harvest index (%)

3.4.9 Detailed Procedures of Recording Data

A brief outline of the data recording procedure followed during the study is given below:

A. Crop Growth Characters

i. Plant height (cm)

Plant height was measured at 30, 50, 70 DAS/T and at harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading.

ii. Number of tillers $hill^{-1}$ (no.)

Number of tillers $hill^{-1}$ were counted at 30, 50, 70 DAS/T and at harvest from ten randomly pre-selected hills and was expressed as number $hill^{-1}$. Only those tillers having three or more leaves were used for counting.

iii. Leaf area index (LAI)

Leaf area index were estimated measuring the length and average width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

iv. Dry weight of plant (g)

The sub-samples of 5 hills plot^{-1} uprooted from second line were oven dried until a constant leveled. From which the weights of above ground dry matter were recorded at 20 day intervals and at harvest

v. Time of flowering

Time of flowering (days) was recorded when about 50% of the plants within a plot emerged.

B. Yield and Yield Components

i. Effective tillers m^{-2} (no.)

The panicles which had at least one grain was considered as effective tillers. The number of effective tillers of 10 hill was recorded and expressed as effective tillers number m^{-2}.

ii. Ineffective tiller hill^{-1} (no.)

The tillers having no panicle was regarded as ineffective tillers. The number of ineffective tillers 10 hills^{-1} was recorded and was expressed as ineffective tiller number m^{-2}.

iii. Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

iv. Fertile spikelets panicle^{-1} (no.)

Spikelet was considered to be fertile if any kernel was present there in. The number of total fertile spikelets present on ten panicles were recorded and finally averaged.

v. Sterile spikelets panicle^{-1} (no.)

Sterile spikelet means the absence of any kernel inside in and such spikelets present on each of ten panicles were counted and finally averaged.

vi. Total spikelets panicle^{-1} (no.)

The number of fertile spikelets panicle^{-1} plus the number of sterile spikelets panicle^{-1} gave the total number of spikelets panicle^{-1}.

vii. Weight of 1000-grains (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

viii. Grain yield (t ha^{-1})

Grain yield was determined from the central 6.0 m^2 area of each plot and expressed as t ha^{-1} and adjusted with 14% moisture basis. Grain moisture content was measured by using a digital moisture tester.

ix. Straw yield (t ha^{-1})

Straw yield was determined from the central 6 m^2 area of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

x. Biological yield (t ha^{-1})

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated with the following formula and expressed as %.

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

xi. Harvest index (%)

It denotes the ratio of economic yield (grain yield) to biological yield and was calculated with following formula (Donald, 1963; Gardner et al., 1985).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.4.10 Chemical Analysis of Soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of the SRDI, Farmgate, Bangladesh. The properties studied included pH, organic matter, total N, available P and exchangeable K. The soil was analyzed following standard methods. Particle-size analysis of soil was done by Hydrometer method and soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5.

3.4.11 Statistical Analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using MSTAT package and the mean differences were adjudged by LSD technique (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the present study regarding the effects of cultivation methods of inbred and hybrid rice and their interactions on the yield and yield components have been presented, discussed and compared in this chapter. The analytical results have been presented in Tables 1 through 8, Figures 1 through 22 and Appendices V through X. A general view of the experimental plots and treatments have been shown in plates 1 through 9.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of variety

The plant height of boro rice was significantly influenced by different varieties at 30, 50 and 70 days after sowing/transplanting (DAS/T) and at harvest (Appendix V and Table 1). The result revealed that at 30 DAS/T, the hybrid variety Sonarbangla-1 produced the tallest plant (46.37 cm) and the inbred variety BRRI dhan 29 gave the shortest plant (39.84 cm) and the same trend of plant height for hybrid variety over inbred variety was obtained at 50 and 70 DAS/T. However, at harvest, the highest plant height (106.31 cm) was obtained from the BRRI dhan 29 and the lowest height (102.22 cm) was recorded in Sonarbangla-1. In the initial stage of growth, the increase of plant height was very slow and then the crop remained in vegetative stage. The rapid increase of plant height was observed from 30 to 70 DAS/T. After reaching the maximum vegetative stage, the growth of plant became very slow. The inbred variety was about 4% taller at harvest compared to the hybrid variety. Anon. (1998b) and Rahman (2001) also observed tallest plant in the inbred varieties and shortest plant height in Sonarbangla-1.

4.1.1.2 Effect of cultivation method

Significant variation of plant height was found due to different cultivation methods in all the studied durations (Appendix V and Table 1). The results revealed that at 30 DAS/T, the tallest plant (74.08 cm) was obtained from the clonal tillers followed by the SRI (44.41 cm) which was statistically similar with the nursery seedlings (43.53 cm) and the shortest plant height (25.89 cm) was obtained from the sprouted seeds in line that was statistically similar with the sprouted seeds broadcast (27.61 cm). The tallest plant height (95.47 cm) was recorded at 50 DAS/T from the clonal tillers followed by the nursery seedlings (80.74 cm). Similar trend was also observed at 70 DAS/T. The initial establishment of the transplanted crop depended on seedling vigor and in general, the plants from vegetatively propagated tillers established better as the initial advantage in their height and dry weight resulting in better growth and faster acclimatization to the soil (Sharma, 1995). At harvest, the tallest plant (107.73 cm) was obtained from the SRI, which was statistically similar with the nursery seedlings (106.12 cm) and sprouted seeds in line (103.71 cm) and the shortest plant height was obtained from the clonal tillers (102.15 cm) that was similar with the sprouted seeds broadcast (101.98 cm). It might be due to more space, sunlight and nutrients available to wider spaced plants of SRI than close spaced plants which facilitated the plants to attain more height. Haque (2002) found the highest plant height from wider spacing. Younger seedlings have more vigor, root growth and lesser transplant shock because of lesser leaf area during initial growth stages which stimulate increased cell division causing more stem elongation which might increased plant height of SRI (Rahman, 2001 and Sangsu et al., 1999). Shrirame et al. (2000) reported that the number of functional leaves, leaf area and total number of tillers hill^{-1} were higher at wider spacing which increased the photosynthetic rate leading to taller plants. Shortening of plants in tiller crop at harvest might be due to shortage of time for proper vegetative growth and development. Similar results were also reported by Mollah et al. (1992) and Rahman (2001).

These results were also in agreement with the findings of Khisha (2002) and Sarker et al. (2002) who concluded that plant height was greater under SRI than other studied treatments. However, Akita and Tanaka (1992) reported that at maturity the tallest plants were found at low plant density. The direct seeded treatments showed comparatively lower plant height due to dense spacing, though Sarkar et al. (2003) reported tallest plant height from direct seeding compared to transplanted plants. Reddy et al. (1987) reported similar plant height of rice at direct seeded and transplanted condition. Sharma and Ghosh (1998) and Richharia et al. (1964) observed higher plant height in tiller plant than those in seed plants. Nissanka and Bandara (2004) found no variation in plant height between the SRI, conventional transplanting, conventional broadcasting and high density broadcasting.

Table 1. Influence of variety and cultivation method on plant height at different crop growth stages of boro rice

Treatments	Plant height (cm) at different days after sowing/transplanting			
	30	50	70	At harvest
Variety				
V_1	39.84	69.09	91.94	106.31
V_2	46.37	79.05	95.76	102.22
LSD $_{(0.05)}$	0.64	3.69	2.81	2.76
Cultivation method				
P_1	25.89	60.10	87.27	103.71
P_2	27.61	60.20	88.49	101.98
P_3	43.53	80.74	94.20	106.12
P_4	44.41	73.84	97.24	107.73
P_5	74.08	95.47	102.05	102.15
LSD $_{(0.05)}$	4.21	4.53	3.48	4.03
CV (%)	9.46	5.92	3.59	3.74

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.1.1.3. Interaction effect of variety and cultivation method

Significant interaction effect between the variety and cultivation method was observed at 30, 50 and 70 DAS/T but insignificant at harvest (Appendix V and Figure 1). At 30 and 50 DAS/T, the tallest plant was obtained from the clonal tillers of the hybrid variety followed by the clonal tillers of the inbred variety and the shortest was obtained from the sprouted seeds in line of the inbred variety. The higher plant height of clonal tillers at early growth stage might be due to the combination of the initial higher weight and the force to quick completion of the life cycle of the clonally propagated crop. At harvest, the tallest plant (110.3 cm) was obtained from the SRI of the inbred variety and the shortest plant (99.45 cm) was recorded from the clonal tillers of the hybrid variety. Longxing et al. (2002) reported that plant height of the hybrid rice with SRI methods was higher than with traditional method. Rahman (2001) observed shortest plant due to the treatment combination of Sonarbangla-1 and tiller crop.

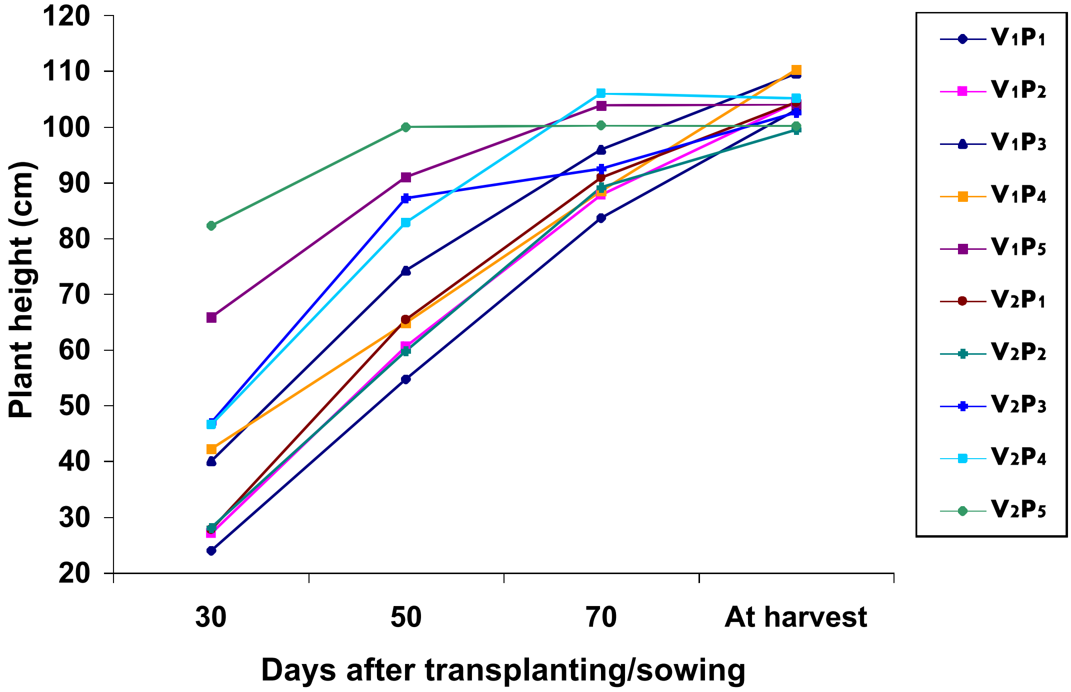

Figure 1. Interaction effect of variety and cultivation method on plant height (cm) at different crop growth stages of boro rice

4.1.2 Number of tillers hill^{-1} at different crop stage

4.1.2.1 Effect of variety

The production of total number of tillers hill^{-1} of boro rice was significantly influenced by different varieties at 30, 50, 70 DAS/T and at harvest (Appendix VI and Table 2). At 30, 50, 70 DAS/T and at harvest, the maximum tiller numbers hill^{-1} was observed in the inbred variety (BRRI dhan 29) and the minimum tiller numbers hill^{-1} was obtained from the hybrid variety (Sonarbangla-1). Davaraju et al. (1998) also found highest number of tillers hill^{-1} in the inbred variety. Lafarge et al. (2004) reported that number of tillers were reduced in hybrid rice that were likely to senesce as productive tiller number plant^{-1} at maturity. However, Yoshida (1972) and Anon. (1998a and 1998b) reported that hybrid variety had more tillering capacity than inbred variety. Akbar (2004) and Rahman (2001) reported that Sonarbangla-1 ranked first in respect of total tillers hill^{-1} among the other studied cultivars.

4.1.2.2 Effect of cultivation method

The production of total tillers hill^{-1} was significantly influenced by different cultivation method at 30, 50, 70 DAS/T and at harvest (Appendix VI and Table 2). At 30 DAS/T, significantly maximum number (12.65) of tillers hill^{-1} was recorded from the clonal tillers followed by the nursery seedlings (9.93) which was similar to the SRI (9.65) and the minimum (2.93) number was from the sprouted seeds broadcast which was similar to the sprouted seeds in line (3.30). At 50 and 70 DAS/T and at harvest, SRI produced significantly maximum number (46.30, 45.85 and 42.55, respectively) of tillers hill^{-1}. The practice of transplanting one young seedling hill^{-1} with wider spacing (SRI) had advantages in reducing transplanting injury and increasing tiller (Horie, 2004) and minimizes the competition between plants (Rabenandrasana, 1999). At the same stages, the second highest number (14.10, 11.83 and 10.98, respectively) of tillers hill^{-1} was obtained from the nursery seedlings and the minimum number of tillers hill^{-1} was obtained from the sprouted seeds broadcast (5.00, 4.53 and 4.00, respectively).

The SRI had higher number of tillers hill^{-1} (Plate 1), which might be due to wider spacing, transplanting younger seedlings, earlier transplanting and better water management. Earlier transplanting induced the transplanting shock at a more convenient point in the growth cycle when they could rebound faster and had little effect on tillerage (Uphoff, 2002). Use of plastic trays for raising seedlings, and dry cultivation of the nursery was beneficial to boost the vigorous root system for early and quick growing of tillers after transplanted in SRI (Ang et al., 2002). Alternate wetting and drying maintaining a thin film of water that might open the soil for both oxygen and nitrogen and promoted the root growth during initial growth stages which ultimately increased tiller density (Uphoff, 2001).

At very early stage, the quick development of clonal tillers resulted in significantly highest number of tillers compared to other treatments. At later stages, shortage of time for new tillering might be responsible for the production of lower number of total tillers hill^{-1} in clonal tillers compared to intact crop. Similar results were also reported by Rahman (2001).

These results were agreement with the findings of Karim et al. (2002) and Sengthong (2002), who reported that SRI performed the highest number of total tillers hill^{-1} in wider spacing of 40cm × 40cm. However, Chris (2002) found the highest number of tillers hill^{-1} from 20cm × 20cm. Wang et al. (2002) mentioned that percentage of effective tillers was higher in the younger seedlings. Saina (2001) reported in SRI practice fifty tillers plant^{-1} were easily obtained and been able to get over 100 tillers from single tiny seedling. Aziz and Hasan (2000) reported that in SRI practice, the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103, respectively. Nissanka and Bandara (2004) observed that the tiller number plant^{-1} was higher in the SRI compared to conventional transplanting, conventional broadcasting and high density broadcasting, but this parameter, when expressed per unit area basis were not significantly different. However, Karmakar et al. (2004) and Lu et al. (2004) found number of tillers per unit area were higher in closer spacing that contributed to obtain higher yield.

Table 2. Influence of variety and cultivation method on tiller numbers hill^{-1} at different crop growth stages of boro rice

Treatment	Number of tillers hill^{-1} at different days after sowing/transplanting			
	30	50	70	At harvest
Variety				
V_1	8.31	20.01	18.86	17.40
V_2	7.07	13.44	12.61	12.01
LSD $_{(0.05)}$	0.35	0.76	1.39	1.02
Cultivation method				
P_1	3.30	6.38	5.33	5.13
P_2	2.93	5.00	4.53	4.00
P_3	9.93	14.10	11.83	10.98
P_4	9.65	46.30	45.85	42.55
P_5	12.65	11.75	11.15	10.88
LSD $_{(0.05)}$	1.05	1.39	1.69	1.27
CV (%)	9.20	8.03	10.41	8.40

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.1.2.3. Interaction effect of variety and cultivation method

Different cultivation method significantly influenced the production of total tillers hill^{-1} at 30, 50, 70 DAS/T and at harvest (Appendix VI and Figure 2). At 30 DAS/T, the maximum number of tillers hill^{-1} (15.10) was obtained from the clonal tillers of the inbred variety followed by the SRI of the same variety (11.05) which was similar to the nursery seedlings of the same variety (10.95). At 50 and 70 DAS/T and at harvest, the maximum number of tillers hill^{-1} (59.55, 58.40 and 53.35, respectively) was obtained from the SRI of the inbred variety followed by the SRI (33.05, 33.30 and 31.75, respectively) of the hybrid variety (Plate 2, 3 and 4). Ang et al. (2002) indicated that hybrid rice variety with SRI method had a more vigorous tillering potential and good regulation of leaf and tiller growth. The minimum number of tillers hill^{-1} (4.7, 4.35 and 3.70, respectively) was obtained from sprouted seeds broadcast of the hybrid variety.

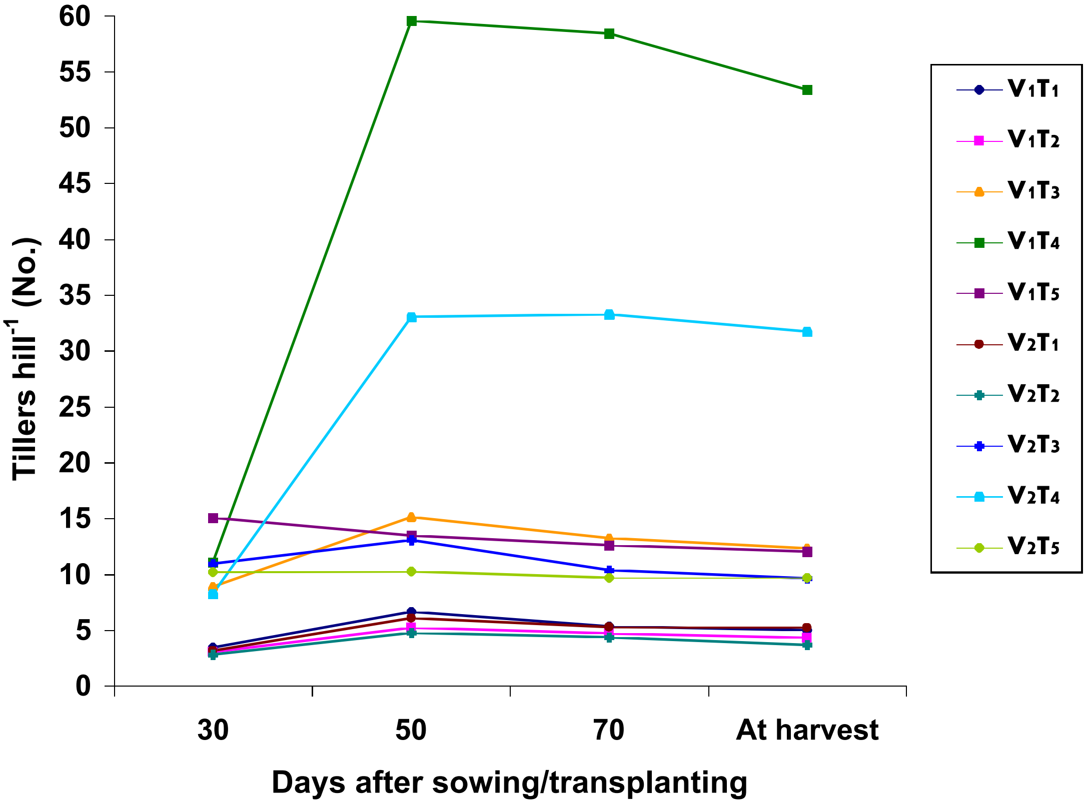

Figure 2. Interaction effect of variety and cultivation method on tiller numbers hill^{-1} at different crop growth stages of boro rice

4.1.3 Leaf area index (LAI) at different crop stage

The leaf area of plant is one of the major determinants of its growth. It is the ratio of leaf area to its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the growth, number of leaves plant^{-1}, population density and leaf senescence (Khan, 1981). The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of crop photosynthesis depends on the LAI. After germination LAI increases and reaches the peak levels after that it declines due to increased senescence (Katiya, 1980).

4.1.3.1 Effect of variety

Varietal effect significantly influenced leaf area index (LAI) of boro rice at 50 and 70 DAS/T and at harvest, however, it was not significantly influenced at 30 DAS/T (Appendix VII and Table 3). At 50 and 70 DAS/T and at harvest, the highest leaf area index (5.53, 7.52 and 1.75, respectively) was found in the inbred variety and the lowest leaf area index (5.49, 5.76 and 1.66, respectively) was found in the hybrid variety. This might be due to the production of comparatively lower tillers of the hybrid variety than the inbred variety which consequently decreased the number of leaves plant^{-1} and leaf area index. Takeda et al. (1983) observed that high-yielding rice varieties had higher LAI.

4.1.3.2 Effect of cultivation method

Cultivation method significantly influenced Leaf area index (LAI) of boro rice was at 30, 50 and 70 DAS/T and at harvest (Appendix VII and Table 3). At 30 DAS/T, clonal tillers produced the maximum leaf area index (3.23) followed by the nursery seedlings (0.83) and SRI produced the minimum leaf area index (0.27). At 50 and 70 DAS/T and at harvest, sprouted seeds broadcast produced the maximum leaf area index (6.69, 9.58 and 1.90, respectively) that was followed by the sprouted seeds broadcast sown in line. This result might be due to the higher number of leaves m^{-2} in both treatments. At 50 DAS/T and at harvest, SRI produced the minimum leaf area index (3.0 and 1.54, respectively). However at 70 DAS/T, clonal tillers produced the minimum leaf area index (4.09). Kim et al. (1999) and Ray et al. (2000) reported higher LAI in closer spacing, but Vijayakumar et al. (2006) observed maximum LAI in wider spacing.

Table 3. Influence of variety and cultivation method on LAI at different crop growth stages of boro rice

Treatment	Leaf area index at different days after sowing/transplanting			
	30	50	70	At harvest
Variety				
V_1	1.09	5.53	7.52	1.75
V_2	1.02	5.49	5.76	1.66
LSD $_{(0.05)}$	ns	0.02	0.75	0.04
Cultivation method				
P_1	0.47	6.34	8.63	1.78
P_2	0.48	6.69	9.58	1.89
P_3	0.83	5.89	5.88	1.72
P_4	0.27	3.00	5.02	1.54
P_5	3.23	5.63	4.09	1.58
LSD $_{(0.05)}$	0.16	0.73	0.78	0.033
CV (%)	14.77	12.77	11.37	12.66

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.1.3.3 Interaction effect of variety and cultivation method

Interaction effect of variety and cultivation method significantly influenced leaf area index (LAI) of boro rice at 30, 50 and 70 DAS/T and at harvest (Appendix VII and Figure 3). At 30 DAS/T, clonal tillers of the inbred variety produced the maximum leaf area index (3.57) followed by the same treatment of the hybrid variety (2.89). At 50 and 70 DAS/T and at harvest, sprouted seeds broadcast of BRRI dhan 29 produced the maximum leaf area index (6.76, 9.79 and 1.96, respectively). At 30 and 50 DAS/T and at harvest, SRI of the hybrid variety produced the minimum leaf area index. However, at 70 DAS/T, clonal tillers of the hybrid variety produced the minimum leaf area index (1.57). Clonal tillers of the hybrid variety required lower duration to complete their life cycle and hence it produced lower leaf area index at 30 and 50 DAS/T and at harvest compared to the other treatments.

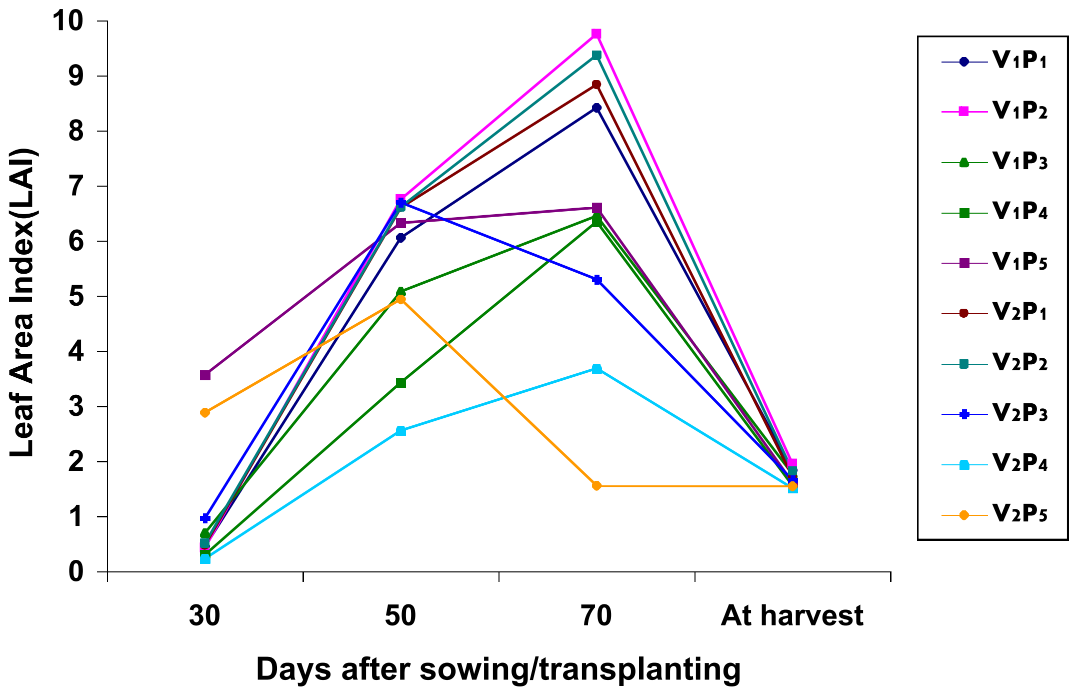

Figure 3. Interaction effect of variety and cultivation method on Leaf Area Index (LAI) of boro rice at different crop growth stages

4.1.4 Dry matter production

4.1.4.1 Effect of variety

Variety significantly influenced the total dry weight of plant at 30 DAS/T and at harvest but was similar at 50 and 70 DAS/T (Appendix VIII and Table 4). At 30 DAS/T, the hybrid variety Sonarbangla-1 produced higher dry weight (99.48 g m^{-2}) compared to the inbred variety BRRI dhan 29 (69.84 g m^{-2}). However at harvest, inbred variety produced the maximum dry weight (1774.26 g m^{-2}) which was 17.27% higher than the hybrid variety (1512.95 g m^{-2}).

The dry matter production of different plant parts at harvesting time was recorded in which all partitioned components were statistically influenced by variety (Appendix IX). The dry matter production of different plant parts except grain was always higher in the inbred variety compared to the hybrid variety (Figure 4).

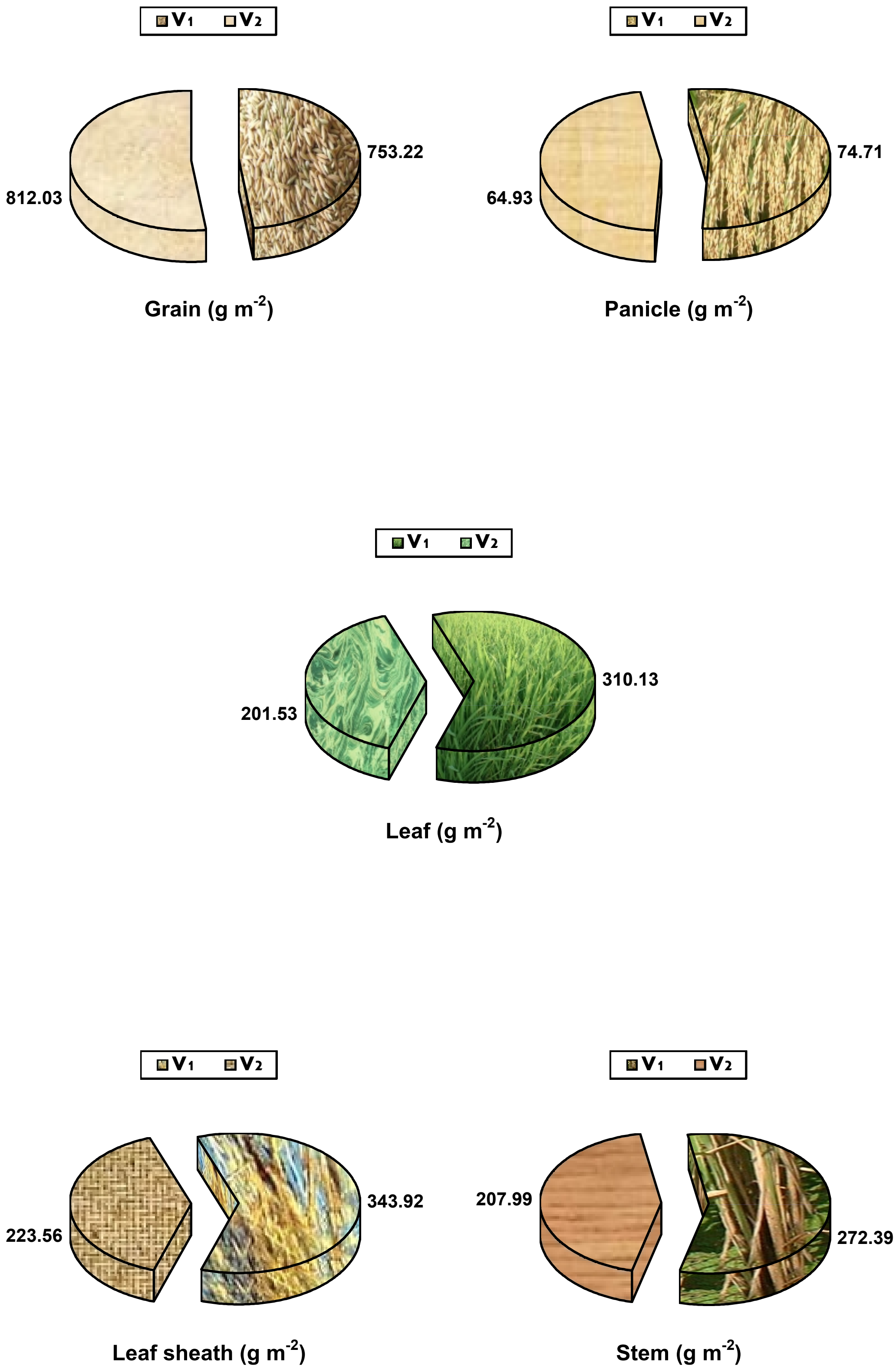

Figure 4. Influence of variety on dry matter production of different plant parts at harvest

4.1.4.2 Effect of cultivation method

The total dry weight of plant was significantly influenced by cultivation method at 30, 50 and 70 DAS/T and at harvest (Appendix VIII and Table 4). At 30 DAS/T, the maximum dry weight (317.66 g m^{-2}) was recorded in the clonal tillers followed by the nursery seedlings (58.75 g m^{-2}) and the minimum dry weight (12.79 g m^{-2}) was recorded in the SRI. Similar trend of dry matter production was also observed at 50 DAS/T. At 70 DAS/T, clonal tillers produced the maximum dry weight (1272.89 g m^{-2}) followed by the sprouted seeds in line (934.52 g m^{-2}) which was similar with the sprouted seeds broadcast (905.76 g m^{-2}) and nursery seedlings (887.67 g m^{-2}). Sharma and Ghosh (1998) and Sharma (1992) also observed highest dry weight in clonally propagated crop compared to nursery seedlings. The lowest dry weight (702.56 g m^{-2}) was obtained from the SRI. At harvest, the maximum dry weight (1855.30 g m^{-2}) was obtained from the nursery seedlings followed by the sprouted seeds in line which was similar with the sprouted seeds broadcast and clonal tillers. The lowest dry weight (1440.31 g m^{-2}) was obtained from the SRI. However, Sarkar et al. (2003) and Naklana et al. (1996) reported that the crops from anaerobic direct sowing had greater above-ground dry matter than transplanting. Lu et al. (2004) reported that dense spacing increased the dry matter production of rice.

The dry matter production of different plant parts at harvesting time was recorded in which dry weight of all parts were influenced by cultivation method (Appendix IX and Figure 5). Statistically highest dry weight of grain, stem, leaf and panicle was produced by the nursery seedlings. However, the sprouted seeds broadcast produced significantly highest dry weight of leaf sheath. The lowest dry weight of all plant parts was obtained from the SRI.

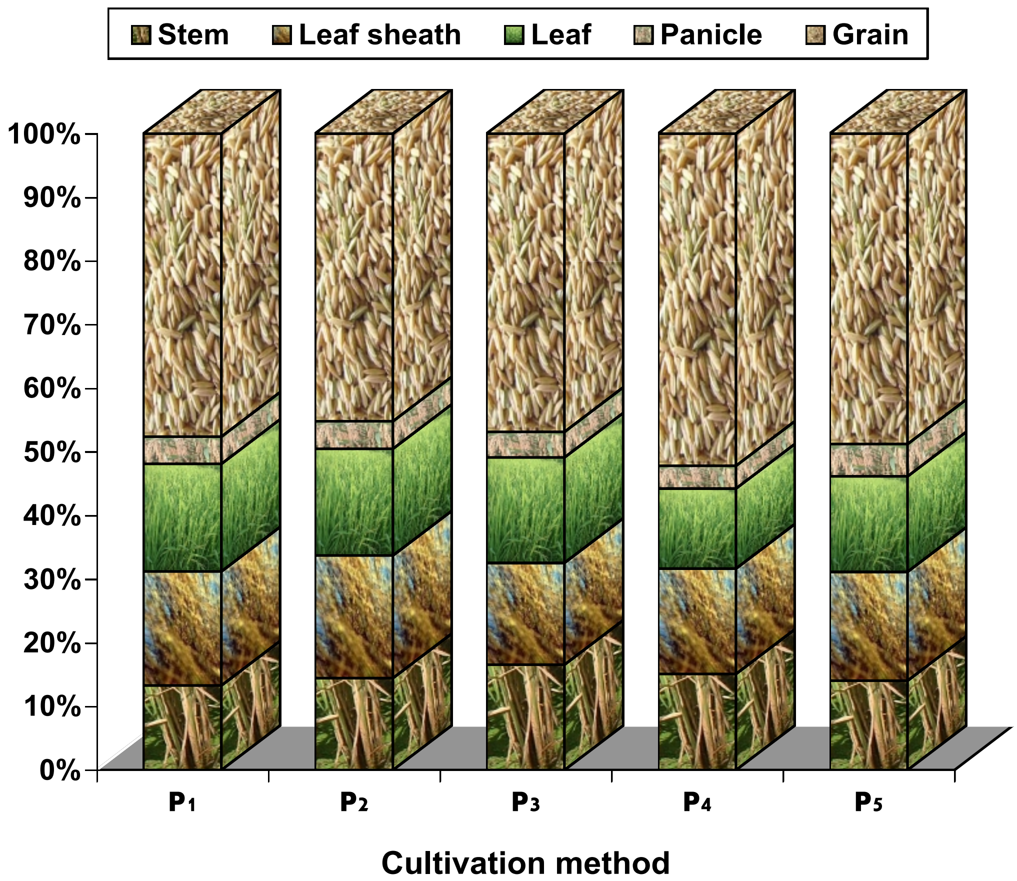

Figure 5. Influence of cultivation method on dry matter production in different plant parts at harvest

Table 4. Influence of variety and cultivation method on total dry matter at different crop growth stages of boro rice

Treatment	Total dry weight (g m^{-2}) at different days after sowing/transplanting			
	30	50	70	At harvest
Variety				
V_1	69.84	368.62	896.30	1774.26
V_2	99.48	423.69	985.06	1512.95
LSD $_{(0.05)}$	26.72	ns	ns	251.70
Cultivation method				
P_1	13.55	254.78	934.52	1670.87
P_2	20.54	312.16	905.76	1659.58
P_3	58.75	409.74	887.67	1855.30
P_4	12.79	231.50	702.56	1440.31
P_5	317.66	772.60	1272.89	1591.97
LSD $_{(0.05)}$	22.68	76.72	136.80	136.70
CV (%)	13.73	12.53	14.09	8.06

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.1.4.3 Interaction Effect of variety and cultivation method

Interaction effect of variety and cultivation method influenced the dry matter production of boro rice at 30 DAS/T and at harvest but not influenced significantly at 50 and 70 DAS/T (Appendix VIII and Figure 6). At 30 DAS/T, the highest dry weight (367.15 g m^{-2}) was observed in the clonal tillers of the hybrid variety. However at 50 DAS/T, the highest dry weight (790.63 g m^{-2}) was obtained from the clonal tillers of the inbred variety which was similar with the clonal tillers of the hybrid variety (754.56 g m^{-2}). Again at 70 DAS/T, maximum dry weight (1414.23 g m^{-2}) was produced by the clonal tillers of the hybrid variety. These results might be due to the short life cycle of the clonal tillers of the hybrid variety. As it was retransplanted in the main field after 70 (40+30) days of seeding in the seed bed, it showed quick development to complete its vegetative growth. At all these stages, the lowest dry weight was observed in SRI of the inbred variety. This might be due to the less vigor of the inbred variety at the early stages and wide spacing used for SRI which reduced the number of tillers m^{-2} and ultimately reduced the total dry weight. At harvest, the nursery seedlings of the inbred variety produced the highest dry weight (1863.92 g m^{-2}) which was similar with the nursery seedlings of the hybrid variety and sprouted seeds in line of the inbred variety, whereas, the lowest dry weight was produced by the SRI of the hybrid variety.

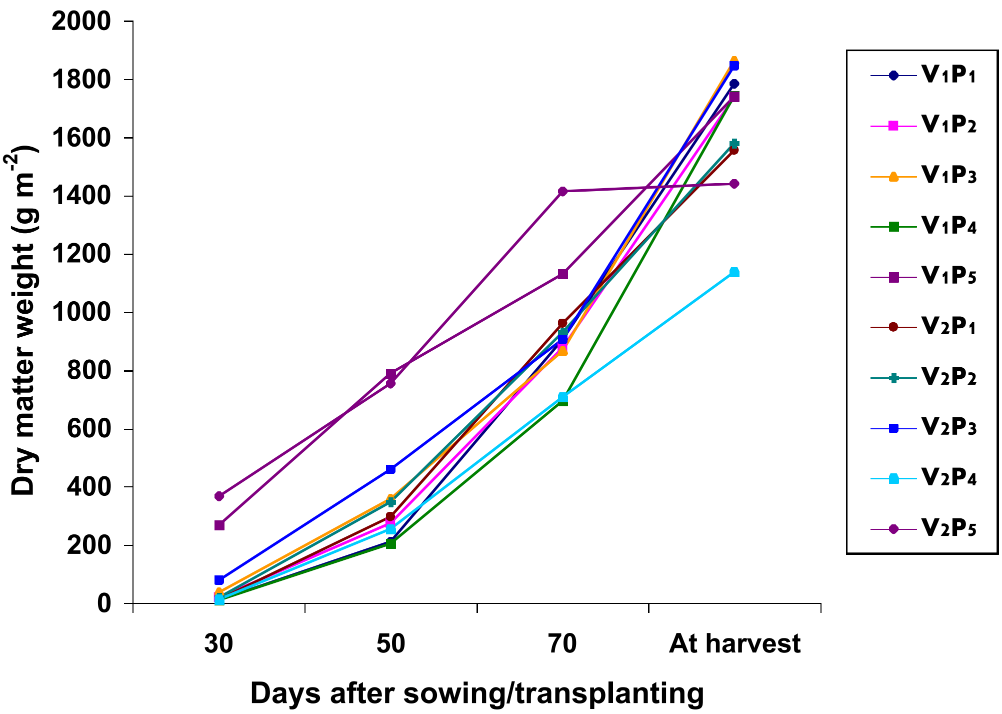

Figure 6. Interaction effect of variety and cultivation method on dry weight at different crop growth stages of boro rice

In case of the dry matter production of different plant parts at harvesting, only dry weight of grain and stem was statistically influenced by the interaction effect of variety and cultivation method (Appendix IX and Figure 7).

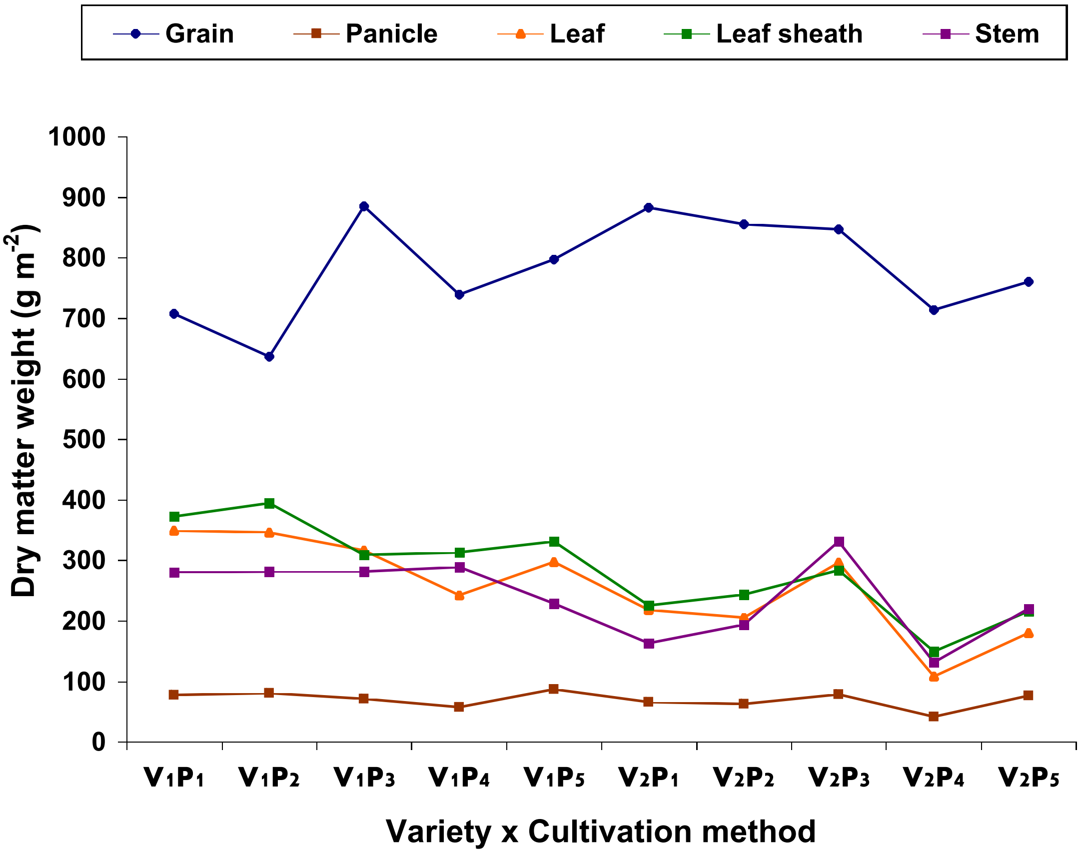

Figure 7. Interaction effect of variety and cultivation method on dry matter production of different plant parts of rice at harvest

4.1.5 Days to flowering and maturity

4.1.5.1 Effect of variety

The flowering and maturity dates significantly varied between the varieties (Appendix X and Table 5), where the inbred variety needed longer time for flowering (108 days) and maturity (143 days) compared to the hybrid variety. The hybrid variety matured 17 days earlier than the inbred variety. This might be due to the shortest life span of hybrid variety compared to that of inbred variety.

4.1.5.2 Effect of cultivation method

Various cultivation methods affected flowering and maturity time of both the varieties (Appendix X and Table 5). The clonal tillers needed the longest duration for flowering (116 days) and for maturity (150 days). It required 3 days more for maturity than that of the nursery seedlings. This might be due to removal of tillers from the mother hill and replanting again (Mollah et al., 1992). However, Richharia et al. (1964) observed that flowering of the tiller crops occurred about ten days earlier. The nursery seedlings needed the second highest duration for flowering (111 days) and for maturity (147 days). SRI matured 13 days earlier than that of the nursery seedlings. Uphoff (2005) reported that SRI required reduced time for maturity but Khan et al. (2003) mentioned it as irregular maturity (the most undesirable phenomenon). The lowest duration for flowering (83 days) and for maturity (119 days) was observed in the sprouted seeds in line. The sprouted seeds in line and sprouted seeds broadcast matured 28 and 26 days earlier than that of the nursery seedlings, respectively. Field duration of the crop was considerably reduced in direct seeded rice might be due to the absence of 'transplanting shock'. Direct seeding enhanced crop establishment and vegetative growth and reduced crop duration by two weeks (Javellana et al., 1988). Valarmathi and Leenakumary (1998) observed shorter duration required for maturity in sprouted seeds than transplanted crop. Bari (2004) observed that crop duration was shortened by six to ten days in direct wet seeded line sowing method compared to transplanted method. Bo and Min (1995) also observed that transplanted rice delayed flowering by 20 days than the direct wet-seeded rice. This might be beneficial if a second crop was grown after the direct seeded crop (Gudoy, 1959).

Table 5. Influence of variety and cultivation method on flowering and maturity duration of boro rice

Treatment	Days to flowering	Days to maturity
Variety		
V_1	108	143
V_2	88	126
LSD $_{(0.05)}$	0.19	0.35
Cultivation method		
P_1	83	119
P_2	83	121
P_3	111	147
P_4	98	134
P_5	116	150
LSD $_{(0.05)}$	0.16	0.33
CV (%)	3.16	5.24

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.1.5.3 Interaction effect of variety and cultivation method

Interaction effect of variety and cultivation method significantly influenced the flowering and maturity dates (Appendix X and Figure 8 & 9). Clonal tillers of the inbred variety required the highest duration for flowering (125 days) and sprouted seeds broadcast of the hybrid variety needed the lowest duration for flowering (72 days). Similar trend was observed in maturity, where clonal tillers of the inbred variety needed the highest duration (159 days) and sprouted seeds in line of the hybrid variety required the lowest duration (112 days).

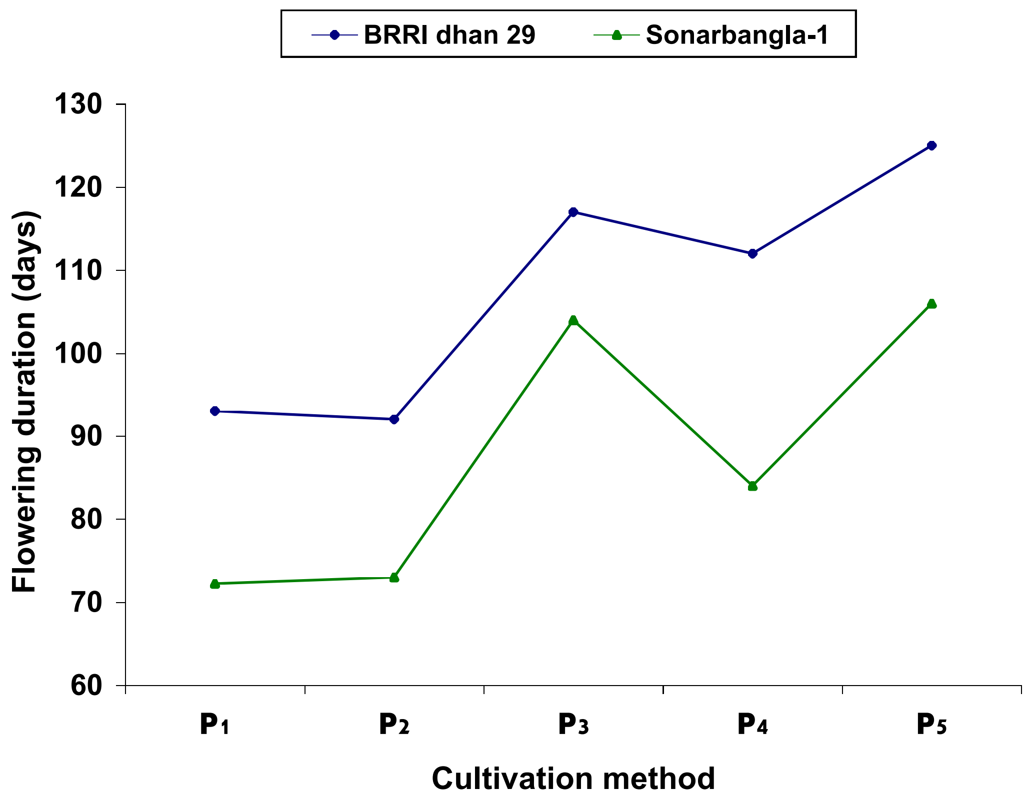

Figure 8. Interaction effect of variety and cultivation method on flowering duration of rice ($LSD_{0.05}$ = 0.23)

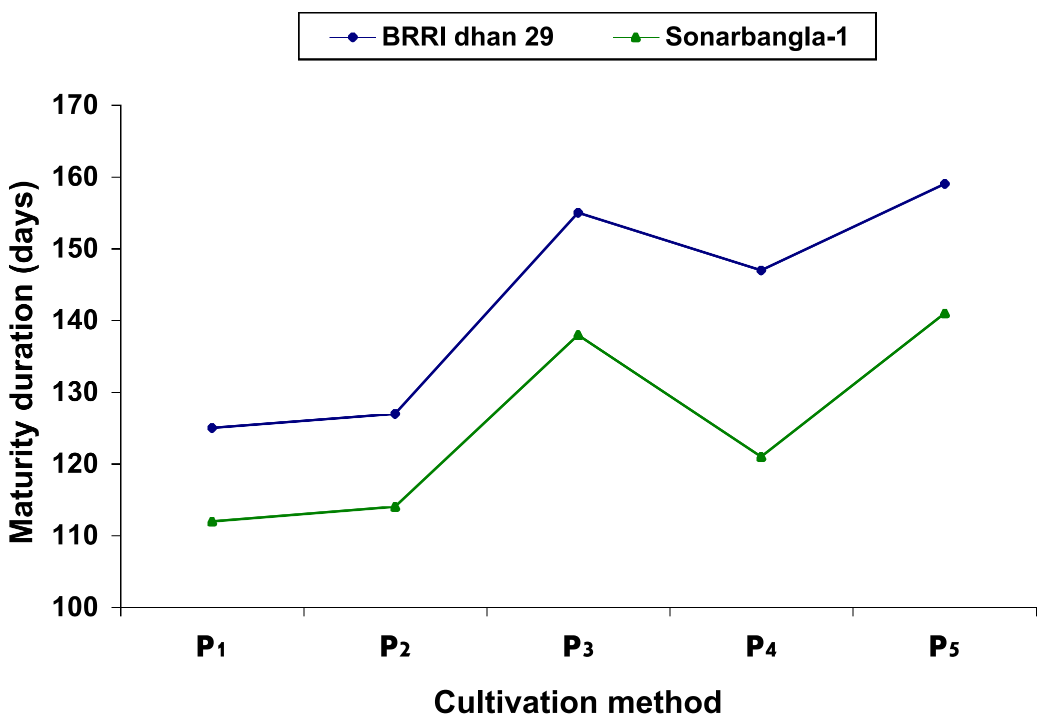

Figure 9. Interaction effect of variety and cultivation method on maturity duration of rice ($LSD_{0.05}$ = 0.46)

4.2 Yield contributing characters

4.2.1 Number of effective tillers m^{-2}

4.2.1.1 Effect of variety

The number of effective tillers m^{-2} was significantly influenced by variety (Appendix X and Table 6). Results showed that, the inbred variety (BRRI dhan 29) produced maximum number of effective tillers m^{-2} and the minimum was obtained from the hybrid variety (Sonarbangla-1). The variation in the production of effective tillers m^{-2} might be due to genetic constituents of the varieties. Anon. (1992) reported that the proportion of effective tillers was more or less similar in BRRI dhan 29 and Sonarbangla-1. However, Anon. (1998a) suggested that high yielding variety had more bearing tillers m^{-2} over the inbred variety.

Tiller mortality from maximum tillering stage to harvesting was not significantly influenced by variety (Appendix X and Figure 10). This might be due to the fact that the reduction of tiller number from maximum tillering stage to the final tiller number at maturity is a genetical behavior of the crop (Yoshida, 1981; Anon., 1970; Matsuo and Hoshikawa, 1993).

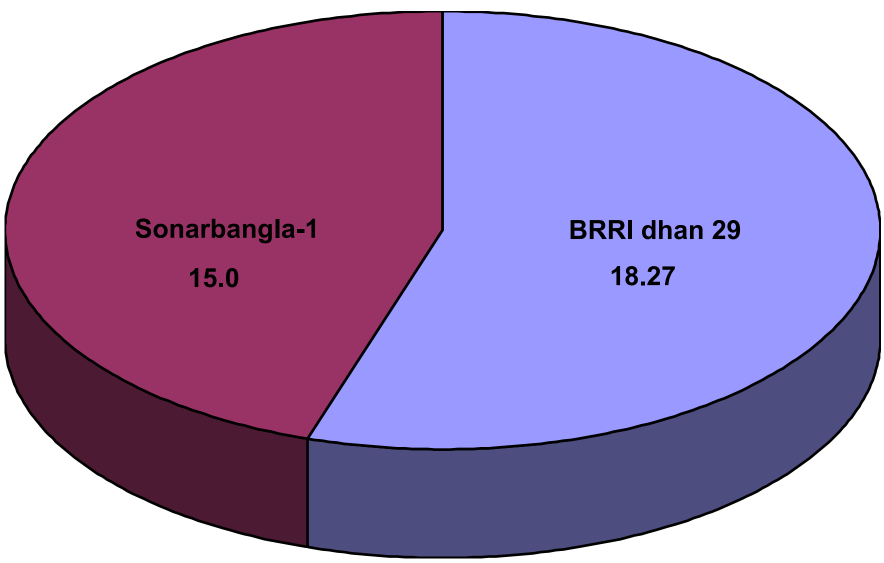

Figure 10. Influence of variety on tiller mortality percentage of boro rice

4.2.1.2 Effect of cultivation method

Cultivation method significantly influenced the number of effective tillers m^{-2} (Appendix X and Table 6). The maximum number of effective tillers m^{-2} (529.0) was obtained from the sprouted seeds broadcast followed by the sprouted seeds in line (423.0), nursery seedlings (305.0) and clonal tillers (278.6), respectively. This might be due to the closer spacing of sprouted seeds which increased plants m^{-2}, consequently increased effective tillers m^{-2}. Tiller crop could not produce more effective tillers m^{-2} might be due to the shortage of time for vegetative growth. The lowest effective tillers m^{-2} (249.3) was obtained from the SRI. Though the tillers $hill^{-1}$ of the SRI was the highest among all the studied treatments, but because of the wider spacing (40cm × 40cm), it might have failed to perform well in terms of effective tillers m^{-2}. However, Husain et al. (2004) observed higher number of effective tiller under SRI compared to farmers' practice.

These results were in agreement with the findings of Xiang et al. (1999); Yang et al. (1998) and Ye and Ye (1997) who observed maximum number of effective tillers m^{-2} in the sprouted seeds than the nursery seedlings. But Rajkhowa and Gogoi (2004); Maqsood et al. (1997) and Dwivedi et al. (1996) disagreed with this finding, they found more productive tillers in transplanting of seedlings than sprouted seeds. However, Rahman (2001) observed that number of effective tillers was highest in intact crop compared to clonal tillers. Mollah et al. (1992) observed that late tiller separation at 40 DAT significantly reduced effective tillers from both $plant^{-1}$ and $unit^{-1}$ area. Husain et al. (2003a) found more effective tillers in the SRI than the conventional transplanting method. Sengthong (2002) noticed highest number of effective tillers when transplanted at spacing of 40cm × 40cm and Wang et al. (2002) reported higher number of effective tillers in the younger seedlings.

Table 6. Influence of variety and cultivation method on effective and ineffective tillers of boro rice

Treatment	Effective tillers (no. m^{-2})	Ineffective tillers (no. m^{-2})
Variety		
V_1	412.97	51.83
V_2	301.00	58.65
LSD $_{(0.05)}$	24.25	5.70
Cultivation method		
P_1	423.00	80.25
P_2	529.00	103.00
P_3	305.05	35.80
P_4	249.30	20.38
P_5	278.58	36.78
LSD $_{(0.05)}$	24.93	16.83
CV (%)	6.77	9.52

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

Variation of cultivation method influenced tiller mortality from maximum tillering stage to harvesting (Appendix X and Figure 11). The maximum tiller mortality (22.18%) was observed in the nursery seedlings which was similar with the sprouted seeds broadcast (20.05%) and in line (18.97%). The minimum tiller mortality (7.87%) was observed in the SRI. Differences among the treatments might be due to the intraplant competition for light, nutrient, space etc.

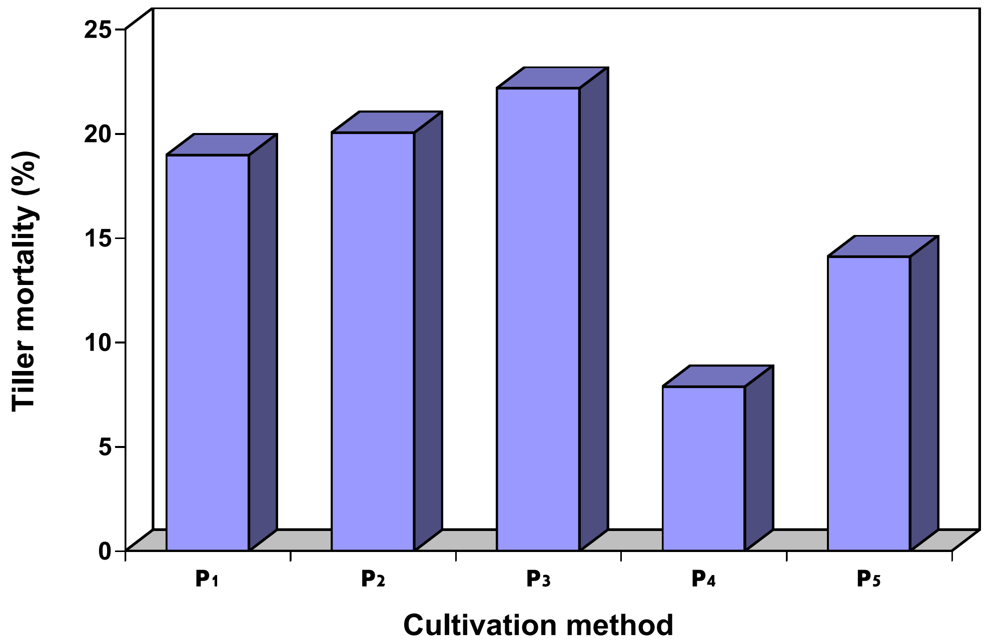

Figure 11. Influence of cultivation method on tiller mortality of boro rice (LSD value = 5.947)

4.2.1.3 Interaction effect of variety and cultivation method

The number of effective tillers m^{-2} was significantly influenced by the interaction effect of variety and cultivation method (Appendix X and Figure 12). The maximum number of effective tillers m^{-2} (594.0) was obtained from the sprouted seeds broadcast of the inbred variety followed by the sprouted seeds in line (479.0) of the same variety which was similar with the sprouted seeds broadcast (464.0) of the hybrid variety. These results might be due to the combination of the higher tiller production ability of the inbred variety than that of the hybrid variety and due to the dense spacing. The lowest number of effective tillers m^{-2} (196.5) was obtained from the SRI of the hybrid variety. Since, the hybrid variety (Sonarbagla-1) completed its life cycle within 140 DAS/T and the clonal tillers were retransplanted after 30 days of planting in the main field, as a result it failed to produce more number of tillers m^{-2}.

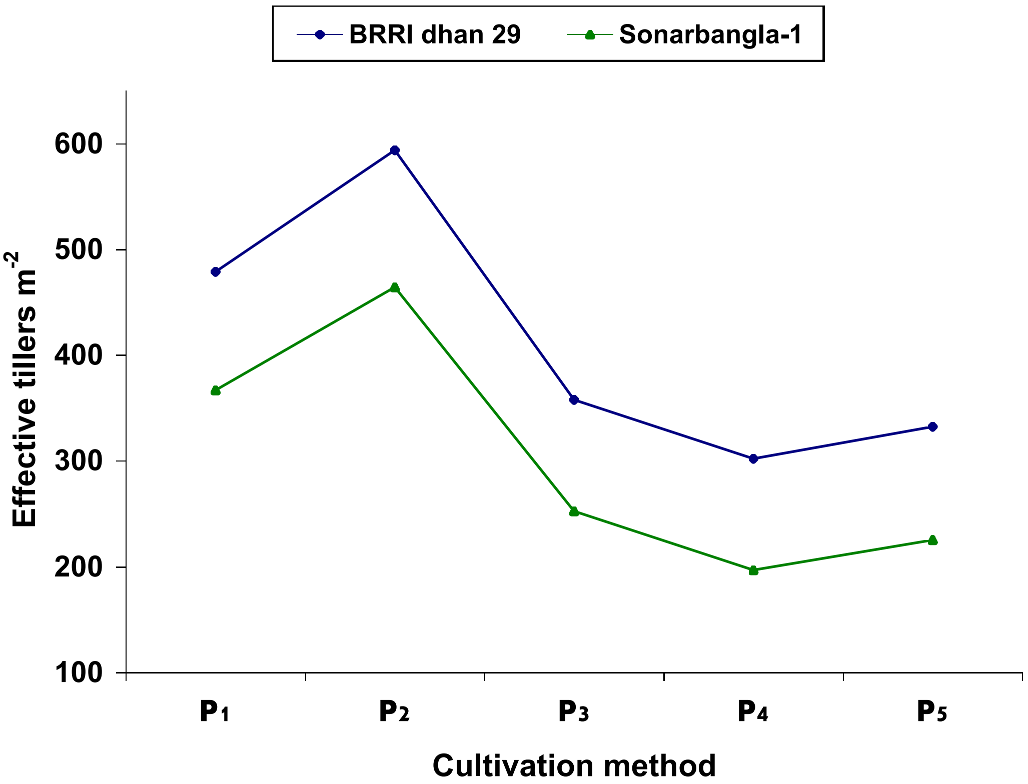

Figure 12. Interaction effect of variety and cultivation method on number of effective tillers of boro rice ($LSD_{0.05}$ = 24.93)

Tiller mortality from maximum tillering stage to harvesting was significantly influenced by the interaction effect of variety and cultivation method (Appendix X and Figure 13). The highest tiller mortality (25.78%) was observed from the nursery seedlings of the hybrid variety which was similar with the sprouted seeds in line of the inbred variety (24.03%). The SRI of the hybrid variety showed the lowest tiller mortality (5.35%) that was followed by the clonal tillers of the same variety.

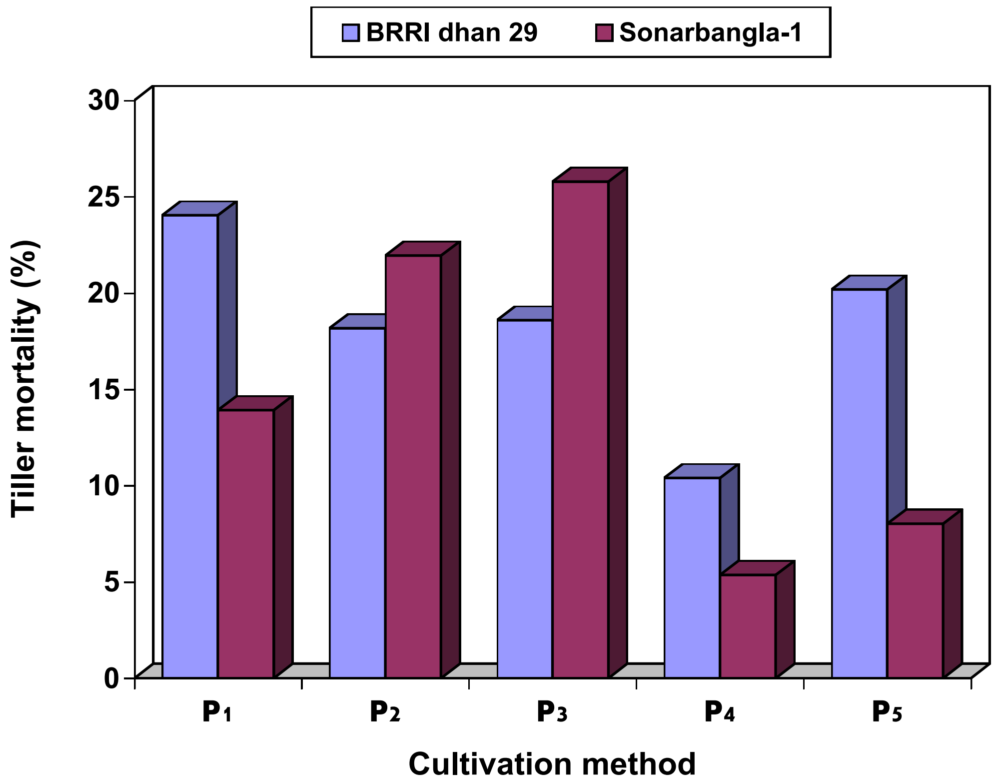

Figure 13. Percentage of tiller mortality as influenced by variety and cultivation method ($LSD_{0.05}$ = 8.411)

4.2.2 Panicle length

4.2.2.1. Effect of variety

The panicle length was not varied significantly due to the variety (Appendix X and Table 7). The maximum (28.15 cm) and minimum (27.79 cm) panicle length was obtained from BRRI dhan 29 and Sonarbangla-1 respectively. Such findings might be due to the genetic make-up of the varieties though Babiker (1986) observed that panicle length differed due to the varietal variation.

4.2.2.2. Effect of cultivation method

There were no difference in panicle length due to cultivation method (Appendix X and Table 7). The maximum (28.28 cm) and minimum (27.52 cm) panicle length were observed in SRI and sprouted seeds broadcast treatments respectively. Bari (2004) also observed that planting method had no significant influence on panicle length. However, Gasparillo et al. (2001) noted significant variation of panicle length between the SRI and non-SRI methods. Chowhan (2003) and Hossain et al. (2003) reported that the SRI produced the highest panicle length than the conventional planting method. Goel and Verma (2000) found higher panicle length from the transplanting method than the direct sowing method. Paul (1999) and Rahman (2001) found that nursery seedlings gave the longest panicles compared to the clonally propagated tillers.

Table 7. Influence of variety and cultivation method on yield contributing characters of boro rice

Treatments	Panicle length (cm)	Total grains/ panicle (No.)	Filled grains/ panicle (No.)	Unfilled grains/ Panicle (No.)	1000-grain weight (g)
Variety					
V_1	28.15	243.95	193.45	50.53	23.04
V_2	27.79	235.60	209.28	28.43	28.32
LSD $_{(0.05)}$	ns	ns	11.35	8.67	2.28
Cultivation method					
P_1	27.99	221.03	179.96	41.06	24.97
P_2	27.52	224.96	182.51	42.51	24.04
P_3	27.89	264.74	239.20	30.80	26.56
P_4	28.28	242.15	201.33	40.83	26.61
P_5	28.20	246.00	203.80	42.20	26.21
LSD $_{(0.05)}$	ns	23.94	20.15	Ns	Ns
CV (%)	3.40	9.67	9.70	13.67	8.96

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.2.2.3. Interaction effect of variety and cultivation method

Panicle length was not significantly affected by the interaction effect of variety and cultivation method (Appendix X and Figure 14). The maximum panicle length (29.00 cm) was obtained from the SRI of the inbred variety and the minimum panicle length (27.02 cm) was obtained from the sprouted seeds broadcast of the same variety.

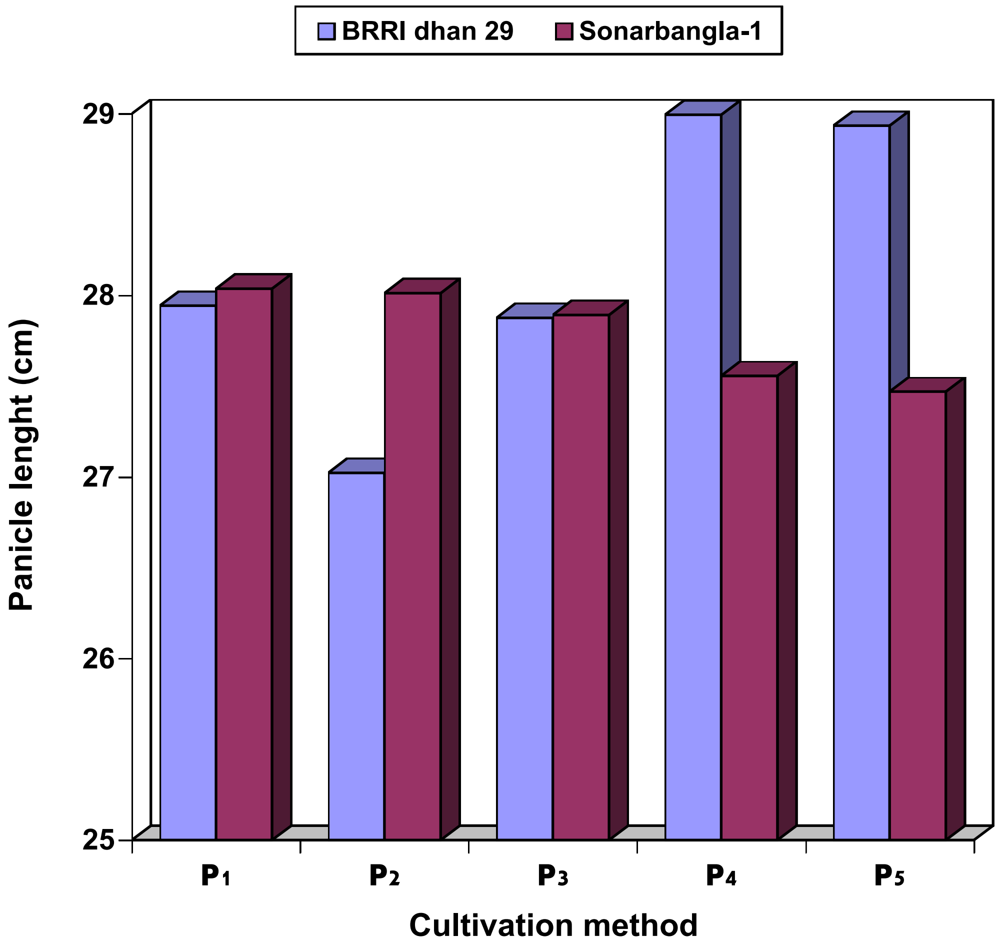

Figure 14. Interaction effect of variety and cultivation method on panicle length of boro rice ($LSD_{0.05}$ = 1.387)

4.2.3 Total number of grains panicle^{-1}

The total number of grains panicle^{-1} is an important factor which contributes towards grain yield. Variety did not show any significant effect however cultivation method had a significant effect on the total number of grains panicle^{-1}.

4.2.3.1 Effect of variety

The total number of grains panicle^{-1} was not significantly influenced by the variety (Appendix X and Table 7) though the maximum number of grains panicle^{-1} (243.95) was obtained from the inbred variety BRRI dhan 29 and the minimum number of grains panicle^{-1} (235.60) was obtained from the hybrid variety Sonarbangla-1. Hossain and Alam (1991) reported varietal variation in number of grains panicle^{-1} and Anon. (1998b) found higher number of grains panicle^{-1} in the hybrid varieties.

4.2.3.2 Effect of cultivation method

The grains panicle^{-1} was significantly affected by the cultivation method (Appendix X and Table 7). The highest number of total grains panicle^{-1} (264.74) was obtained from the nursery seedlings that was similar to clonal tillers and SRI and the lowest number of grains panicle^{-1} (221.03) was recorded from the sprouted seeds sown in line. Dwivedi et al. (1996) found higher total grains panicle^{-1} in transplanting than sprouted seeds sowing. Rahman (2001) found highest number of grains panicle^{-1} in the nursery seedlings than the clonal tillers. However, Biswas (2001) reported higher grain in the clonal tillers than the nursery seedling. Xiang et al. (1999) and Yang et al. (1998) found higher number of grains in sprouted seeds compared to that transplanting seedling. Husain et al. (2004) observed higher number of grains panicle^{-1} under SRI compared to the farmers' practice.

4.2.3.3 Interaction effect of variety and cultivation method

The total numbers of grains panicle^{-1} was significantly influenced by the interaction effect between variety and cultivation method (Appendix X and Figure 15). The maximum (266.95) number of grains panicle^{-1} was obtained from the nursery seedlings of the hybrid variety and the minimum (218.48) number grains panicle^{-1} was obtained from the sprouted seeds in line of the hybrid variety which was similar with the sprouted seeds in line (223.58) and sprouted seeds broadcast of the inbred variety (221.30).

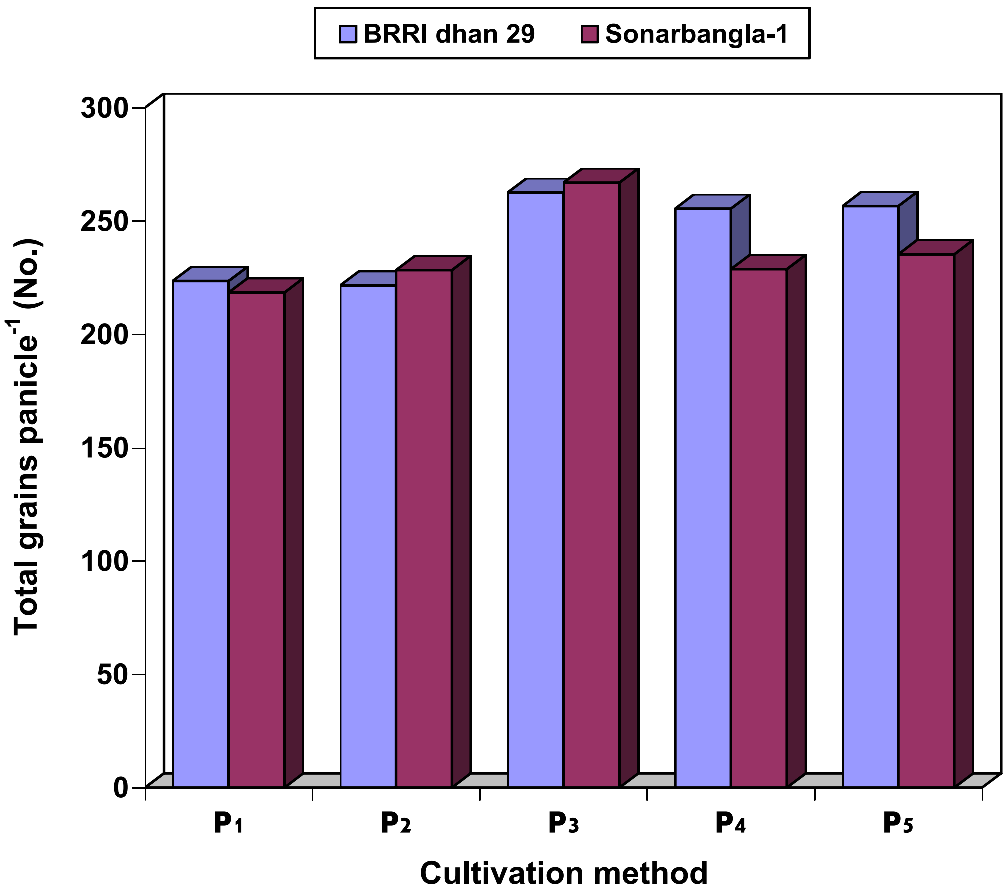

Figure 15. Interaction effect of variety and cultivation method on total number of grains of boro rice ($LSD_{0.05}$ = 33.85)

4.2.4 Filled grains panicle^{-1}

4.2.4.1 Effect of variety

The filled grains panicle^{-1} differed significantly for variation of the variety (Appendix X and Table 7). The maximum number of filled grains panicle^{-1} (209.28) was found in the hybrid variety Sonarbangla-1 and the lowest number of filled grains panicle^{-1} (193.45) was obtained from the inbred variety BRRI dhan 29.

4.2.4.2 Effect of cultivation method

The different methods of cultivation showed significant variation on the number of filled grains panicle^{-1} (Appendix X and Table 7). The highest number of filled grains panicle^{-1} (239.2) was obtained from the nursery seedlings followed by the clonal tillers (203.8) and the lowest number of filled grains panicle^{-1} (179.96) was obtained from the sprouted seeds in line. Dwivedi et al. (1996) found higher number of filled grains panicle^{-1} in nursery seedlings than sprouted seeds. Ang et al. (2002) obtained maximum filled grains panicle^{-1} from 40cm × 40cm spacing of the SRI.

4.2.4.3 Interaction effect of variety and cultivation method

Interaction effect between variety and cultivation method was significant in respect of filled grains panicle^{-1} (Appendix X and Figure 16). The highest number of filled grains panicle^{-1} (255.5) was obtained from the nursery seedlings of the hybrid variety followed by the same treatment of the inbred variety (222.9) and the lowest number of filled grains panicle^{-1} was obtained from the sprouted seeds in line of the inbred variety.

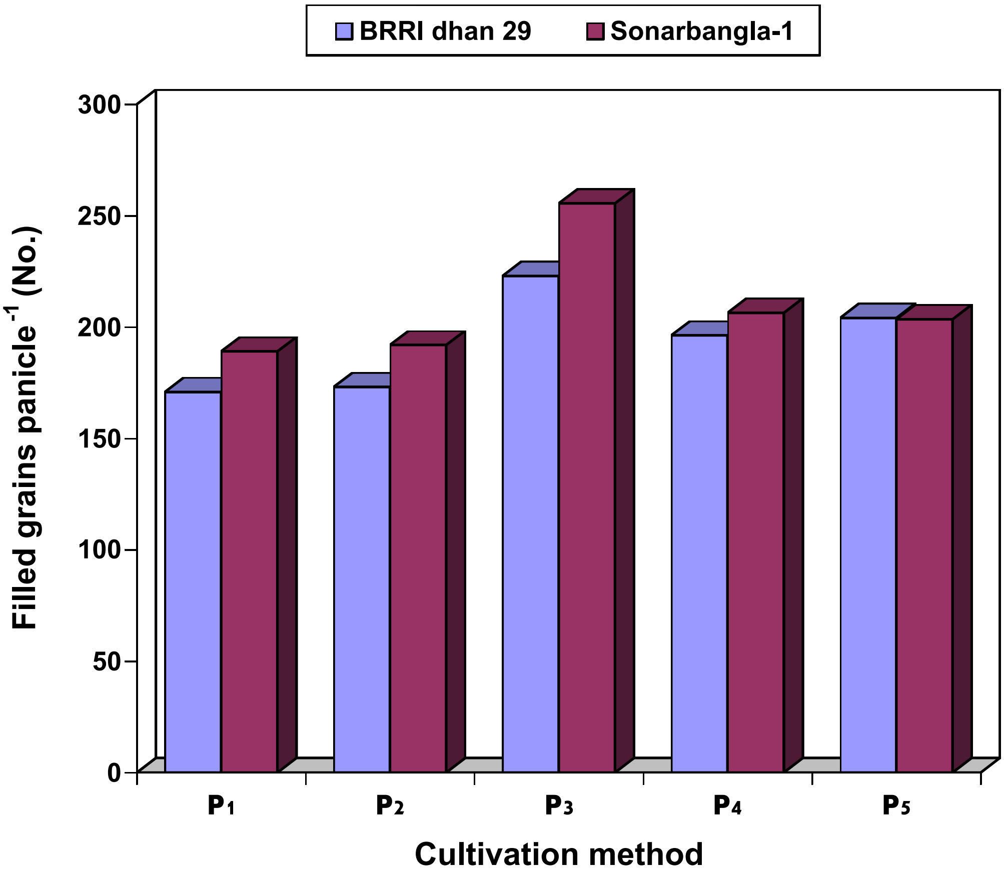

Figure 16. Interaction effect of variety and cultivation method on number of filled grains of boro rice ($LSD_{0.05}$ = 28.50)

4.2.5 Unfilled grains panicle^{-1}

4.2.5.1 Effect of variety

The unfilled grains panicle^{-1} was significantly differed between the inbred and hybrid variety (Appendix X and Table 7). The maximum number of unfilled grains panicle^{-1} (50.53) was counted in the inbred variety BRRI dhan 29 and the minimum number of unfilled grains panicle^{-1} (28.43) was counted in the hybrid variety Sonarbangla-1. Akbar (2004) found highest number of unfilled grains panicle^{-1} in Sonarbangla-1.

4.2.5.2 Effect of cultivation method

Analysis of variance showed that number of unfilled grains panicle^{-1} was not statistically differed due to the different cultivation method (Appendix X and Table 7). Though the maximum number of unfilled grains panicle^{-1} (42.51) was counted in the sprouted seeds broadcast and the minimum number of unfilled grains panicle^{-1} (30.80) was counted in the nursery seedlings.

4.2.5.3 Interaction effect of variety and cultivation method

Unfilled grains panicle^{-1} was statistically influenced by interaction effect of variety and cultivation method (Appendix X and Figure 17). The highest (59.20) number of unfilled grains panicle^{-1} was recorded under the SRI of the inbred variety whereas the lowest number (21.98) was counted in the Nursery seedlings of the hybrid variety which was similar with the SRI (22.45) and sprouted seeds in line (29.40) of the same variety.

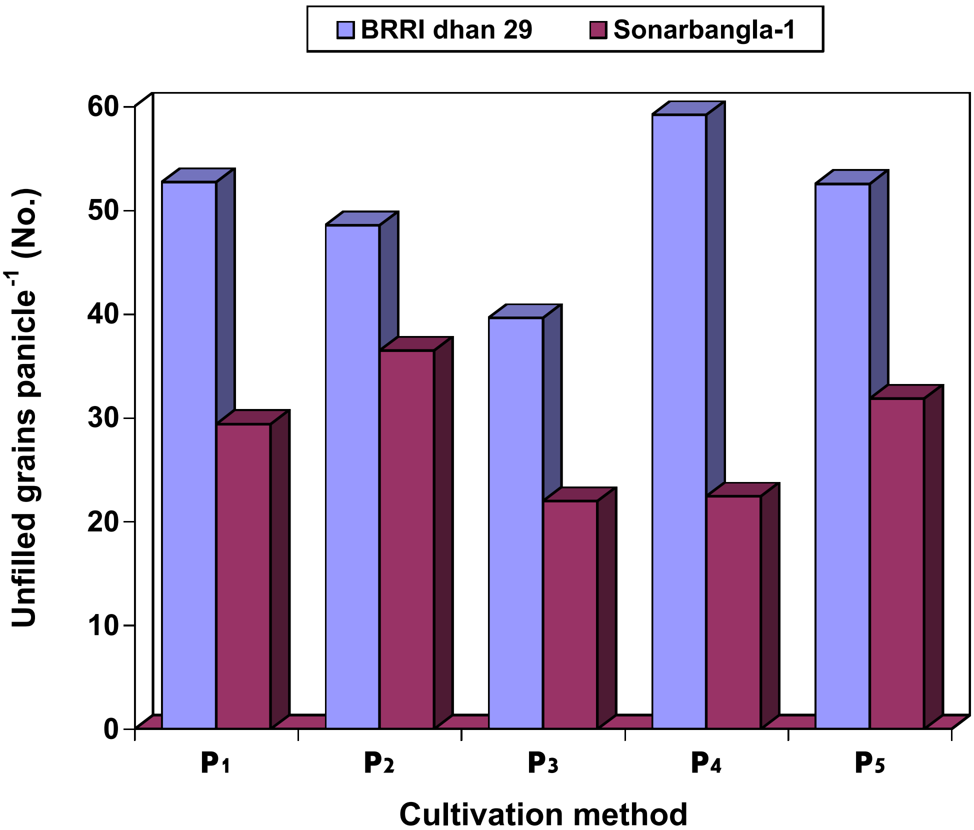

Figure 17. Interaction effect of variety and cultivation method on number of unfilled grains of boro rice ($LSD_{0.05}$ = 15.78)

4.2.6 Weight of 1000-grains

4.2.6.1 Effect of variety

The weight of 1000-grains was significantly influenced by the variety (Appendix X and Table 7). The highest weight of 1000-grains (28.32 g) was obtained from the hybrid variety Sonarbangla-1 and the lowest weight of 1000-grains (23.04 g) was obtained from the inbred variety BRRI dhan 29. The variation of 1000-grains weight among varieties might be due to genetic constituents. The result supports the findings of Akbar (2004) and Rahman (2001) who found highest weight of 1000-grains in Sonarbangla-1 than the other studied varieties.

4.2.6.2 Effect of cultivation method

There was no significant effect among the cultivation method in respect of weight of 1000-grains (Appendix X and Table 7) though the maximum weight of 1000-grains (26.61 g) was obtained from the SRI and the minimum weight of 1000-grains (24.04 g) was obtained from the sprouted seeds broadcast. This might be due to the wider spacing of SRI that encouraged proper crop growth and development and assimilate synthesis in the grains. Bari (2004) also observed that planting method had no significant influence on 1000-grains weight. But Husain et al. (2004) and Hossain et al. (2003) observed higher 1000-grains weight under SRI compared to the farmers' practice. Rahman (2001) reported higher weight of 1000-grains in nursery seedlings compared to the clonally propagated crops. Dwivedi et al. (1996) found higher weight of 1000-grains in Nursery seedlings than sprouted seeds. Xiang et al. (1999) and Richharia et al. (1964) found higher 1000-grains weight in sprouted seeds than transplanting seedlings. Goel and Verma (2000) reported higher 1000-grains weight in the direct sowing compared to the transplanting method.

4.2.6.3 Interaction effect of variety and cultivation method

Interaction effect between variety and cultivation method was found significant in respect of weight of 1000-grains (Appendix X and Figure 18). The highest weight of 1000-grains (29.49 g) was obtained from the SRI of the hybrid variety, which was similar with the clonal tillers and nursery seedlings of the same variety. The lowest weight of 1000-grains (22.09 g) was obtained from the sprouted seeds in line of the inbred variety, which was similar to the sprouted seeds broadcast of the same variety. Rahman (2001) found highest 1000-grains weight in the combination of Sonarbangla-1 and nursery seedlings.

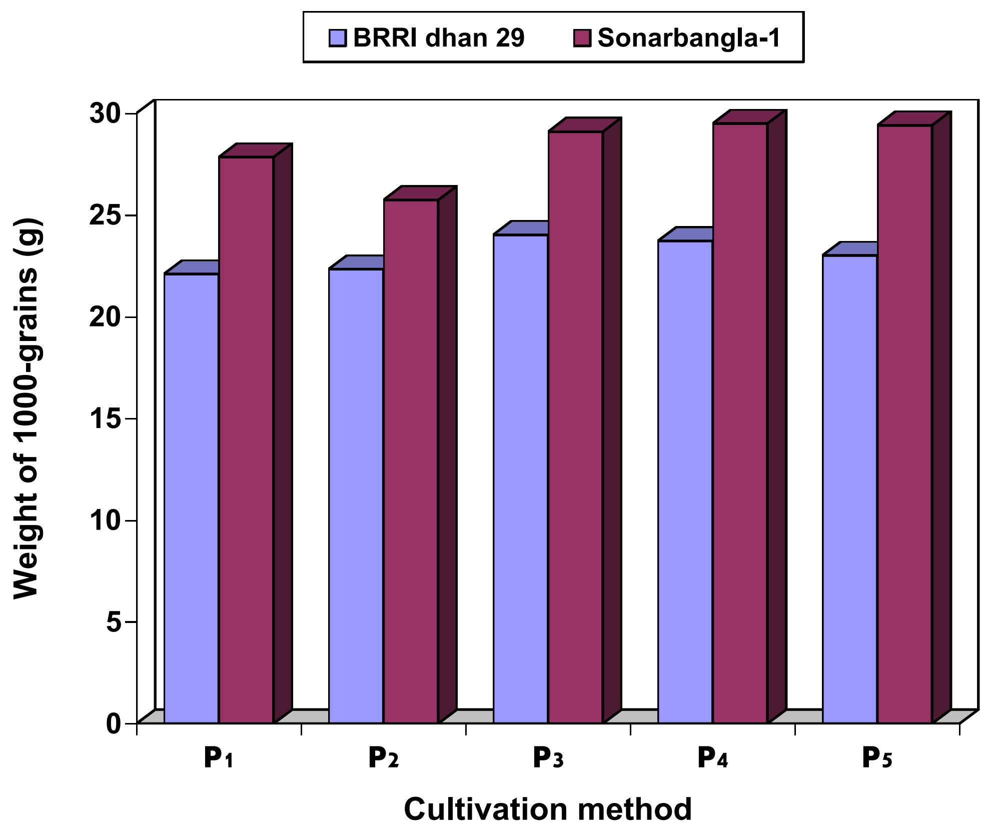

Figure 18. Interaction effect of variety and cultivation method on weight of 1000-grains of boro rice ($LSD_{0.05}$ = 3.36)

4.2.7 Grain yield

4.2.7.1. Effect of variety

Grain yield was significantly influenced by the variety (Appendix X and Table 8). The highest grain yield (8.26 t ha^{-1}) was obtained from the hybrid variety Sonarbangla-1 compared to the yield (7.53 t ha^{-1}) of inbred variety BRRI dhan 29. The hybrid variety gave 9.69% higher yield than the inbred variety. The yield improvement in the hybrid has been associated with an increase in total biomass as well as higher harvest index (Damodaran, 2001). Lafarge et al. (2004) reported that grain yield was significantly higher for hybrid rice as hybrid increased assimilates allocation towards productive tillers. Davaraju et al. (1998); Anon. (1998a); Anon. (1998b); Julfiquar et al. (1998) and Leenakumari et al. (1993) also found higher grain yield from the hybrid varieties over the inbred varieties.

4.2.7.2. Effect of cultivation method

Cultivation method has significant effect on grain yield (Appendix X and Table 8) Nursery seedlings produced significantly the highest grain yield (8.73 t ha^{-1}) that was followed by clonal tillers and sprouted seeds in line (7.96 t ha^{-1}). Similar highest yield of nursery seedlings was also reported by Mazid et al., 2003; Rahman, 2001; Lee et al., 1996). However, Hossain et al. (2003) reported that conventional planting method produced the lowest grain yield. The reduction of yield in clonal tillers compared to nursery seedlings might be due to the removal of tillers from the mother plant (Murthy et al., 1991). However, tillers can be separated at 25 or 35 DAT without hampering the grain yield (Paul et al., 2002). Mollah et al. (1992) observed that late tiller separation at 40 DAT significantly reduced grain yield by 0.41 t ha^{-1} compared to an early tiller separation at 30 DAT. The yield decrease in late tiller separation might be accompanied by a reduction in effective tillers from both $plant^{-1}$ and $unit^{-1}$ area. Mondal (1977) reported that both the tiller crop and seedling crop produced identical grain yield. The similar yield was recorded in sprouted seeds in line (7.96 t ha^{-1}) and sprouted seeds broadcast (7.56 t ha^{-1}). Lower yield of these two treatments compared to nursery seedlings and clonal tillers might be caused by faster growth rate and excessively large LAI beyond an optimum, which in turn were closely related to high tillering capacity of the seedling materials. Too dense population might caused inter and intra plant competition, reduced the overall efficiency of the crop. Bhuiyan et al. (1995) and Kundu et al. (1993) recorded higher grain yield in direct wet-seeded rice than the transplanted rice. Budhar and Tamilselvan (2001) observed highest grain yield in wet sowing by manual broadcasting followed by direct sowing using a drum seeder and traditional transplanting. Bari (2004) also found significantly higher grain yield from direct wet seeded line sowing method than those from transplanted method. However, Park et al. (1989) and Anon. (1981) reported that there was little difference in grain yields between direct seeding in rows and broadcast sown treatments, while Subbaiah et al. (2002); Venkatachalapathy and Veerabadran (2002) reported superior yield of drum seeder. However, Roknuzzaman (1997); Rajput and Yadav (1993); Varughese et al. (1993) found higher yield of rice from the haphazard or broadcast method.

The lowest grain yield (7.23 t ha^{-1}) was obtained from the SRI, which might be due to the wider spacing of 40 cm × 40 cm (Latif et al., 2005; Mazid et al., 2003; Anon., 2001b). Number of tillers and panicle per unit area were lower in wider spacing that contributed to obtain lower yield. However, Zheng et al. (2004) reported that yield of the SRI exceeded 12 t ha^{-1}, 46% higher than in control using field comparison. Nissanka and Bandara (2004) reported that grain yield was 7.6 t ha^{-1} in the SRI and it was 9%, 20% and 12% greater than the conventional transplanting, and normal and high density broadcasting and further suggested that the higher grain yield production in the SRI farming system might be attributed to the vigorous and healthy growth, development of more productive tillers and leaves ensuring greater resource utilization in the SRI compared to conventional transplanting and broadcasting systems.

Table 8. Influence of variety and cultivation method on yield contributing characters of boro rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Variety				
V_1	7.53	9.58	16.62	42.65
V_2	8.26	7.25	14.78	55.75
LSD $_{(0.05)}$	0.25	ns	ns	4.41
Cultivation method				
P_1	7.96	8.76	16.71	48.31
P_2	7.56	9.03	16.60	46.22
P_3	8.73	9.21	17.92	48.80
P_4	7.23	7.17	12.97	52.47
P_5	8.00	7.90	14.31	50.21
LSD $_{(0.05)}$	0.59	ns	2.09	3.28
CV (%)	7.20	13.31	12.88	6.45

V_1 = BRRI dhan 29, V_2 = Sonarbangla-1, P_1 = Sprouted seeds in line, P_2 = Sprouted seeds broadcast, P_3 = Nursery seedlings, P_4 = SRI and P_5 = Clonal tillers

4.2.7.3. Interaction effect of variety and cultivation method

Interaction between variety and cultivation method played an important role for promoting the yield. Grain yield was significantly influenced by the interaction effect of variety and cultivation method (Appendix X and Figure 19). Among the treatments, the highest grain yield was observed in Nursery seedlings of the inbred variety (8.88 t ha^{-1}), which was similar with sprouted seeds in line (8.83 t ha^{-1}), sprouted seeds broadcast (8.78 t ha^{-1}) and nursery seedlings (8.56 t ha^{-1}) of the hybrid variety. However, Ang et al. (2002) reported that the grain yield of the two-line super hybrid rice variety Liangyoupei 9 with the cultivation methods of SRI reached to 12.15 t ha^{-1}, a yield increase of 21.3% compared with use of conventional methods. Akbar (2004) found highest grain yield in the combination of the inbred variety and 15 day-old seedlings. The lowest yield (6.35 t ha^{-1}) was observed in sprouted seeds broadcast of the inbred variety, which might be due to dense plant population.

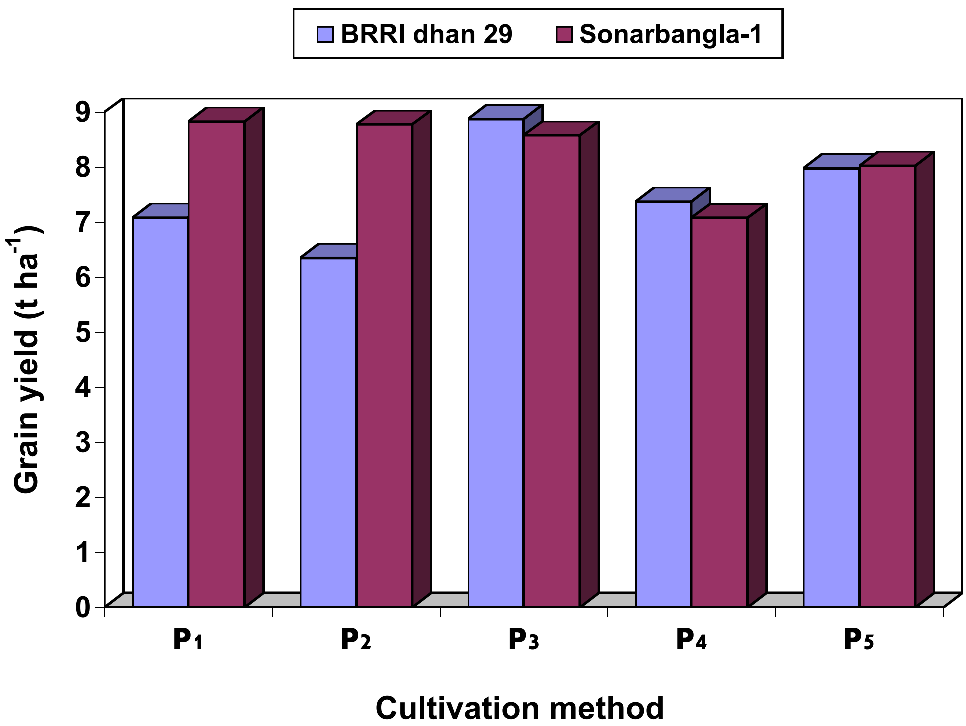

Figure 19. Interaction effect of variety and cultivation method on grain yield at harvest ($LSD_{0.05}$ = 0.83)

4.2.8 Straw yield

4.2.8.1 Effect of variety

Straw yield was not significantly affected by the variety (Appendix X and Table 8) though the higher straw yield (9.58 t ha^{-1}) was obtained from the inbred variety BRRI dhan 29 compared to the other variety Sonarbangla-1 (7.25 t ha^{-1}). The straw yield was 32.1% higher in the inbred variety compared to the hybrid variety. This might be due to the highest plant height and higher number of tillers $hill^{-1}$ of the inbred variety than the hybrid one. Akbar (2004) reported that inbred variety produced higher straw yield than the hybrid varieties.

4.2.8.2 Effect of cultivation method

There was no significant difference observed among the cultivation method in respect of straw yield (Appendix X and Table 8) though the increased straw yield (9.21 t ha^{-1}) was obtained from the nursery seedlings. The probable reasons of increased straw yield in the nursery seedlings might be due to higher total number of tillers m^{-2} and taller plants. The minimum straw yield (7.17 t ha^{-1}) was obtained from the SRI. Baquial et al. (1981) found higher straw yield in transplanted crops than the direct seeded crops. Dwivedi et al. (1996) also found higher straw yield in Nursery seedlings than sprouted seeds. Budhar and Tamilselvan (2001) observed highest straw yield in wet sowing by manual broadcasting followed by direct sowing using a drum seeder and traditional transplanting. Roknuzzaman (1997) found highest straw yield in row planting comparing in haphazard planting. Hossain et al. (2003) reported lowest straw yield in conventional planting methods. Mamin et al. (1999) observed that straw yields were markedly higher in intact mother hills than those of split replanted tillers. In contrast, Mollah et al. (1992) reported reduced straw yield in clonally propagated crops. However, Husain et al. (2003a) found 39% higher straw yield in SRI compared to traditional methods.

4.2.8.3 Interaction effect of variety and cultivation method

Interaction effect between variety and cultivation method was not significant in respect of straw yield (Appendix X and Figure 20) though the maximum straw yield (11.01 t ha^{-1}) was recorded in the sprouted seeds broadcast of the inbred variety which was similar with the sprouted seeds in line of the same variety (10.79 t ha^{-1}). The minimum straw yield (6.51 t ha^{-1}) was found in the SRI of the hybrid variety which was statistically identical with the sprouted seeds in line, sprouted seeds broadcast and clonal tillers of hybrid variety. Akbar (2004) found highest straw yield in the combination of inbred variety and 15 day-old seedlings.

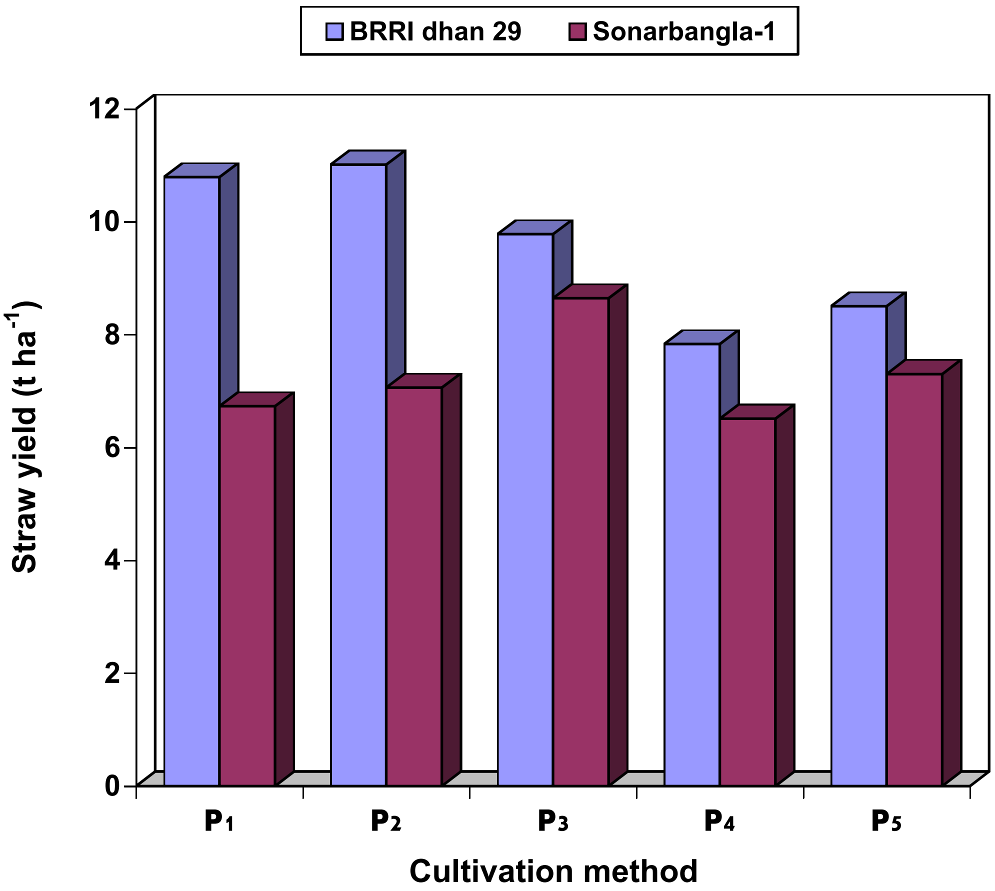

Figure 20. Interaction effect of variety and cultivation method on straw yield at harvest ($LSD_{0.05}$ = ns)

4.2.9 Biological yield

4.2.9.1 Effect of variety

Variety had no effect on biological yield (Appendix X and Table 8) though the maximum biological yield (16.62 t ha^{-1}) was found from the inbred variety BRRI dhan 29 and the lowest biological yield (14.78 t ha^{-1}) was found from the hybrid variety Sonarbangla-1. However, Rahman (2001) reported that Sonarbangla-1 produced higher biological yield compared to the inbred varieties which was supported by Singh and Gangwer (1989).

4.2.9.2 Effect of cultivation method

There was significant difference among the cultivation method observed in respect of biological yield (Appendix X and Table 8). The highest biological yield (17.92 t ha^{-1}) was found from the nursery seedlings which was similar with the sprouted seeds broadcast (16.71) and sprouted seeds in line (16.60). Nursery seedlings produced highest grain yield and straw yield which resulted in the highest biological yield. However, Bari (2004) found significantly higher biological yield from direct wet seeded line sowing method than those from transplanted method. Uninhibited growth of direct seeded rice during the vegetative stage led to superior biological yield at maturity (Garcia et al., 1995). Rahman (2001) observed highest biological yield in the intact crop comparing to the clonally propagated crops. The lowest biological yield (12.97 t ha^{-1}) was found from the SRI. This might be due to the wider spacing which is associated with the lower dry matter production. Though, Haque (2002) and Hossain et al. (2003) found highest biological yield in the SRI compared to the conventional planting method. Haque (2002) also obtained the highest biological yield in the SRI with the spacing of 30cm × 30cm.

4.2.9.3 Interaction effect of variety and cultivation method

Interaction effect between variety and cultivation method was significant in respect of biological yield (Appendix X and Figure 21). The highest biological yield (18.65 t ha^{-1}) was recorded in the nursery seedlings of the inbred variety and the lowest biological yield (11.38 t ha^{-1}) in the SRI of the hybrid variety. Akbar (2004) found highest biological yield in combination of the inbred variety and 15 day-old seedlings.

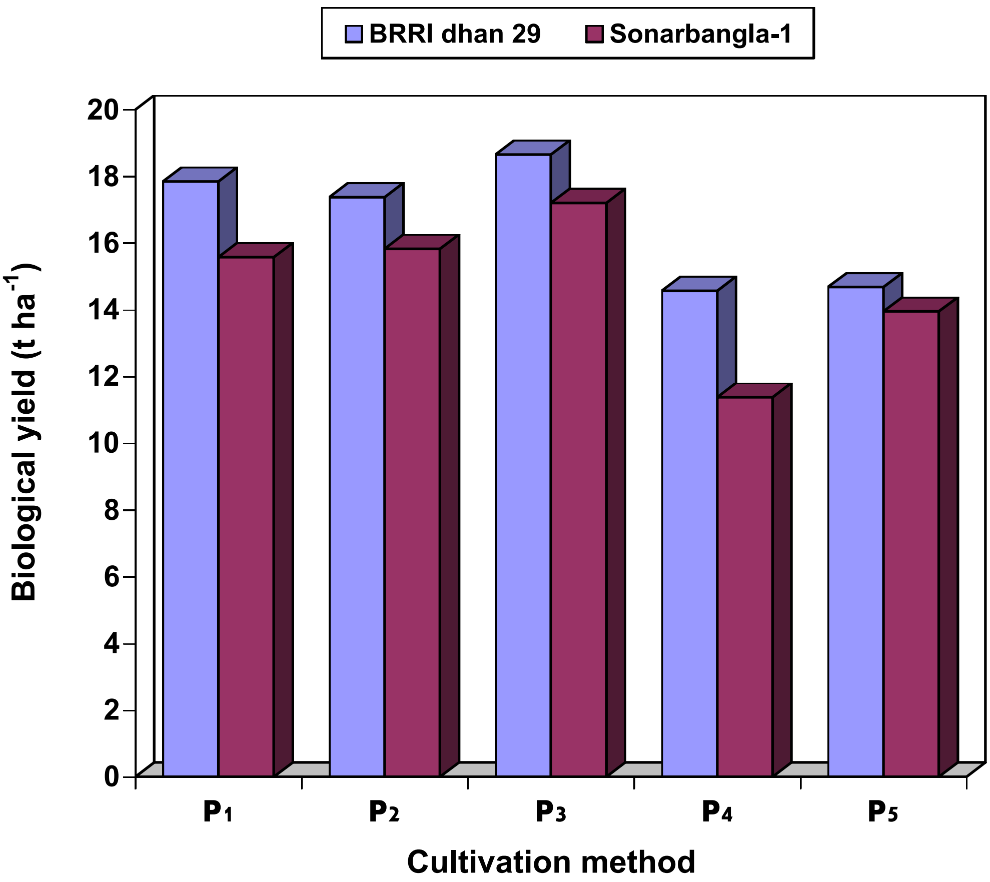

Figure 21. Interaction effect of variety and cultivation method on biological yield at harvest ($LSD_{0.05}$ = 2.95)

4.2.10 Harvest index

4.2.10.1 Effect of variety

Harvest index was significantly influenced by the variety (Appendix X and Table 8). The highest harvest index (55.75) was found from the hybrid variety Sonarbangla-1 and the lowest harvest index (42.65) was found from the inbred variety BRRI dhan 29. The harvest index was 30.72% higher in the hybrid variety compared to the inbred variety. Higher grain yield and lower biological yield was the probable reason for the maximum harvest index in Sonarbangla-1. Muir (1998) reported that hybrid varieties generally have a higher harvest index than do conventional varieties. Rahman (2001) also observed highest harvest index in Sonarbangla-1 than the inbred varieties. Similar result was also reported by Cui et al. (2000).

4.2.10.2 Effect of cultivation method

Cultivation method produced significant differences in respect of harvest index (Appendix X and Table 8). The highest harvest index (52.47) was found from the SRI which was similar to the clonal tillers (50.21). Stoop (2005) and Hossain et al. (2003) also found higher harvest index in SRI comparing the conventional method, though, Barison (2003) found no difference for the same. Biswas (2001) observed higher harvest index in clonal tillers than transplanted crop. The lowest harvest index (46.22) was found from the sprouted seeds broadcast. Dwivedi et al. (1996) observed higher harvest index in transplanting than sprouted seeds crop but Sarkar et al. (2003) disagree with this finding and reported higher harvest index in direct seeded crops than the nursery seedlings. Roknuzzaman (1997) found highest harvest index in haphazard planting compared to row planting.

4.2.10.3 Interaction effect of variety and cultivation method

Interaction effect between variety and cultivation method was significant in respect of harvest index (Appendix X and Figure 22). The highest harvest index (62.20) was recorded in the SRI of the hybrid variety followed by the sprouted seeds in line (56.74) of the same variety. The lowest harvest index (37.03) was found in the sprouted seeds broadcast of the inbred variety.

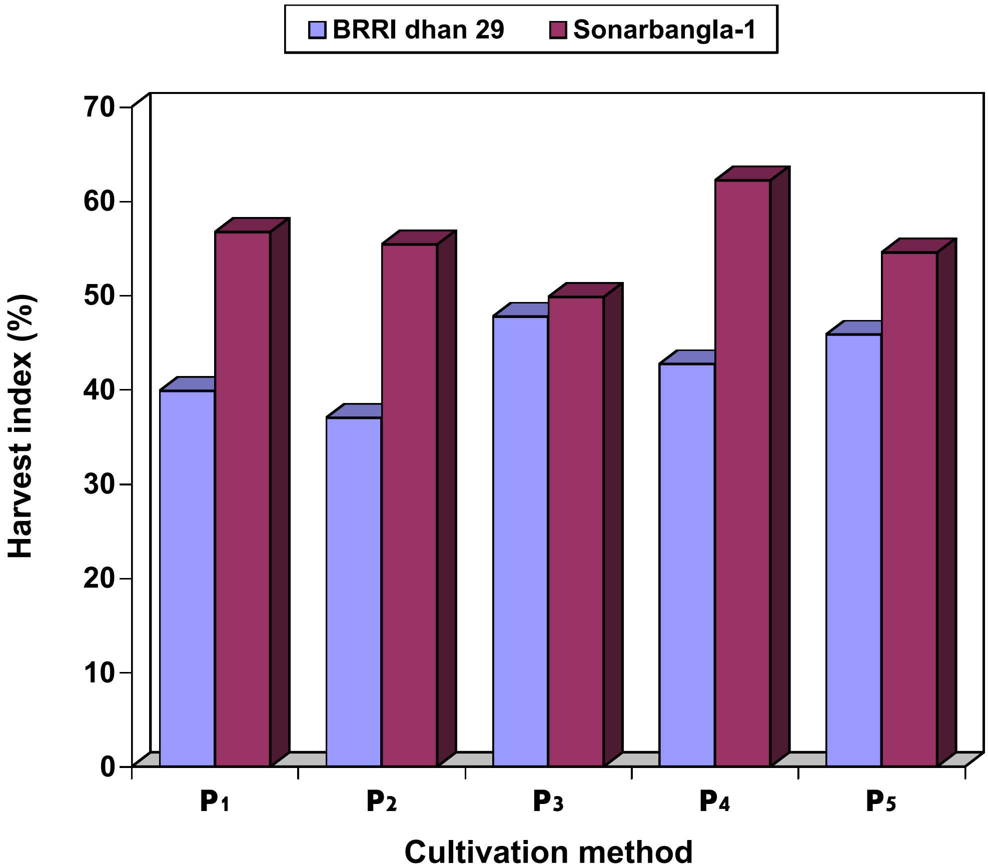

Figure 22. Interaction effect of variety and cultivation method on harvest index of boro rice ($LSD_{0.05}$ = 4.63)

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from December 2005 to May 2006 to study the performance of different cultivation methods on hybrid and inbred rice in boro season under the Modhupur Tract (AEZ-28). The experiment was comprised with two varieties viz. inbred variety BRRI dhan 29 (V_1) and hybrid variety Sonarbangla-1 (V_2) and five planting techniques viz. sprouted seeds in line (P_1), sprouted seeds broadcast (P_2), nursery seedlings (P_3), SRI (P_4) and clonal tillers (P_5). The experiment was laid out in a split-plot design with four replications having varieties in the main plots and cultivation methods in the sub-plots.

The data on crop growth parameters like plant height, number of tillers hill^{-1}, leaf area index, dry matter and time of flowering and maturity were recorded at different growth stages. Yield parameters like number of effective tillers m^{-2}, panicle length, number of grains panicle^{-1}, filled and unfilled grains panicle^{-1}, 1000-grains weight, grain and straw yield were recorded after harvest. Data were analyzed using MSTAT package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Results showed that variety had significant effect on growth parameters except panicle length, total grains panicle^{-1}, straw yield and biological yield. The rapid increase of plant height and dry weight was observed from 30 days to 70 days of growth stages which was higher in the hybrid variety compared to the inbred variety, however, at harvest it was higher in the inbred variety BRRI dhan 29. The higher number of tillers and LAI at all the growth stages and at harvest was found in BRRI dhan 29. Again, BRRI dhan 29 needed longer duration for flowering and maturity compared to the hybrid variety Sonarbangla-1. BRRI dhan 29 produced maximum number of effective tillers m^{-2} and longer panicle compare to Sonarbangla-1. The higher number of grains $panicle^{-1}$ (243.95) was obtained from BRRI dhan 29 and the lower number of grains $panicle^{-1}$ (235.60) was obtained from Sonarbangla-1. However, the maximum number of filled grains $panicle^{-1}$ (209.28) was counted in Sonarbangla-1 and the minimum number (193.45) was obtained from BRRI dhan 29. The higher weight of 1000-grains (28.32g) was obtained from Sonarbangla-1 and the lower weight of 1000-grains (23.04g) was obtained from BRRI dhan 29. Sonarbangla-1 produced the higher grain yield (8.26 t ha^{-1}), the lower straw yield (7.25 t ha^{-1}) and the lower biological yield (14.78 t ha^{-1}), whereas, BRRI dhan 29 produced the lower grain yield (7.53 t ha^{-1}), the higher straw yield (9.58 t ha^{-1}) and the higher biological yield (16.62 t ha^{-1}). The grain yield increase was found 9.69% higher in Sonarbangla-1 than BRRI dhan 29. The maximum harvest index (55.75) was found from Sonarbangla-1 and the lower harvest index (42.65) was found from BRRI dhan 29. The harvest index was 30.72% higher in Sonarbangla-1 compared to BRRI dhan 29.

Cultivation method also significantly influenced all growth and yield attributes except unfilled grains $panicle^{-1}$, 1000-grains weight and straw yield. The results revealed that the clonal tillers produced the highest plant height at all the growth stages, however, at harvest the highest plant height was found in the SRI. In case of number of tillers $hill^{-1}$, the SRI secured the highest position at 50 and 70 days of crop stage and at harvest, however, it contributed the lowest effective tillers m^{-2}. The maximum effective tillers m^{-2} was observed in the sprouted seeds broadcast. At 50 and 70 days of crop stage and at harvest, the maximum leaf area index was obtained from the sprouted seeds broadcast. The clonal tillers produced maximum dry weight at 30, 50 and 70 days of crop stage, however the nursery seedlings produced maximum dry weight at harvest. The clonal tillers needed the longest duration for flowering and maturity, whereas, the lowest duration for flowering and maturity was observed in the sprouted seeds in line. The highest number of grains panicle^{-1} (264.74) and filled grains panicle^{-1} (239.2) was obtained from the nursery seedlings and the lowest number of grains panicle^{-1} (221.03) and filled grains panicle^{-1} (180.0) was recorded from the sprouted seeds in line. The maximum number of unfilled grains panicle^{-1} (42.51) was counted in the sprouted seeds broadcast and the minimum number of unfilled grains panicle^{-1} (30.80) was counted in the nursery seedlings. The highest weight of 1000-grains (26.61 g) was obtained from the SRI whereas the lowest weight of 1000-grains (24.04 g) was obtained from the sprouted seeds broadcast. The nursery seedling produced the significantly highest grain yield (8.73 t ha^{-1}) than the other methods and the lowest grain yield (7.23 t ha^{-1}) was obtained from the SRI. The nursery seedlings produced the highest straw yield (9.21 t ha^{-1}) and biological yield (17.92 t ha^{-1}), however, the lowest straw yield (7.19 t ha^{-1}) and biological yield (12.97 t ha^{-1}) were obtained from the SRI. The highest harvest index (52.47) was found from the SRI and the lowest harvest index (46.22) was found from the sprouted seeds broadcast.

Interaction effect of variety and cultivation method also significantly affected growth as well as yield and yield contributing characters except panicle length and weight of 1000-grains. The tallest plant height was initially found in the clonal tillers of Sonarbangla-1 but at later tallest plant height was observed in the SRI of BRRI dhan 29. In the later stages, the maximum number of tillers hill^{-1} was obtained from the SRI of BRRI dhan 29 and the highest leaf area index was observed in the sprouted seeds broadcast of BRRI dhan 29. At harvest, the nursery seedlings of BRRI dhan 29 produced highest dry weight. The clonal tillers of BRRI dhan 29 needed the longest duration for flowering and maturity, whereas, the lowest duration for flowering and maturity was observed in the sprouted seeds broadcast and sprouted seeds in line of Sonarbangla-1 respectively.

The maximum number of effective tillers m^{-2} (594.0) was obtained from the sprouted seeds broadcast of BRRI dhan 29, however the lowest number of effective tillers m^{-2} (196.5) was obtained from the clonal tillers of Sonarbangla-1. The maximum number of grains $panicle^{-1}$ (266.95) was obtained from the nursery seedlings of Sonarbangla-1 and the minimum number grains $panicle^{-1}$ (218.48) was obtained from the sprouted seeds in line of Sonarbangla-1. The highest number of filled grains $panicle^{-1}$ (255.5) was obtained from the clonal tillers of Sonarbangla-1 and the lowest number was obtained from the sprouted seeds in line of BRRI dhan 29. The maximum number of unfilled grains $panicle^{-1}$ (42.51) was counted in the sprouted seeds broadcast and the minimum number of unfilled grains $panicle^{-1}$ (30.80) was counted in the nursery seedlings. The highest weight of 1000-grains (29.49 g) was obtained from the SRI of Sonarbangla-1, which was similar with the clonal tillers of the same variety. The lowest weight of 1000-grains (22.09 g) was obtained from the sprouted seeds in line of BRRI dhan 29. Among the treatments, the highest grain yield was observed in nursery seedling of BRRI dhan 29 (8.88 t ha^{-1}) that was similar with sprouted seeds broadcast or in line along with the nursery seedlings of the hybrid variety and the lowest yield (6.35 t ha^{-1}) was observed in sprouted seeds broadcast of BRRI dhan 29. The highest straw yield (11.01 t ha^{-1}) was recorded in the sprouted seeds broadcast of BRRI dhan 29 and the lowest straw yield (6.51 t ha^{-1}) was found in the SRI of Sonarbangla-1. The highest biological yield (18.65 t ha^{-1}) was recorded in the nursery seedlings of BRRI dhan 29 and the lowest biological yield (11.38 t ha^{-1}) in the SRI of Sonarbangla-1. The highest harvest index (62.20) was recorded in the SRI of Sonarbangla-1 and the lowest harvest index (37.03) in the sprouted seeds broadcast of BRRI dhan 29.

Based on the results of the present study, the following conclusions may be drawn-

- The hybrid variety Sonarbangla-1 showed higher yield potential than the inbred variety

- Though the highest yield was observed in the nursery seedlings, other treatments like clonal tillers, sprouted seeds sown in line or broadcast also showed higher yield which is important in socio economic aspect

- Although SRI failed to produce better yield, it provided an early harvest and it needs further research to utilize its maximum potentiality

- Sprouted seeds sown in line or broadcast showed similar yield potentiality that encouraged practicing sprouted seeds broadcast rather depending only on drum seeder (sprouted seeds in line) technique.

However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones.

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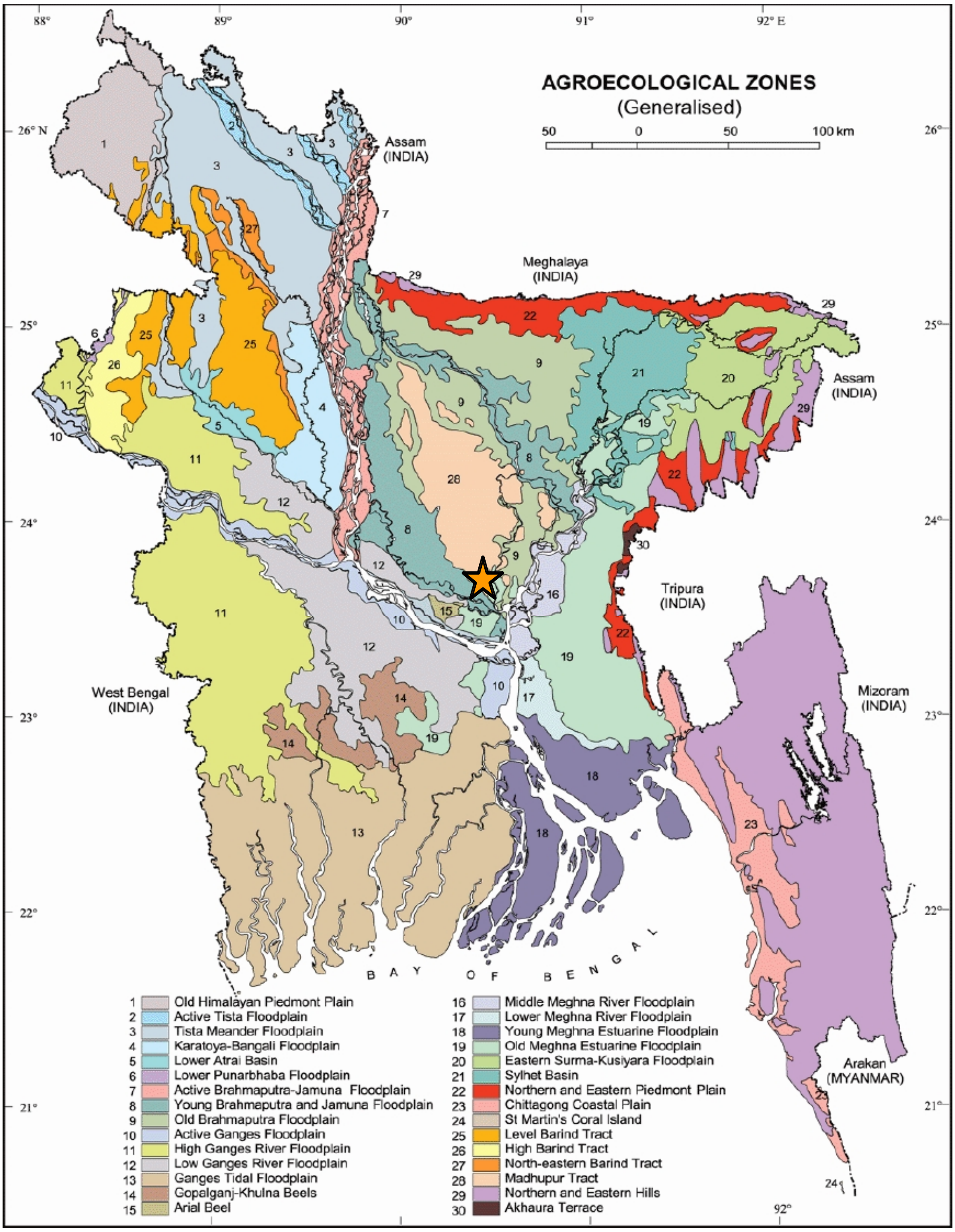
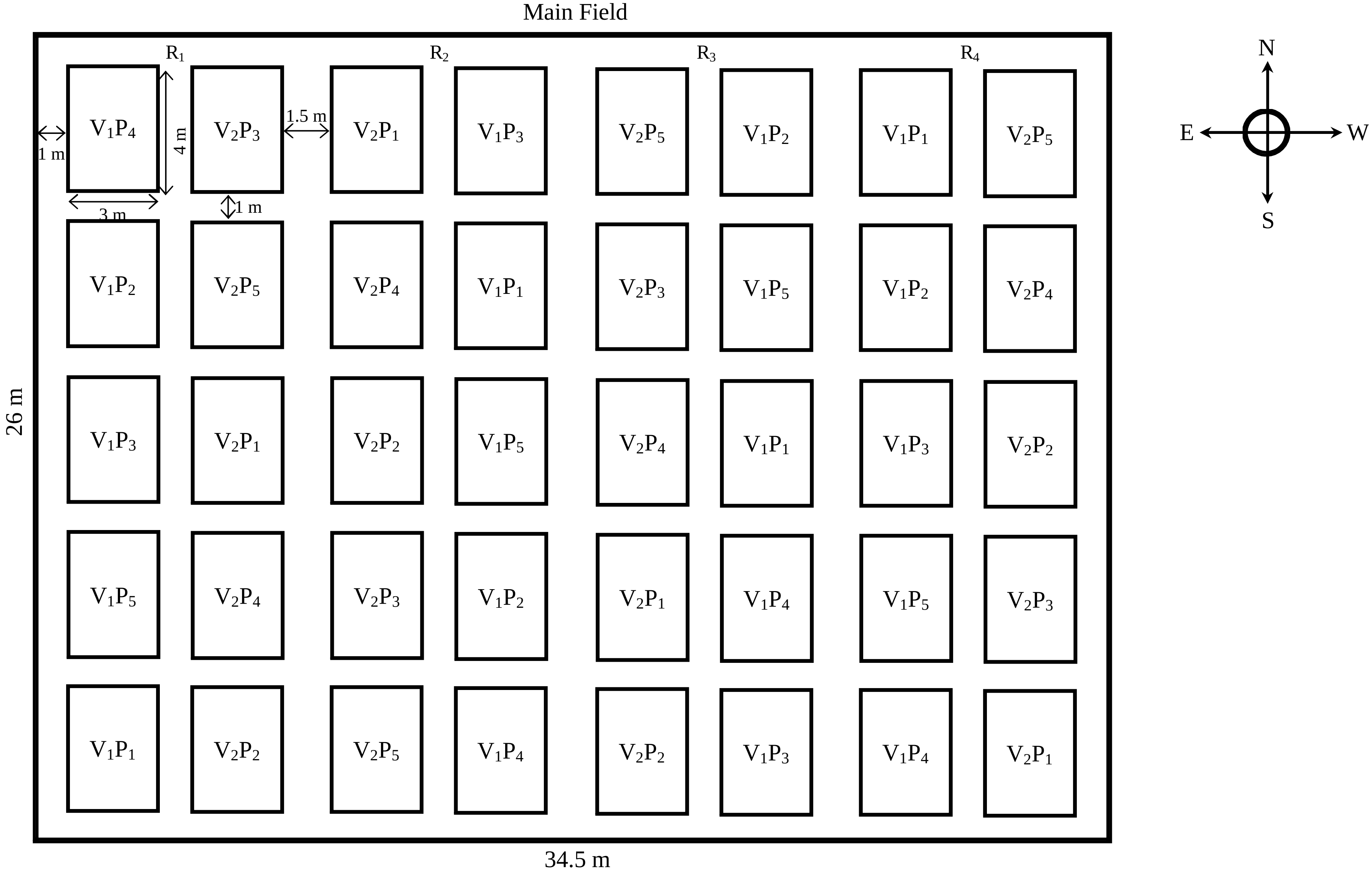
APPENDICES

Appendix I. Map showing the experimental sites under study

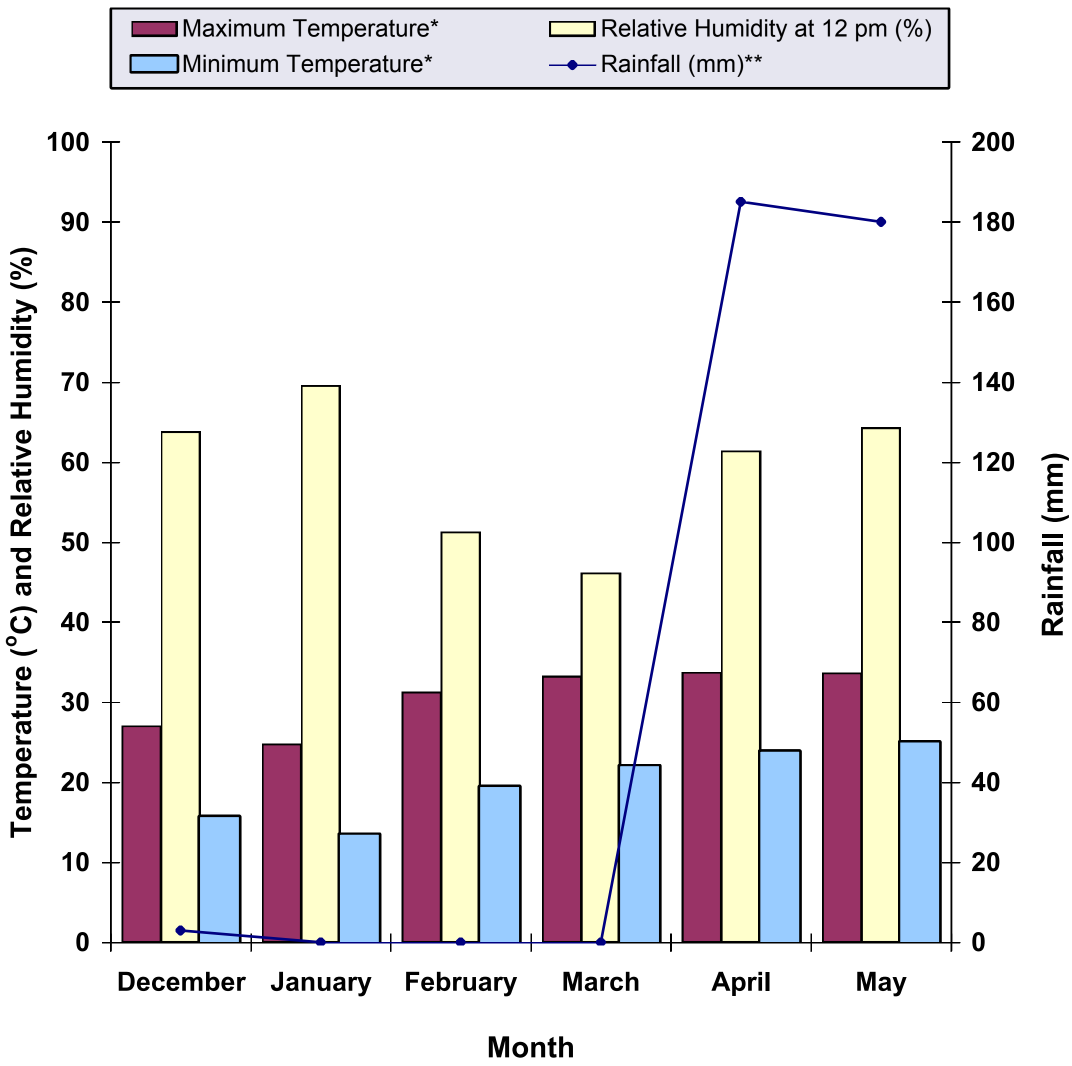


☆ The experimental site under study

Appendix II. Layout of experimental field



Appendix III. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from December 2005 to May 2006 [Source: Bangladesh Meteorological Department, Agargoan, Dhaka-1212]



* Monthly average

** Monthly total

Appendix IV. Physiochemical properties of the soil

Soil sample	pH	Organic matter (%)	Exchangeable potassium (ml/100 g soil)	Total Nitrogen (%)	Available Phosphorus (ppm)
V_1P_1	6.1	1.34	0.12	0.067	22.9
V_1P_2	6.0	1.29	0.13	0.065	22.9
V_1P_3	6.1	1.46	0.24	0.073	27.9
V_1P_4	6.2	1.30	0.10	0.065	23.5
V_1P_5	6.1	1.27	0.09	0.064	26.6
V_2P_1	6.3	1.30	0.08	0.065	26.9
V_2P_2	6.1	1.21	0.10	0.061	26.1
V_2P_3	6.2	1.22	0.09	0.061	22.2
V_2P_4	6.3	1.25	0.11	0.063	28.2
V_2P_5	6.2	1.22	0.09	0.061	24.8
Mean	6.16	1.29	0.12	0.065	25.2

Appendix V. Mean square values for plant height of boro rice at different days after sowing/transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after sowing/transplanting			
		30	50	70	At harvest
Replication	3	10.38	5.06	1.90	0.69
Variety	1	427.45**	991.72**	145.41*	156.18*
Error (a)	3	0.34	11.27	6.50	6.29
Cultivation method	4	2995.57**	1780.23**	301.75**	50.76*
Variety × cultivation method	4	69.24*	95.39**	157.84**	20.05
Error (b)	24	16.62	19.24	11.34	15.26

* Significant at 5% level

** Significant at 1% level

Appendix VI. Mean square values for tiller numbers hill^{-1} at different days after sowing/transplanting and tiller mortality of boro rice

Sources of variation	Degrees of freedom	Mean square values at different days after sowing/transplanting				
		30	50	70	At harvest	% tiller mortality
Replication	3	0.54	1.86	0.84	0.73	76.98
Variety	1	15.38**	431.65**	390.63**	290.52**	106.95
Error (a)	3	0.10	0.57	1.61	0.86	51.41
Cultivation method	4	150.83**	2299.87**	2354.5**	2020.60**	1049.1**
Variety × cultivation method	4	14.26**	250.81**	225.68**	167.13**	576.52**
Error (b)	24	1.03	1.80	2.68	1.52	797.15

* Significant at 5% level

** Significant at 1% level

Appendix VII. Mean square values for leaf area index of boro rice at different days after sowing/transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after sowing/transplanting			
		30	50	70	At harvest
Replication	3	0.008	1.08	0.08	0.004
Variety	1	0.053	0.02**	31.29**	0.085**
Error (a)	3	0.006	2.11	0.47	0.001
Cultivation method	4	12.158**	17.11**	44.64**	0.168**
Variety × cultivation method	4	0.259**	2.83**	9.26**	0.003**
Error (b)	24	0.024	0.50	0.57	0.001

* Significant at 5% level

** Significant at 1% level

Appendix VIII. Mean square values for total dry matter weight of boro rice at different days after sowing/transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after sowing/transplanting			
		30	50	70	At harvest
Replication	3	206.79	12713.66	3110.40	18881.67
Variety	1	8785.30*	30319.34	78794.01	682857.95*
Error (a)	3	589.05	3579.97	12438.60	52251.70
Cultivation method	4	138583.58**	392090.4**	342254.0**	179612.5**
Variety × cultivation method	4	3616.30**	5878.12	24106.64	95619.08**
Error (b)	24	483.01	5527.17	17573.85	17549.08

* Significant at 5% level

** Significant at 1% level

Appendix IX. Mean square values for dry matter weight of different parts of boro rice at harvest

Sources of variation	Degrees of freedom	Mean square values				
		Stem	Leaf	Leaf sheath	Panicle	Grain
Replication	3	1732.8	842.9	834.5	33.7	1569.6
Variety	1	41465.9*	117940.7*	144874.9*	956.3**	34575.6*
Error (a)	3	2779.6	4093.8	6447.4	15.1	1638.4
Cultivation method	4	11688.6*	20910.5**	9027.1*	1152.1**	23191.1**
Variety × cultivation method	4	14024.0*	5049.9	6196.4	196.5	32532.3**
Error (b)	24	3461.0	2296.8	2850.0	147.3	1743.3

* Significant at 5% level

** Significant at 1% level

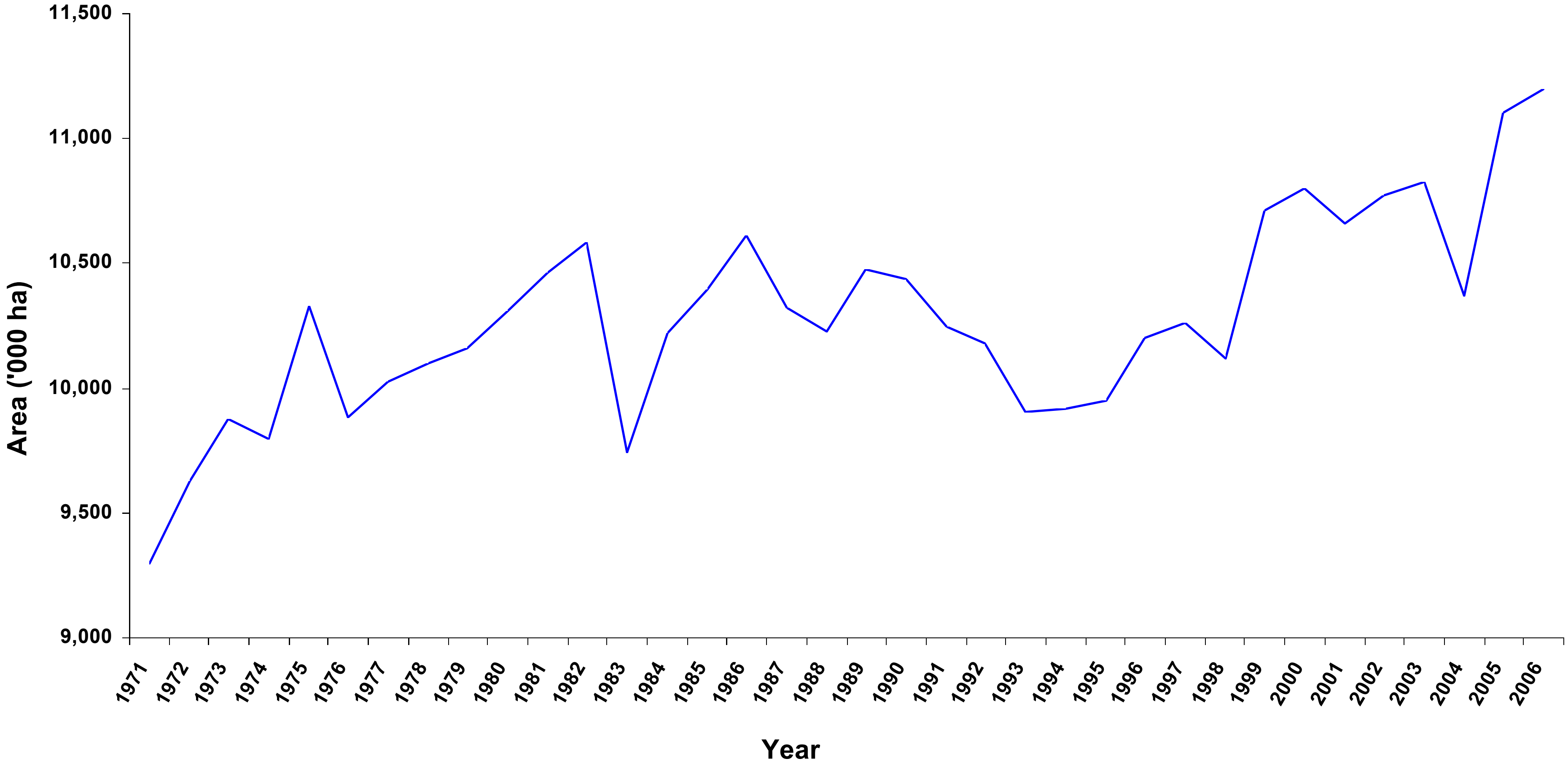
Appendix X. Summery of analysis of variance for crop characters, yield and yield components of BRII dhan 29 and Sonarbangla-1 at harvest

Source of Variation	Degrees of freedom	Mean square values												
		Duration of flowering	Duration of maturity	Effective tillers m^{-2} (no.)	Ineffective tillers m^{-2} (no.)	Panicle length (cm)	Total grains/ panicle (no.)	Filled grains/ panicle (no.)	Unfilled grains/ panicle (no.)	1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biolo-gical yield (t ha^{-1})	Harvest index (%)
Replication	3	7.36	2.52	1931.70	847.41	0.909	330.14	582.409	80.978	4.860	0.19	1.70	19.75	5.30
Variety	1	3980.03**	2992.90**	125372.81**	465.12**	1.299	697.31	2505.89*	4884.32**	278.678**	5.23**	54.50	33.80	1717.28**
Error (a)	3	0.03	0.10	485.14	488.95	0.53	85.56	106.32	61.94	4.30	0.05	10.07	28.37	16.05
Cultivation method	4	1877.98**	1654.10**	108777.15**	9681.91**	0.720**	2476.95**	4501.804**	192.487	10.219	2.53**	5.91	32.31**	43.07**
Variety × cultivation method	4	57.78**	58.90**	218.04**	1513.85**	2.276	454.11**	299.358**	169.190	2.644**	3.24**	4.66	1.75**	111.58**
Error (b)	24	0.03	0.10	583.60	265.94	0.903	538.01	381.414	116.866	5.299	0.32	3.85	4.09	10.08

* Significant at 5% level

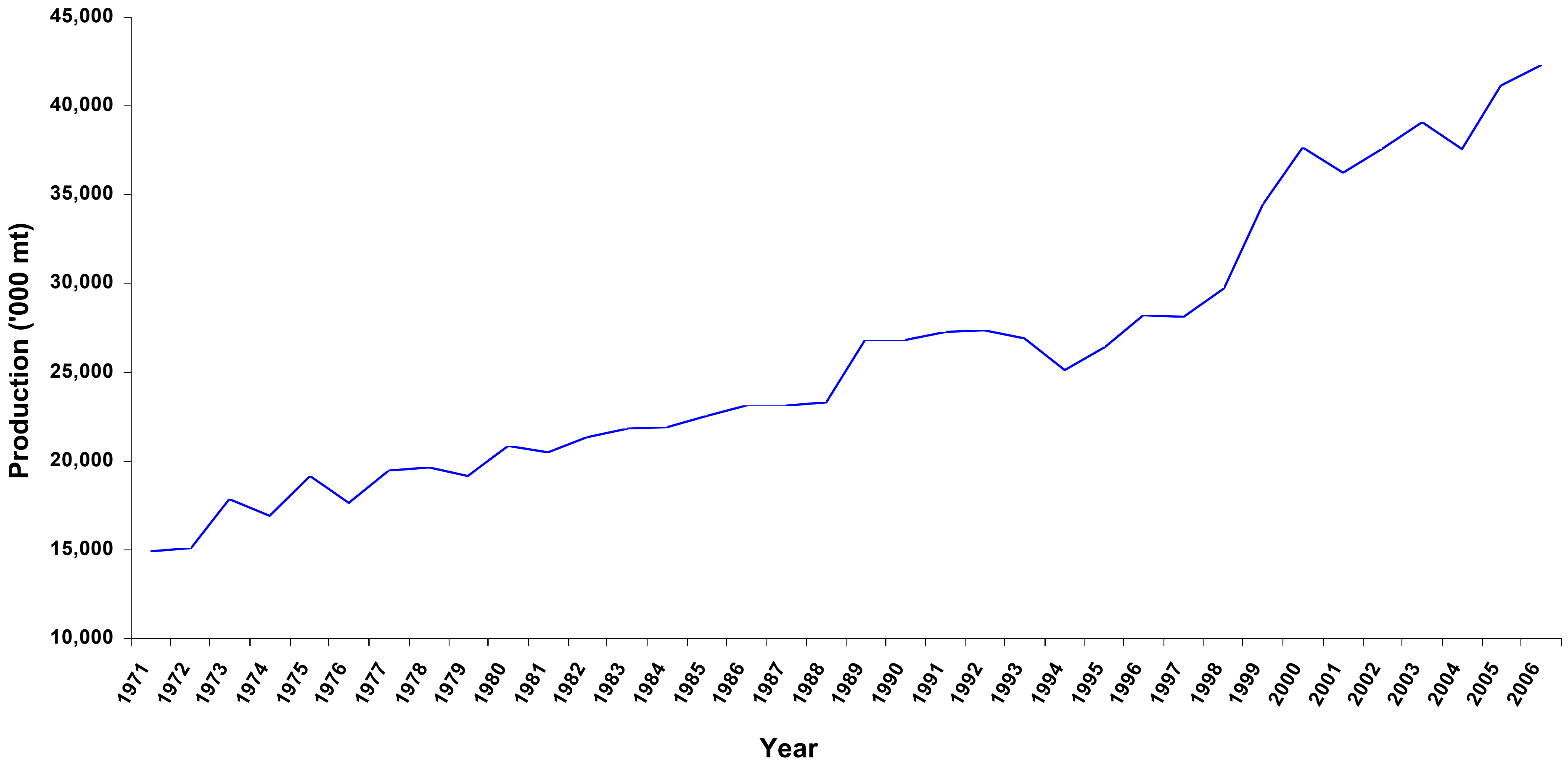
** Significant at 1% level

Appendix XI. Area under rice cultivation in Bangladesh (1971-2006)



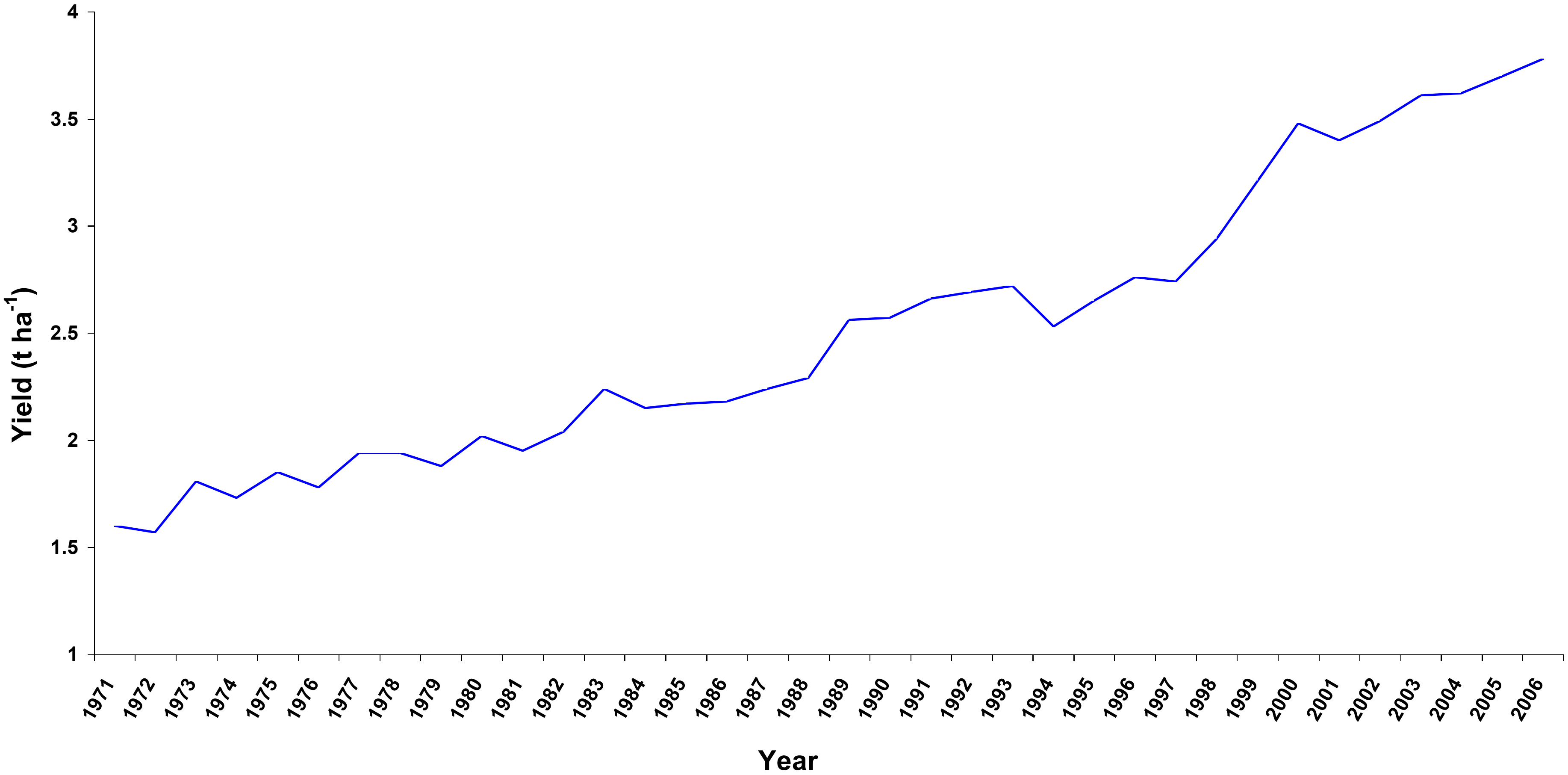
Source: Anon. (2006)

Appendix XII. Production of rice in Bangladesh (1971-2006)



Source: Anon. (2006)

Appendix XIII. Average yield of rice in Bangladesh (1971-2006)



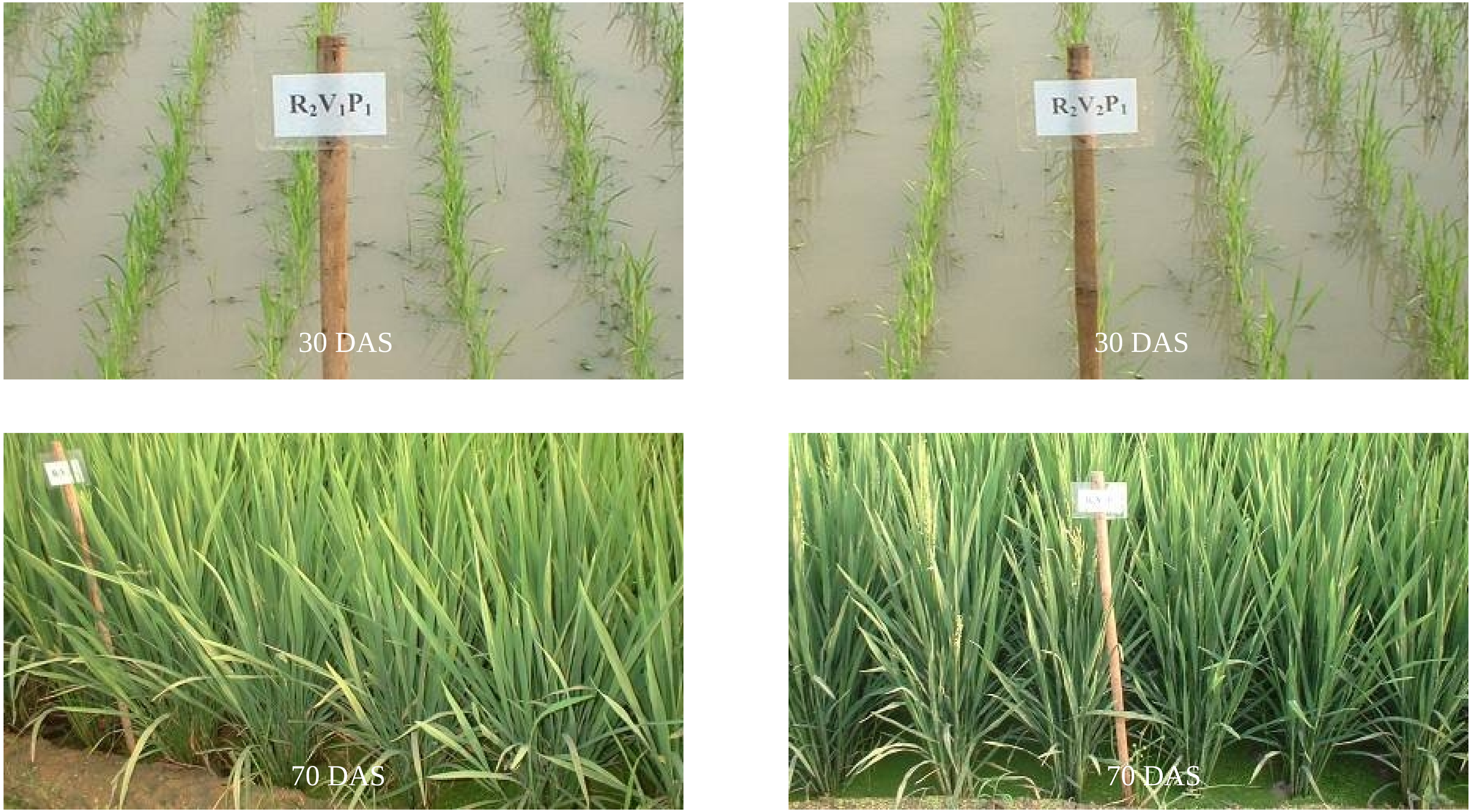
Source: FAO (2006)

Plate 1. A SRI plant having 74 tillers

Plate 2. A view of tiller production hill^{-1} of two rice varieties at 50 days after transplanting in SRI

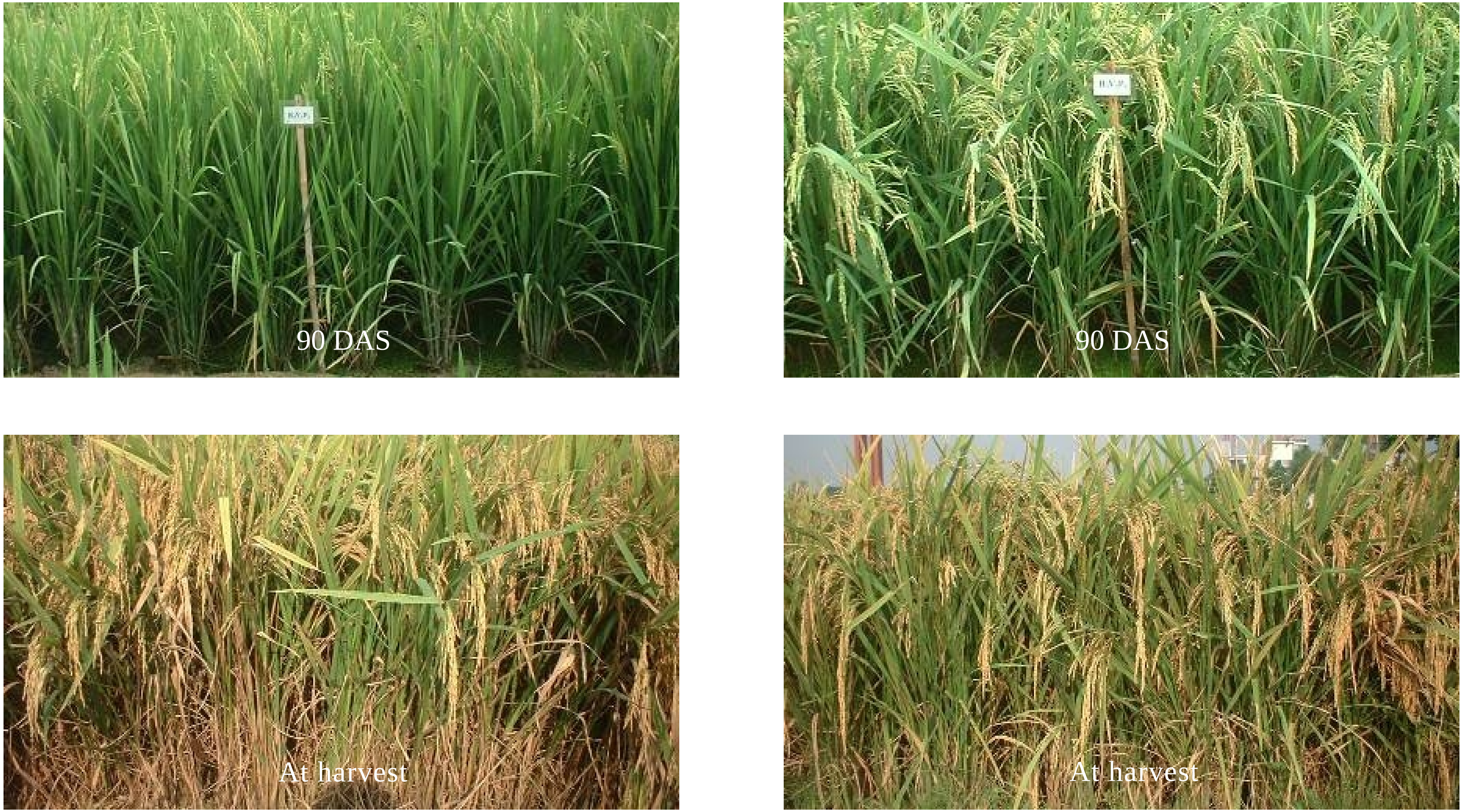
Plate 3. A view of tiller production hill^{-1} of two rice varieties at 70 days after transplanting in SRI

Plate 4. A view of tiller production hill^{-1} of two rice varieties at 90 days after transplanting in SRI



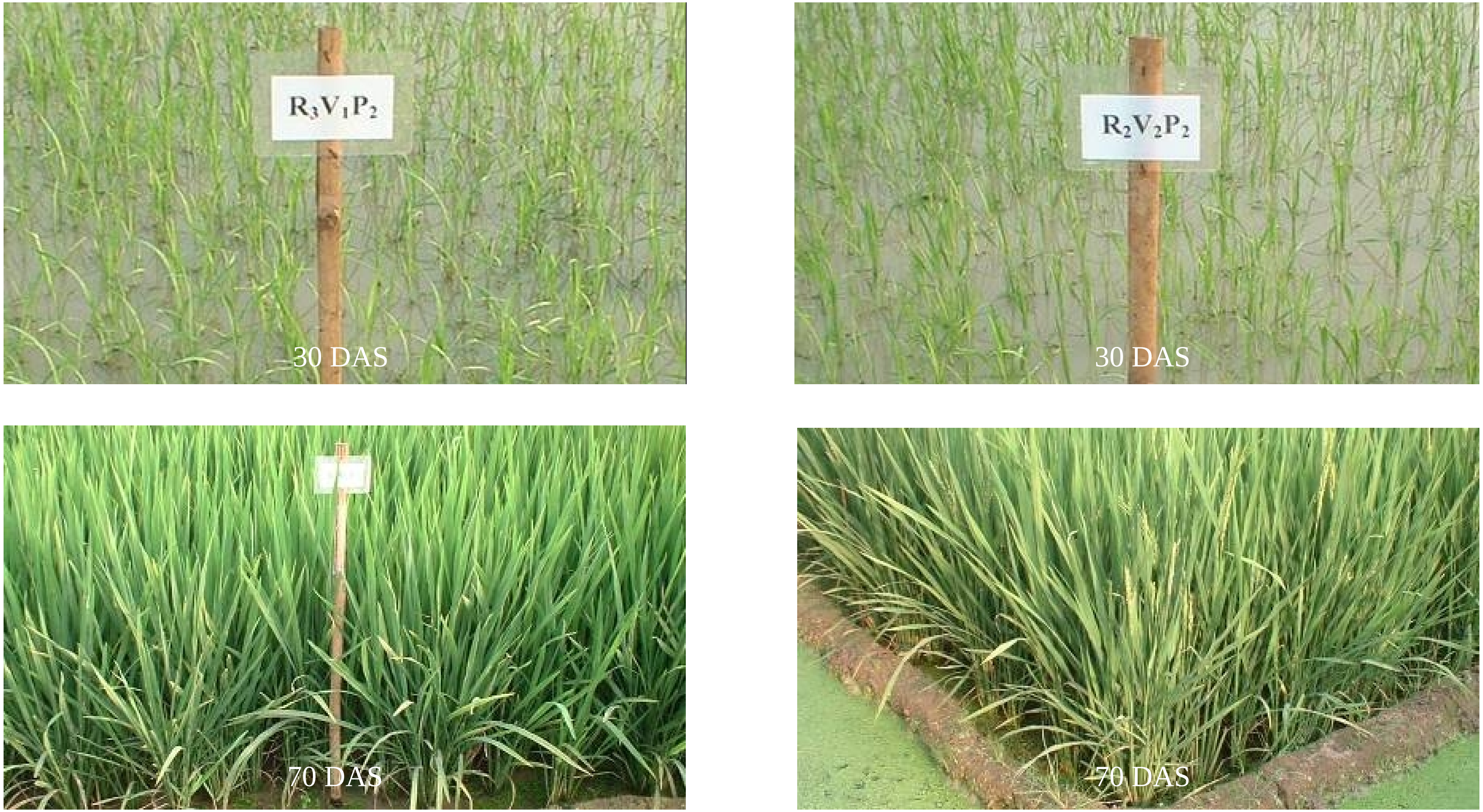
BRRI dhan 29 Sonarbangla-1

Plate 5: Sprouted seeds in line



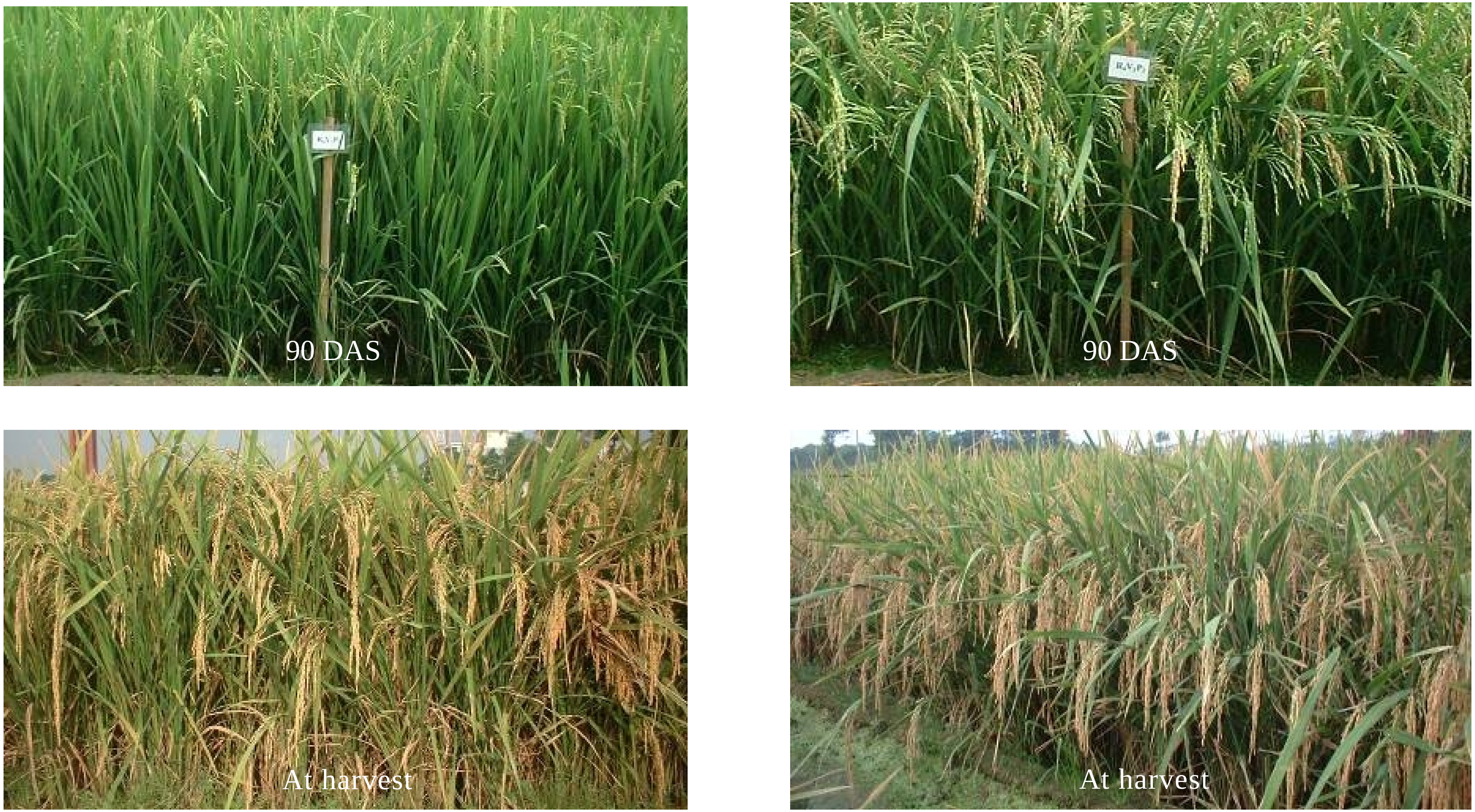
BRRI dhan 29 Sonarbangla-1

Plate 5: Continued



BRRI dhan 29 Sonarbangla-1

Plate 6: Sprouted seeds broadcast

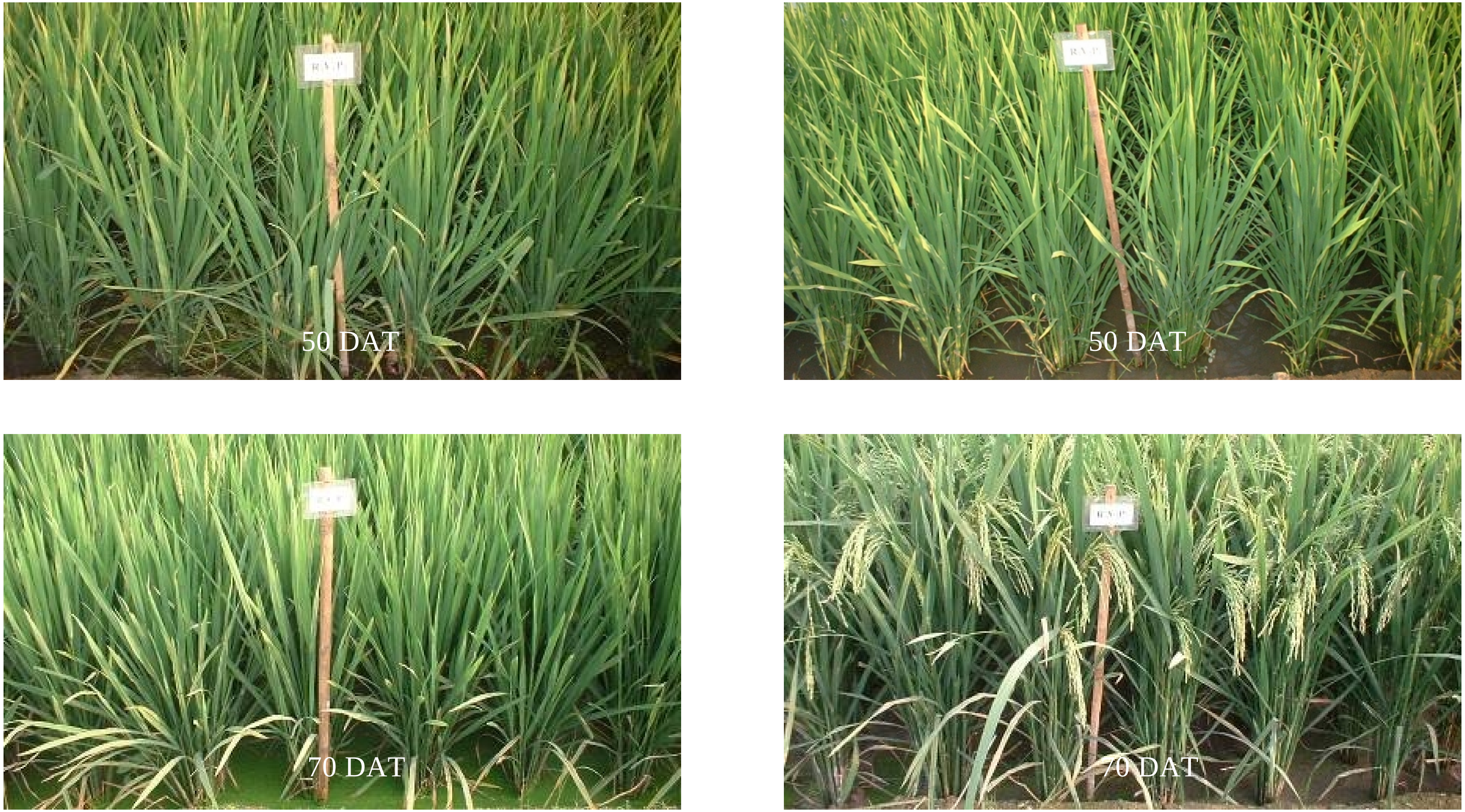


BRRI dhan 29 | Sonarbangla-1

Plate 6: Continued

BRRI dhan 29 | Sonarbangla-1

Plate 7: Nursery seedlings



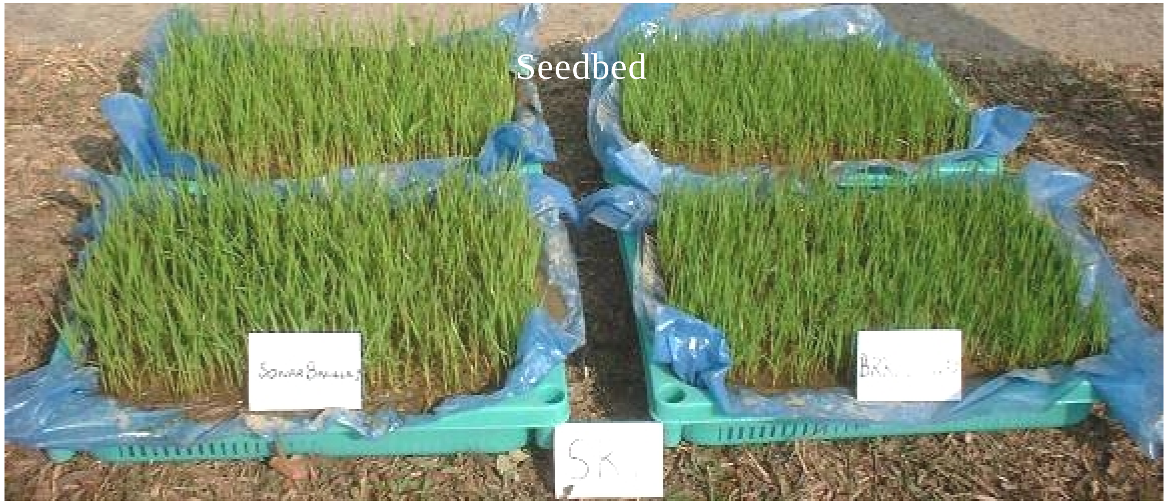
BRRI dhan 29 Sonarbangla-1

Plate 7: Continued

BRRI dhan 29

Sonarbangla-1

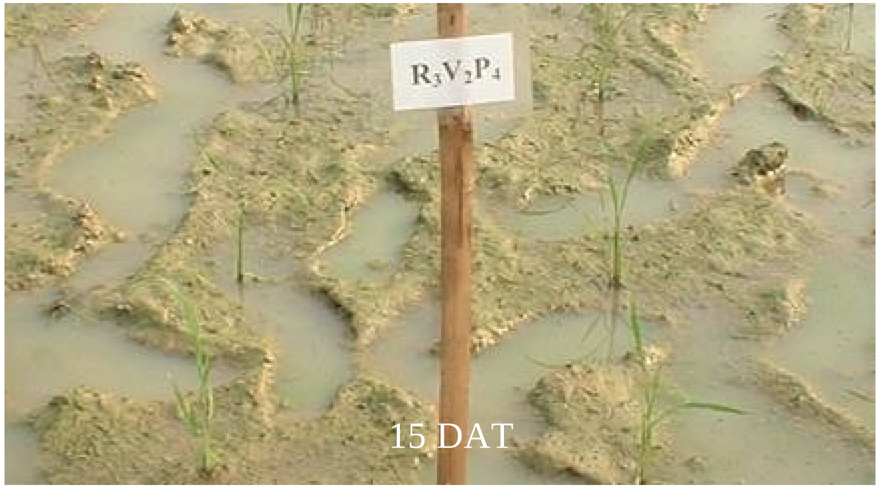
Plate 7: Continued



BRRI dhan 29

Sonarbangla-1

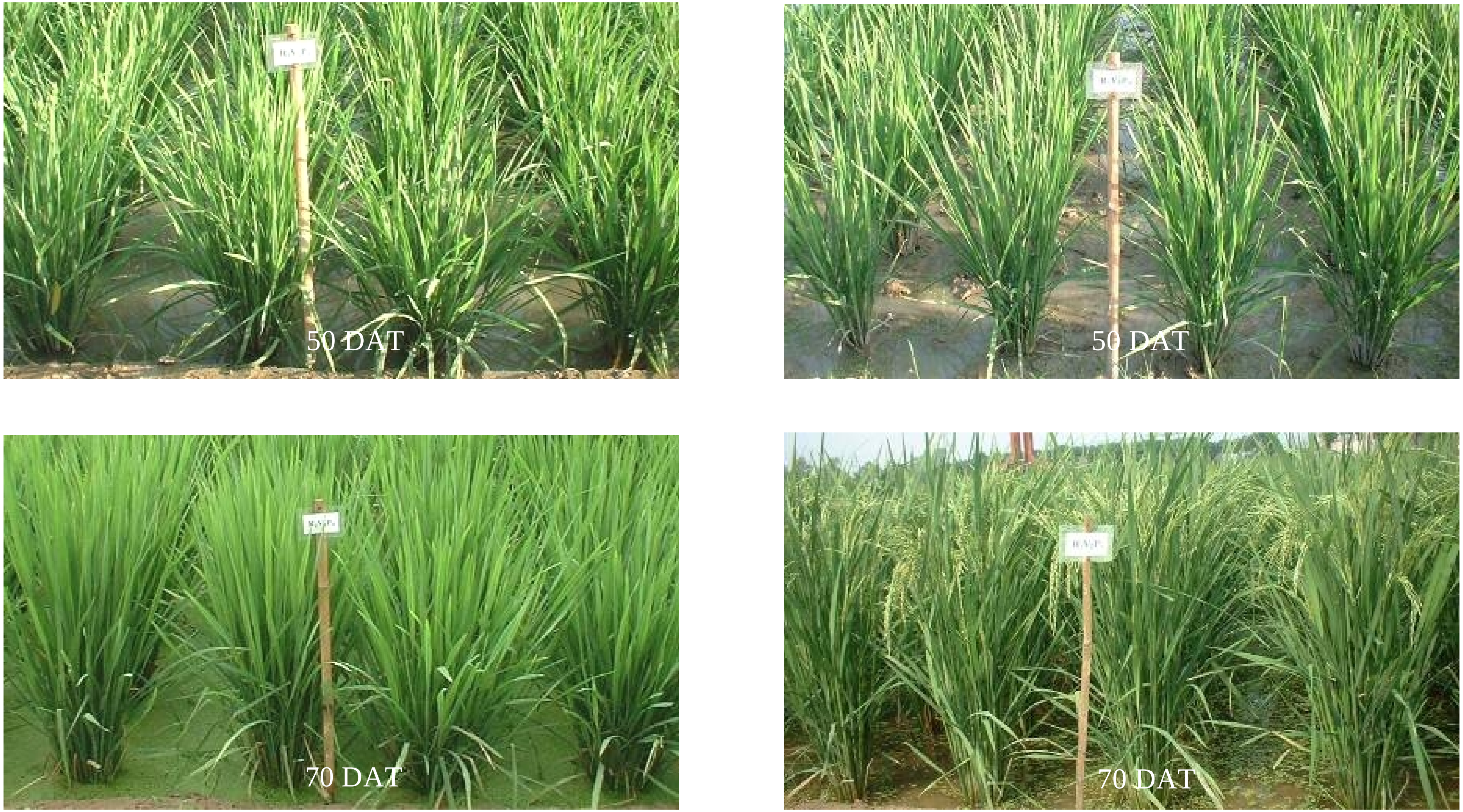
Plate 8: SRI



BRRI dhan 29

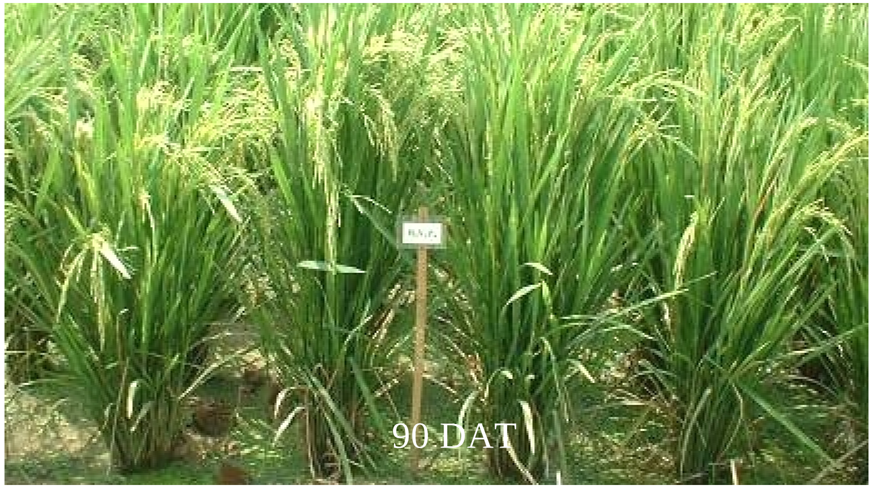
Sonarbangla-1

Plate 8: Continued



BRRI dhan 29 Sonarbangla-1

Plate 8: Continued



BRRI dhan 29

Sonarbangla-1

Plate 8: Continued

BRRI dhan 29

Sonarbangla-1

Plate 9: Clonal tillers

BRRI dhan 29

Sonarbangla-1

Plate 9: Continued