GROWTH AND YIELD OF BORO RICE AS AFFECTED BY SEEDLING AGE AND PLANTING GEOMETRY UNDER SYSTEM OF RICE INTENSIFICATION

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TO

MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled **"Growth and Yield of Boro Rice as Affected by Seedling Age and Planting Geometry Under System of Rice Intensification"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of *bonafide* research work carried out by **Sudip Chakrabortty**, Registration number: **06-01885** 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 on during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

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GROWTH AND YIELD OF *BORO* RICE AS AFFECTED BY SEEDLING AGE AND PLANTING GEOMETRY UNDER SYSTEM OF RICE INTENSIFICATION

ABSTRACT

The experiment was conducted at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to May 2012 to study the growth and yield of *Boro* rice as affected by seedling age and planting geometry under System of Rice Intensification (SRI). BRRI dhan50 were used as the test crop of this experiment. The experiment comprised of two factors. Factor A: Seedling age (4 levels); 12 days old seedling, 14 days old seedling, 16 days old seedling & 30 days old seedling and Factor B: Plant spacing: (5 levels); 25 cm × 25 cm, 30 cm × 30 cm, 35 cm × 35 cm, 40 cm × 40 cm and 25 cm × 15 cm. The experiment was laid out in split-plot design with three replications. Due to the interaction effect of seedling age and planting geometry, the maximum number of effective tillers hill^{-1} (39.20) was found in the treatment combination of 12 days old seedlings transplanted in 40 cm × 40 cm spacing and the minimum number (16.20) in same seedling age with 25 cm × 15 cm spacing. The longest panicle (23.90 cm) was found in the treatment combination of 14 days old seedlings with 30 cm × 30 cm spacing and the shortest (22.38 cm) in 16 days old seedlings having 25 cm × 25 cm spacing. The maximum number of filled grains panicle^{-1} (108.97) was found in the treatment combination of 14 days old seedlings with 40 cm × 40 cm spacing and the minimum number (84.60) in 16 days old seedlings having 25 cm × 25 cm spacing. The highest grain yield (7.11 t ha^{-1}) and straw yield (6.86 t ha^{-1}) were found in the treatment combination of 16 days old seedlings transplanted in 40 cm × 40 cm spacing whereas the lowest grain yield (3.21 t ha^{-1}) in 30 days old seedlings with 30 cm × 30 cm spacing but straw yield (2.70 t ha^{-1}) in 16 days old seedlings with 30 cm × 30 cm spacing. The 16 days old seedlings planted in 40 cm × 40 cm spacing showed the better response in most of the studied parameters.

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CHAPTER I

INTRODUCTION

Rice is the most important food for majority of people around the world. It is the staple food for more than two billion people in Asia (Hien *et al.,* 2006). In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. About 75% of the total cropped area and more than 80% of the total irrigated area is planted to rice (Hossain and Deb, 2003). However, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low compared to those of other rice growing countries, like 8.75 t ha^{-1} in China, 8.22 t ha^{-1} in Japan and 8.04 t ha^{-1} in Korea (FAO, 2009).

A conservative statistics given by Bhuiyan *et al.* (2002) indicated that about 21% higher amount of rice than the production of 2000 have to be produced to feed the population of Bangladesh 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. Horizontal expansion of rice area, rice yield $unit^{-1}$ area should be increased to meet this ever-increasing demand of food in the country. Clearly, it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. (Wang *et al.*, 2002). There should be need to develop appropriate management technique. Proper planting and management practices are the most effective means for increasing yield of rice at farmers level using inbred and hybrid varieties (Alauddin, 2004).

The age of rice seedling plays a vital role in the growth and development of rice and as well as the production of grain. Rice seedlings lose much of their growth potential if they are transplanted more than 15 days after they emerge in their nursery. Early aged seedlings utilize maximum time for vegetative growth, whereas older seedling recover slowly particularly when injured during up rooting and produce fewer tillers, delay maturity and may reduce yield (De Datta, 1981).

BRRI (2003) reported that the best age for transplanting wet-bed seedling is 20-30 days and according to the optimum age of seedling for *aus*, and *boro* rice are 20-30, 30-40 and 35-50 days, respectively. Seedlings should be transplanted before the fourth phyllochron begins to preserve the tillering potential (Rafaralahy, 2002). Seedling age is known to influence the seed yield (Singh *et al*., 2004).

System of rice intensification (SRI) developed in Madagascar, is a system approach to increase rice productivity with less external and inexpensive inputs. SRI method of cultivation is slowly gaining momentum all over the world. SRI cultivation is visualized as a water saving system of rice cultivation. 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 techniques encompasses a set of principles, each of them fairly simple, but working synergistically with the others in order to achieve higher grain yield in *boro* rice (Uphoff, 2002; Anon., 1992; Vallois, 1996).

Early transplanting of rice seedlings assumes special significance and principal means in obtaining higher yields in SRI cultivation. It is reported that the rice yields obtained in this method is similar to the yields obtained under conventional system although it requires 50 per cent less water. This is the most important feature, since the water table depletion has become a global phenomenon, which is sending alarming signals to rice growing countries (Laulanie, 1993). The SRI is also one such type of methodology, which revolves around this concept. One of the sound principles of SRI is, wider spacing of plants leading to greater root growth and better tillering potential. SRI is now a proven technology worldwide that can increase the productivity of irrigated rice cultivation by changing the management of plants, soil water and nutrients (Haden *et al*., 2007; Kabir and Uphoff, 2007; Mishra *et al*., 2006; Ceesay *et al*., 2006; Latif *et al*., 2005).

SRI is a package of technologies that cuts the seed cost by 80-90% water savings of 25 to 50%. The system may require more labor but once the methods are mastered and complemented are being developed labor is saved. Furthermore SRI is environment friendly; accessible for farmers which have small land holdings and need to get highest yields possible from their available land, higher outrun with fewer broken grains, ripening about 7 days sooner than regular crops of the same variety, reducing the application of agrochemicals. The plant geometry and spatial configuration exploit the initial vigour of the genotypes, enhances soil aeration and provides congenial condition for better establishment. Hence, there is a need to study the effect of seedling age and planting geometry to get higher seed yield of better quality in Bangladesh condition.

Considering these matters this research work was undertaken with the following objectives:

i. To find out the optimum planting geometry in SRI

ii. To find out the optimum seedling age to be used in SRI.

CHAPTER II

REVIEW OF LITERATURE

Horizontal expansion of rice area, rice yield unit^{-1} area should be increased to meet this ever-increasing demand of food in the country but it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. Management practices have considerable effects on the growth and development of any crop particularly rice. Among these, seedling age and planting geometry are the two important factors. Numerous studies have been performed evaluating the influence of seedling age and planting geometry on the performance of rice. Among the above factors some of the recent past information on seedling age and planting geometry on rice have been reviewed under the following headings:

2.1 Influence of seedling age on the growth and yield of rice

Kavitha *et al.* (2010) carried out a field experiment during kharif seasons to study the effect of age of seedlings, weed management practices and humic acid application on SRI. Transplanting 14 days old seedlings with pre emergence application of Pretilachlor at the rate of 0.75 kg ha^{-1} and one mechanical weeding at 30 DAT and humic acid application as seedling dip (0.3%) and foliar spray twice significantly reduced weed growth and improved growth parameters, yield attributes of rice.

Thakur *et al.* (2010) conducted an experiment in eastern India over three years, 2005-2007, to compare the performance of certain System of Rice Intensification (SRI) practices: transplanting single, young (10 days old) seedlings the Central Rice Research Institute of India. All plots received the same fertilization, a combination of organic and inorganic nutrients, and the SRI spacing used was 20% less than usually recommended. These selected SRI practices out-yielded RMP by 42%, with the higher yield. Significant measurable changes were observed in physiological processes and plant characteristics, such as longer panicles, more grains panicle^{-1} and higher percentage of grain-filling.

Krishna and Biradarpatil (2009) conducted an experiment to study the Influence of age of seedlings and spacings on seed yield and quality under SRI (system of Rice Intensification) method of cultivation in ES-18 short duration variety during rabi season at Agricultural Research Station Gangavati, Karnataka during 2004-05 and reported that the younger seedlings (8 days-old) flowered early. Time of 50% flowering increased as the age of the seedling increased from 8 days old to 12 days old, 16 days old, 25 days old.

Krishna *et al.* (2008) conducted an investigation to evaluate the influence of system of rice intensification (SRI) on seed yield and quality in rice variety BPT-5204 was conducted at Agricultural Research Station (Paddy), Sirsi during kharif 2004-05. They reported that the 12 days seedlings produced more number of tillers per plant and productive tillers per plant. Wider spacing of 40 × 40 cm found to have significant influence on growth parameters. The younger seedlings (8 days-old) flowered about four to five days earlier as compared to 25 days-old seedlings. Significantly higher seed yield per ha (3.19 t) was produced by 12 days seedlings. The treatment combination of 12 days old seedling with wider spacing recorded maximum seed yield ha^{-1}.

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

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 larger individual plants, and dry mater 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. Root growth was markedly greater in the plants raised under

SRI than in traditional system, root dry matter and root depth were also more in SRI compared to traditional rice.

Banarjee *et al.* (1992) reported that seedlings of 25 days old were the best yield potential of *aman* rice. The optimum age of seedling for transplanting *aus*, *aman* and *boro* rice are 20-30, 30-40 and 35 - 45 days respectively (DAE, 1992). Tillering is one of the most important development stages of rice, since it has a decisive character bearing on yield. Tiller number, particularly effective tiller is strongly correlated with grain yield, depending on the cultivar and crop environment. The number of tillers is regulated by tillering duration, which varies with cultivars seedling age, environmental conditions, availability of nutrients in the soil, etc.

Roy *et al.* (1992) reported other wise, where they mentioned that the number of panicles per plant decreased as seeding age increased. The 20 days old seedlings of IR 50 produced 24 panicles and this number decreased to 21 in 80 days old seedlings. In highest number of field grains/panicle of BR 14 and IR 50 was obtained with 60 days old seedlings than those of 20 and 40 days old seedlings. The older seedlings had reduced number of tillers per plant due to the reduction in field duration and thus, low yield were observed. Harvest index increased with the increase of seedling age. It was 0.41 for 20 and 0.51 for 80 days old seedlings of BR 14 and for IR50 it was 0.45 for 20 and 0.57 for 80 days old seedling. The lower harvest index with younger seedlings indicated that the partitioning of dry matter in their case was less efficient as compared to the older seedlings.

Generally, plant height of rice is a genetically controlled trait which varies with species as well as varieties within the same species. For example, the modern rice cultivars are generally short to intermediate stature, where as the traditional cultivars are taller (Hossain and Alam, 1991). Harun *et al.* (1991) however, mentioned that grain yield decreased gradually with increased of seedling age in *boro* rice.

Mannan *et al.* (1991) mentioned that the average number of panicles in the September 30 planting did not differ significantly due to seedling age while in the October 15 planting, 60 days old seedlings contributing to more number of panicles than the seedling 30, 45 and 75 days old in T. *aman* rice. In 15 September planting, 30 and 45 days old seedlings gave slightly higher grain yield than 60 days old seedlings in Joydebpur (BRRI, 1991). BRRI (1991) further reported that 20 to 40 days old seedling produce higher grain yield.

Ashraf and Mahmood (1989) studied the effect of over aged seedlings of two Basmati rice varieties and reported that yield and yield attributes declined significantly with the increase in seedling age; the reduction in yield was partly attributed to fewer productive tillers per hill and fewer spikelets per panicle. The filled grain percentage and 1000 grain weight were significantly higher with 30 and 40 days old seedlings than with 50 days old ones during the wet season at Pantnagar, India (Datta and Goutam, 1988).

Seedling quality was affected considerably by management and seedling age and the proper age of rice seedling during transplanting was of prime importance for uniform stand establishment (Kosta *et al.*, 1987). Maurya and Yadav (1987) in India observed that yield components were adversely affected by planting over-aged seedlings resulting in lower grain yield irrespective of the varieties. In Southern India planting of up to 50 day old seedling did not affect plant height and yield components during the wet season (Balasubramaniyan, 1987).

In transplanting rice culture, seedlings are raised in especially cared nursery bed. Seedling quality affects growth and development of the plant after transplanting (Sattar *et al.*, 1986). The older seedling (50 days old) was better than the younger ones (30 days old) for increasing yield of late T. *aman* rice (BRRI, 1986).

Older seedling reduced field duration more than the younger seedlings and compared to 30 days old seedlings, 60 days old seedlings of BR 6 enhanced crop maturity by more than one week, respectively (BRRI, 1985). BRRI (1985) reported a decrease in field duration with the increase in seedling age irrespective of the *aus* season. Seedling age affects dry matter accumulation. Crop raised with young seedling showed higher dry matter accumulation than older seedling (Mondal and Roy, 1984).

Seedling height and seedling strength at transplanting increased with the increase in seedling age (BRRI, 1983). However, management practices also influence plant height as well. Twenty day old seedling produced the tallest plant as compared to seedling age of 28 and 36 days (Sundersingh *et al.,* 1983 and Kosta *et al.,* 1982).

Padalia (1981) concluded that the decrease in yield components was possibly due to shorter effective duration. He also indicated that it was the panicle weight but not the panicle number that decreased with increase in seedling age of the photo-period sensitive varieties in wet season.

De Datta (1981) reported that younger seedling recover faster than the older seedling when transplanted. The grain yield was affected by seedling age but the effect was not similar in all varieties. In BR14 the highest grain yield (6.61 tha^{-1}) was obtained from 40 days old seedlings which was statistically similar to that from 20 and 60 days old seedlings but in IR50 the highest grain yield (6.30 tha^{-1}) was obtained from 20 days old seedling although yield with age up to 80 days did not vary significantly.

Although the field duration was shorter when older seedlings were transplanted, the total growth duration was higher with older seedling that with younger seedlings (BRRI, 1981). However, this increase was not proportional to the increase in seedling age. Lal *et al.* (1981) mentioned otherwise where they reported that the yield reduction caused by transplanting older (55 days) seedlings were small and non significant as compared to younger (25 days) ones. In *boro*, optimum seedling ages were 20-40 days for long and 20 days for short duration varieties but in *aus* rice, seedling age had no effect on grain yield.

2.2 Influence of plant spacing on the growth and yield of rice

The field experiment was conducted by Sridhara *et al*. (2011) at College of Agriculture, Navile Farm, Shivamogga during Kharif 2004 and 2005 to assess the response of genotypes, planting geometry and methods of establishment on root traits and yield of aerobic rice. The study revealed that among planting geometry, 30 cm × 30 cm recorded significantly higher root length (24.4 cm), root volume (60.30 cc), root number (154.2) and root weight (6.5 g) as compared to 45 cm × 20 cm. Direct seeded recorded significantly higher root length (25.9 cm), root volume (67.66 cc), root number (161.1) and root weight (7.6 g) compared to other methods. Significantly higher dry matter accumulation, number of panicles plant^{-1}, test weight was recorded in BI-43 with 30 cm × 30 cm spacing under direct seeding.

Krishna *et al*. (2008) conducted an investigation to evaluate the influence of system of rice intensification (SRI) on seed yield and quality in rice variety BPT-5204 was conducted at Agricultural Research Station (Paddy), Sirsi during kharif 2004-05. Wider spacing of 40 × 40 cm found to have significant influence on growth parameters.

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

Mazid *et al.* (2003) found that conventional practices of rice cultivation gave significantly higher grain yield compared to the SRI method of crop establishment. SRI method with 30 cm × 30 cm and 40 cm × 40 cm spacing and younger seedlings increased number of panicles/hill but total number of panicles per unit area was found to be low.

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 intra row 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.

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 35 cm × 35 cm spacing in Department of Agricultural Extension trials at Kishoregonj. But with the same spacing the number was 342 m^{-2} in locality 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 20 cm × 20 cm and 20 cm × 15cm spacing, respectively. At Kisoregonj the average number of filled grains per panicle with 35 cm × 35 cm spacing was found more promising, which was 173 filled grains per panicle and 42 unfilled grain per panicle. At Rajshahi the average number of filled grains per panicle was 106 in case of SRI practice for local Parija variety and 70 in case of farmers practices. The grain weight was found 12% higher with SRI practice over farmers' practice (FP). The weight of 1000 grains was the lowest (18.75g) with 20 cm × 15 cm spacing in case of farmers practice (FP) and the higher (28 g) with 40 cm × 40 cm spacing in case of SRI. Spacing of 35 cm × 35 cm showed better performance both at locally Intensified Farming Enterprises and Department of Agricultural Extension trial 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 20 cm × 15 cm spacing, respectively.

Islam (1999) carried out a field experiment and reported that plant spacing of 25 cm × 25 cm or 20 cm × 20 cm, yields of rice were about the same (9.5 t ha^{-1} and 9.2 tha^{-1}, respectively) but with spacing of 30 cm × 30 cm, the yield increased up to 10.5 t ha^{-1}.

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), 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 cm 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. The net assimilation rates for B, MD, TT and HT 20 × 20 cm exceeded those for other methods.

Dwivedi *et al*. (1996) conducted field experiments 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 $hill^{-1}$) gave significant the higher yield attributes, yield and net returns.

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.

Rao *et al*. (1981) conducted a field experiment and reported that number of productive tillers m^{-2} were higher in local method of planting as compared to transplanting in 15 cm × 10 cm spacing but both grain yield and straw yield were higher in transplanting in row than local planting method with transplanting in 15 cm × 10 cm. They further found no significant difference in panicle length, number of grains and1000-grains weight between local planting method and transplanting in rows.

2.3 Influence of SRI on the growth and yield of rice

2.3.1 Plant height

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season. The experiment consisted of sixteen treatments *viz.* BR3 (V_1), BR14 (V_2) BR16 (V_3), BRRI dhan28 (V_4), BRRI dhan29 (V_5), BRRI dhan36 (V_6), BRRI dhan45 (V_7), BRRI dhan50 (V_8), Binadhan-6 (V_9), Bina new line (V_{10}), BRRI hybrid dhan1 (V_{11}), BRRI hybrid dhan2 (V_{12}), BRRI hybrid dhan3 (V_{13}), Chamak (V_{14}), Hira1 (V_{15}) and Bhajan (V_{16}). Experimental results showed that the sixteen varieties cultivated in *boro* season had significant difference among them in all agronomic parameters including plant height in SRI system.

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. Sarker *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.

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.

2.3.2 Number of tillers hill^{-1}

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BR14 had the highest tiller number hill^{-1} at 90 DAT (32.80) and at harvest (26.37). BR16 had the highest number of effective tillers hill^{-1} (27.33) in SRI system.

Akbar (2004) reported that hybrid variety Sonarbangla-1 ranked first in respect of total tillers hill^{-1} among the varieties studied. Sarker *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.

2.3.3 Leaf area index

Sarker *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.

2.3.4 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). But the lowest dry matter of culm was recorded in single row (0.42 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.

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.

Sarker *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.

Naklang *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.* (1997) 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.

2.3.5 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. They further concluded that direct-seeded rice had shorter crop duration. Anon. (2004) 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 dhan29. 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 (1995) reported that direct wet-seeded rice was harvested 16 days earlier than transplanted rice.

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.

2.3.6 Number of effective tillers m^{-2}

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season. BR16 had the highest number of effective tillers $hill^{-1}$ (27.33).

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.

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 35 cm × 35 cm 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 20 cm × 20 cm and 20 cm × 15 cm, respectively.

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

2.3.7 Total number of grains panicle^{-1}

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that Binadhan-6 had the highest number of total grains panicle^{-1} (222.70) in SRI system.

Akbar (2004) reported that inbred variety BRRI dhan 41 produced the highest number of grains panicle^{-1} than the hybrid variety Sonarbangla-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.

2.3.8 Filled grains panicle^{-1}

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BR16 had the highest number of filled grains panicle^{-1} (191.00) in SRI system.

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 35 cm × 35 cm 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.

2.3.9 Weight of 1000-grains

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BR3 and BR14 both had the highest 1000-grain weight (30.63 g) in SRI system.

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 (18.75 g) with 20 cm × 15 cm spacing in case of farmers practice and the highest (28 g) with 40 cm × 40 cm 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.

2.3.10 Grain yield

A field study was conducted by Hameed *et al*. (2011) at Al-Mishkhab Rice Research Station (MRRS) during the summer season 2009 to evaluate irrigation water use efficiency (IWUE) using Anbar 33 variety with the System of Rice Intensification compared to traditional methods. During the growth phase, the number of leaves, stems, and roots, and the average plant height were measured every 15 days for the two sets of methods. At maturity, the depth and length of plant roots was assessed, along with leaf area index (LAI) of the flag leaf and plant height. The amount of irrigation water applied was measured by water meter for both methods. SRI principles for plant age, spacing, etc., were implemented in the SRI plots. The results indicated more vigorous growth of roots under SRI methods, reaching 13,004 cm plant^{-1} compared with non-SRI results of 4,722 cm plant^{-1}. There was 42% increase in grain yield when SRI methods were used.

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season. BR16 had the highest grain yield (6.86 t ha^{-1}) in SRI system.

The work was developed at Los Palacios Rice Research Station by Martin *et al*. (2010) for three years and later at small-scale producers' areas belonging to a non-specialized system (popular rice) as an agricultural extension. The study consisted of determining the effect of seedling age, plant spacing and seedling number per site on agricultural yield. Results showed a seed amount reduction in the nursery, to the value of 5 kg ha^{-1} year^{-1}, which represent between 35 and 40% of that used in the traditional transplanting system. In addition, agricultural yields increased up to 2.0 t ha^{-1}; there was a greater tillering and root system development per plant compared to the check control. On the other hand, when crop irrigation was discontinued for 21 days, 3 300 m^3 ha^{-1} year^{-1} of water were saved.

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. Satu (2006) reported that comparison trials had an average SRI yield is 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.

Anonymous (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 (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.

Anonymous (2004) 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.

Bari (2004) reported the grain yield from direct wet seeded line sowing method was significantly higher than those from transplanted method. 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 dhan29 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.

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 (25 cm × 15 cm 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 (2004) 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 tha^{-1} range, and with yields over 15 tha^{-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}, which is 46% greater than in control.

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 dhan32 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.* (2003) 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.

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 to 451 g m^{-2} with direct sowing.

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., 2001). 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, 35 cm × 35 cm 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 20 cm × 15 cm and 20 cm × 20 cm 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}.

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.

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 and reported that 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.

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.

Bhattacharya (1993) conducted an experiment during June to December, 1989 at the Agronomy field Laboratory, Bangladesh Agricultural University, Mymensingh with three spacings viz. 25 cm × 15 cm, 20 cm × 12.5 cm and 15 cm × 10 cm 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 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.

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.

2.3.11 Straw yield

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BRRI hybrid dhan2 had the highest straw yield (7.70 t ha^{-1}) in SRI system.

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}).

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.

2.3.12 Biological yield

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BRRI hybrid dhan2 had the highest biological yield (13.24 t ha^{-1}) in SRI system

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.

2.3.13 Harvest index

A field experiment was carried out by Tohiduzzaman (2011) at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December, 2010 to May 2011 for the screening of rice varieties responsive to SRI in *boro* season and reported that BRRI dhan50 had the highest harvest index (49.30).

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.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during the period from December 2011 to May 2012 to study the growth and yield of *boro* rice as affected by seedling age and planting geometry under System on Rice Intensification (SRI). The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Soil

The soil of the experimental area that used in the plot for rice cultivation belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system. The details of the plot soil have been presented in Appendix I.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatments

The experiment comprised of two factors.

Factor A: Seedling age (4 levels):

i. A_1: 12 days old seedling
ii. A_2: 14 days old seedling
iii. A_3: 16 days old seedling
iv. A_4: 30 days old seedling

Factor B: Plant spacing (5 levels):

i. S_1: 25 cm × 25 cm
ii. S_2: 30 cm × 30 cm
iii. S_3: 35 cm × 35 cm
iv. S_4: 40 cm × 40 cm
v. S_5: 25 cm × 15 cm

As such there were 20 treatment combinations viz., A_1S_1, A_1S_2, A_1S_3, A_1S_4, A_1S_5, A_2S_1, A_2S_2, A_2S_3, A_2S_4, A_2S_5, A_3S_1, A_3S_2, A_3S_3, A_3S_4, A_3S_5, A_4S_1, A_4S_2, A_4S_3, A_4S_4 and A_4S_5.

3.2.2 Experimental design and layout

The experiment was laid out in split-plot design with three replications. Seedling age was assigned to main plots and plant spacings to sub-plots. There were 60 plots for 60 treatment combination and the 20 treatment combinations of the experiment were assigned at random in 20 plots of each replication following split-plot design.

3.3 Growing of crops

3.3.1 Raising seedlings

3.3.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan50 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur**.**

3.3.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then they were kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.3.1.3 Preparation of seedling tray and seed sowing

Seeds were sown in tray on December 11, 25, 27 and 29, 2011, for 30, 16, 14 and 12 days old seedling, respectively in order to transplant the seedlings in the plot as per experimental treatment.

3.3.3 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of plot land. Mixture of cowdung and compost was applied @ 10 t/ha during 15 days before transplantation. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. The dose and method of application of fertilizers are shown in Table 1.

Table 1. Dose and method of fertilizers application

Fertilizers	Dose (kg ha^{-1})	Application (%)			
		Basal	After recovery	1^{st} installment	2^{nd} installment
Urea	150	--	33.33	33.33	33.33
TSP	100	100	--	--	--
MP	100	100	--	--	--
Zinc sulphate	10	100	--	--	--
Gypsum	60	100	--	--	--
Borax	10	100	--	--	--

Source: BRRI, 2012, Adhunik Dhaner Chash, Joydevpur, Gazipur

3.3.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting of the seedlings. The seedlings were uprooted on January 10, 2012 without causing much mechanical injury to the roots.

3.3.5 Transplanting of seedlings in the plots

The rice seedlings were transplanted in the plot at 10 January, 2012 and 1 healthy seedling was transplanted in the plot in a hill for 12, 14 and 16 days old seedlings, 2 seedlings hill^{-1} for 30 days old seedlings following the spacing as per treatments.

3.3.6 After care

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.3.6.1 Irrigation and drainage

Irrigation was provided to maintain a constant level of standing water upto 6 cm in the early stages to establishment of the seedlings and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings.

3.3.6.3 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 30 DAT and 60 DAT by mechanical means.

3.3.6.4 Top dressing

First dose after recovery, the remaining doses of urea were top-dressed in 2 equal installments at tillering and before panicle initiation.

3.3.6.5 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.4 Harvesting, threshing and cleaning

The crop was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 60, 90 and 110 DAT (Days after transplanting). The height was measured from the ground level to the tip of the plant of five hills and finally averaged.

3.5.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of 30, 60, 90 and 110 DAT by counting total tillers of five respective hills and finally averaged to hill^{-1} basis.

3.5.3 Leaf area index

Leaf area index measured manually at the time of 30, 60, 90 and 110 DAT. Data were recorded as the average of 05 plants selected at random the inner rows of each plots. The final data calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.5.4 Dry matter hill^{-1}

Dry matter was recorded at 40, 70 and 100 DAT from 2 randomly collected hills of each plot from inner rows leaving the boarder row. Collected plants including roots, leaves, grain and straw were oven dried at 70^{0}C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into dry matter content hill^{-1}.

3.5.5 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers hill^{-1}. Data on effective tiller hill^{-1} from five hills were counted and value was recorded and averaged to hill^{-1} basis.

3.5.6 Ineffective tillers hill^{-1}

The total number of ineffective tillers hill^{-1} was counted as the number of no panicle bearing tillers hill^{-1}. Data on in effective tillers hill^{-1} were counted at harvest and value was recorded.

3.5.7 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.5.8 Filled grains panicle^{-1}

The total number of filled grains was counted randomly from selected 10 panicles of a plot on the basis of grain in the spikelet and then average number of filled grains panicle^{-1} was recorded.

3.5.9 Unfilled grains panicle^{-1}

The total number of unfilled grains was counted randomly from the same 10 panicles where filled grains were counted of a plot on the basis of no grain in the spikelet and then average number of unfilled grains panicle^{-1} was recorded.

3.5.10 Weight of 1000-grains

One thousand grains were counted randomly from the total cleaned harvested grains of each individual plot and then weighed in grams and recorded.

3.5.11 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully and finally adjusted to 14% moisture basis using a digital moisture meter. The dry weight of grains of each plot from harvested area was measured and converted to t ha^{-1}.

3.5.12 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The sub-samples of the straw of each plot was oven dried and finally converted to t ha^{-1}.

3.5.13 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

3.5.14 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.5.15 Weed population m^{-2}

From the 1m^2 area of each plot, the total weeds were uprooted and counted.

3.5.16 Weed dry matter m^{-2}

The fresh weight of weeds from 1m^2 area of each plot was weighed and oven dried at 80^{0}C until a constant weight was obtained. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken.

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed using IRRISTAT software to observe the significant difference among the treatments. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This study was conducted to determine the growth and yield of *Boro* rice as affected by seedling age and plant spacing under System of Rice Intensification (SRI). Data on different growth parameters, yield attributes and yield were recorded. The results were presented and possible interpretations given under the following headings:

4.1 Plant height

4.1.1 Seedling age

Significant variation was recorded for plant height of *boro* rice at 30 DAT for different seedling age but it was non-significant for 60, 90 and 110 DAT (Appendix III and Table 2). The results revealed that at 30 DAT, the longest plant (19.55 cm) was recorded in A_2 (14 days old seedling) which was statistically similar (19.26 cm and 19.04 cm) with A_3 (16 days old seedling) and A_1 (12 days old seedling), respectively again the shortest plant (17.82 cm) was found in A_4 (30 days old seedling). The 14 days old seedlings showed 1.50, 2.68 and 9.71% higher plant height compared to 16, 12 and 30 days old seedlings respectively. At 60 DAT, the numerically maximum plant height (44.91 cm) was found in A_3, whereas the minimum plant height (43.30 cm) was observed in A_1. At 90 DAT, the maximum plant height (65.59 cm) was observed in A_3, while the minimum plant height (64.07 cm) was recorded in A_4. The same trend of plant height was also observed at 110 DAT. Twenty days old seedlings of rice produced the tallest plant as compared to seedling age of 28 and 36 days reported by Kosta *et al.* (1982) and Sundersingh *et al.* (1983). Touhiduzzaman (2011) also recorded similar increment of plant height having variety BRRI dhan50. The optimum age of seedling for growth parameter under conventional method for transplanting *aus*, *aman* and *boro* rice were 20-30, 30-40 and 35 - 45 days, respectively (DAE, 1992).

Table 2. Effect of seedling age on plant height of *boro* rice

Treatments	Plant height (cm) at			
	30 DAT	60 DAT	90 DAT	110 DAT
A_1	19.04 ab	43.30	64.53	76.23
A_2	19.55 a	44.76	65.13	75.43
A_3	19.26 ab	44.91	65.59	76.69
A_4	17.82 b	44.05	64.07	74.77
$LSD_{(0.05)}$	1.466	NS	NS	NS
CV(%)	8.66	9.93	3.95	2.83

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

NS = Non significant

4.1.2 Plant spacing

Plant height of *boro* rice showed statistically non significant differences at 30, 60 and 110 DAT but significant at 90 DAT due to the different plant spacing (Appendix III and Table 3). At 30 DAT, the numerical maximum plant height (19.47 cm) was found in S_1 (25 cm × 25 cm), while the minimum plant height (18.49 cm) was recorded in S_4 (40 cm × 40 cm). At 60 DAT, the maximum plant height (44.99 cm) was recorded in S_2, while the minimum plant height (43.05 cm) was recorded in S_4. At 90 DAT, the longest plant height (65.98 cm) was observed in S_4 which was statistically similar (65.33 cm, 64.86 cm and 64.15 cm) with S_3, S_2 and S_1, respectively, whereas the shortest plant height (63.85 cm) was found in S_5. The 40 cm × 40 cm spacing gave 0.99, 1.73, 2.85 and 3.34% higher plant height than that of 35 cm × 35 cm, 30 cm × 30 cm, 25 cm × 25 cm and 25 cm × 15 cm spacings respectively. At 110 DAT, the maximum plant height (76.92 cm) was recorded in S_3, and the minimum plant height (75.17 cm) was observed in S_1. Krishna *et al.* (2008) reported that wider spacing of 40 × 40 cm found to have significant influence on growth parameters. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including plant height in SRI system.

Table 3. Effect of plant spacing on plant height of *boro* rice

Treatments	Plant height (cm) at			
	30 DAT	60 DAT	90 DAT	110 DAT
S_1	19.47	43.70	64.15 ab	75.17
S_2	19.31	44.99	64.86 ab	75.96
S_3	18.71	44.90	65.33 ab	76.92
S_4	18.49	43.05	65.98 a	75.53
S_5	18.78	44.64	63.85 b	76.12
$LSD_{(0.05)}$	NS	NS	1.850	NS
CV(%)	12.77	7.32	3.43	4.09

In a column, similar letter do not differ significantly at 0.05 level of probability
S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm
NS = Non significant

4.1.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for plant height of *boro* rice at 30, 60, 90 and 110 DAT (Appendix III and Table 4). At 30 DAT, the longest plant (21.82 cm) was found in the treatment combination of A_3S_1 (16 days old seedling and 25 cm × 25 cm plant spacing) and the shortest plant (16.85 cm) was observed in the treatment combination of A_1S_5 (14 days old seedling and 25 cm × 15 cm plant spacing). At 60 DAT, the longest plant (46.43 cm) was found in the treatment combination of A_3S_2 and the shortest plant (40.69 cm) was observed in the treatment combination of A_1S_4. At 90 DAT, the longest plant (69.07 cm) was found in the treatment combination of A_3S_2 and the shortest plant (63.00 cm) was observed in the treatment combination of A_4S_2. At 110 DAT, the longest plant (78.42 cm) was found in the treatment combination of A_1S_3 and the shortest plant (71.43 cm) was observed in the treatment combination of A_2S_1. Karmakar *et al*. (2004) reported that, conventional practice (25 cm ×15 cm spacing with 15 days old seedlings) gave longest plant. Ashraf and Mahmood (1989) studied the effect of over aged seedlings of two Basmati rice varieties and reported that yield attributes declined significantly with the increase in seedling age.

Table 4. Interaction effect of seedling age and plant spacing on plant height of *boro* rice

Treatments	Plant height (cm) at			
	30 DAT	60 DAT	90 DAT	110 DAT
A_1S_1	19.51 ab	43.89 ab	64.79 bc	76.35 ab
A_1S_2	20.09 ab	43.50ab	63.41 bc	74.81 ab
A_1S_3	19.45 ab	43.34 ab	67.03 ab	78.42 a
A_1S_4	19.31 ab	40.69 b	63.81 bc	74.13 ab
A_1S_5	16.85 b	45.08 ab	63.63 bc	77.42 a
A_2S_1	18.97 ab	41.29 ab	63.89 bc	71.43 b
A_2S_2	20.72 ab	45.40 ab	63.95 bc	76.13 ab
A_2S_3	19.45 ab	45.91 ab	66.61 a-c	77.84 a
A_2S_4	18.91 ab	46.13 a	67.05 ab	76.47 ab
A_2S_5	19.71 ab	45.05 ab	64.16 bc	75.28 ab
A_3S_1	21.82 a	45.67 ab	63.53 bc	77.07 a
A_3S_2	18.75 ab	46.43 a	69.07 a	77.87 a
A_3S_3	18.43 ab	44.96 ab	64.41 bc	76.60 ab
A_3S_4	18.10 ab	43.87 ab	67.10 ab	76.67 a
A_3S_5	19.21 ab	43.64 ab	63.87 bc	75.24 ab
A_4S_1	17.57 b	43.95 ab	64.37 bc	75.85 ab
A_4S_2	17.66 b	44.61 ab	63.00 c	75.03 ab
A_4S_3	17.52 b	45.40 ab	63.29 c	74.81 ab
A_4S_4	17.63 b	41.50 ab	65.96 a-c	74.83 ab
A_4S_5	19.35 a	44.80 ab	63.73 bc	76.54 ab
$LSD_{(0.05)}$	4.025	5.385	3.701	5.163
CV(%)	12.77	7.32	3.43	4.09

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

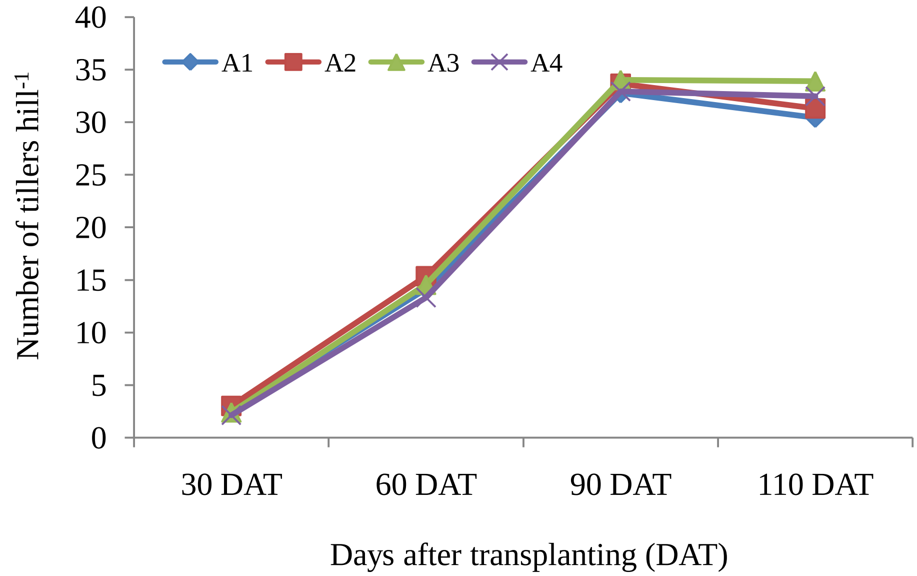
4.2 Number of tillers hill^{-1}

4.2.1 Seedling age

Significant variation was recorded for number of tillers hill^{-1} of *boro* rice at 30 DAT for different seedling age but it was non-significant for 60, 90 and 110 DAT (Appendix IV and Figure 1). The results revealed that at 30 DAT, the maximum number of tillers hill^{-1} (3.03) was recorded in A_2 (14 days old seedling) which was statistically similar (2.56 and 2.41) with A_1 (12 days old seedling) and A_3 (16 days old seedling), again the minimum number of tillers hill^{-1} (2.13) was found in A_4 (30 days old seedling). The 14 days old seedlings showed 18.34, 25.73 and 42.25% higher number of tillers hill^{-1} compared to 12, 16 and 30 days old seedlings respectively. At 60 DAT, the numerically maximum number of tillers hill^{-1} (15.36) was found in A_2, whereas the minimum number of tillers hill^{-1} (13.32) was observed in A_4. At 90 DAT, the maximum number of tillers hill^{-1} (34.03) was observed in A_3, while the minimum number (32.77) was recorded in A_1. The same trend of number of tillers hill^{-1} was also observed at 110 DAT. Krishna *et al.* (2008) reported that the 12 days seedlings produced more number of tillers plant^{-1}. Touhiduzzaman (2011) also recorded similar increment of number of tillers hill^{-1} having variety BRRI dhan50.

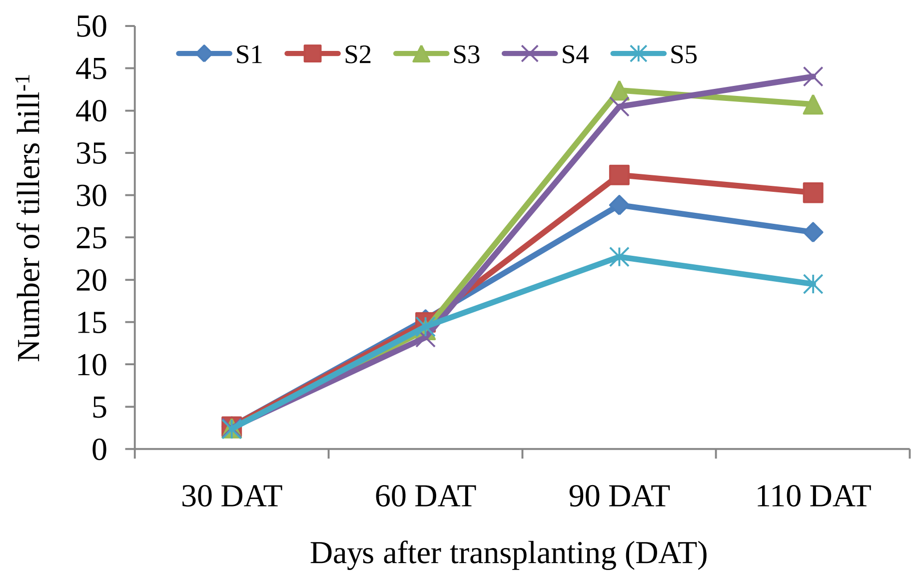
4.2.2 Plant spacing

Number of tillers hill^{-1} of *boro* rice showed statistically non significant differences at 30 and 60 DAT but significant at 90 and 110 DAT due to the different plant spacing (Appendix IV and Figure 2). At 30 DAT, the numerical maximum number of tillers/hill (2.65) was found in S_1 (25 cm × 25 cm) and S_2 (30 cm × 30 cm), while the minimum number (2.38) was recorded in S_5 (25 cm × 15 cm). At 60 DAT, the maximum number of tillers hill^{-1} (15.30) was recorded in S_1, while the minimum number of tillers hill^{-1} (13.20) was recorded in S_4. At 90 DAT, the highest number of tillers hill^{-1} (42.38) was observed in S_3 which was statistically similar (40.47) with S_4 and closely followed (32.37 and 28.83) with S_2 and S_1, respectively, while the minimum number of tillers hill^{-1} (22.70) was found in S_5.



A1= 12 days, A2= 14 days, A3= 16 days and A4= 30 days old seedlings

Figure 1. Effect of seedling age on number of tillers $hill^{-1}$ of *boro* rice (LSD(0.05)= 0.629 for 30 DAT)



S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm,
S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

Figure 2. Effect of planting geometry on number of tillers $hill^{-1}$ of *boro* rice (LSD(0.05)= 3.582 and 3.257 at 90 and 110 DAT , respectively

The 35 cm × 35 cm spacing gave 4.72, 30.92, 47.31 and 87.09% higher number of tillers hill^{-1} than that of 40 cm × 40 cm, 30 cm × 30 cm, 25 cm × 25 cm and 25 cm × 15 cm spacings, respectively. At 110 DAT, the highest number of tillers hill^{-1} (44.03) was recorded in S_4, which was closely followed (40.73) by S_3 and the lowest number (19.50) was observed in S_5. The 40 cm × 40 cm spacing gave 8.10, 45.41, 71.86 and 125.80% higher number of tillers hill^{-1} than that of 35 cm × 35 cm, 30 cm × 30 cm, 25 cm × 25 cm and 25 cm × 15 cm spacings, respectively. Karmakar *et al*. (2004) reported that number of tillers and panicles per unit area were higher in closer spacing. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of tillers hill^{-1} in SRI system.

4.2.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for number of tillers hill^{-1} of *boro* rice at 30, 60, 90 and 110 DAT (Appendix IV and Table 5). At 30 DAT, the highest number of tillers hill^{-1} (3.33) was found in the treatment combination of A_2S_4 (14 days old seedling and 40 cm × 40 cm plant spacing) and the lowest number (1.87) was observed in the treatment combination of A_1S_5 (14 days old seedling and 25 cm × 15 cm plant spacing). At 60 DAT, the highest number of tillers hill^{-1} (18.40) was found in the treatment combination of A_3S_1 and the lowest number of tillers hill^{-1} (11.73) was observed in the treatment combination of A_1S_5. At 90 DAT, the highest number of tillers hill^{-1} (44.53) was found in the treatment combination of A_2S_3 that similar to A_2S_4, A_3S_4, A_1S_3, A_3S_3, A_4S_3 and A_1S_4 and the lowest number (20.73) was observed in the treatment combination of A_3S_5. At 110 DAT, the highest number of tillers hill^{-1} (50.93) was found in the treatment combination of A_3S_4 and the lowest number of tillers hill^{-1} (18.47) was observed in the treatment combination of A_3S_5. Mazid *et al.* (2003) found that SRI method with 30 cm × 30 cm and 40 cm × 40 cm spacing and younger seedlings increased number of tillers hill^{-1}.

Table 5. Interaction effect of seedling age and plant spacing on number of tillers hill^{-1} of *boro* rice

Treatments	Number of tillers hill^{-1} at			
	30 DAT	60 DAT	90 DAT	110 DAT
A_1S_1	2.80 a-d	16.27 ab	26.73 f-j	22.67 f-h
A_1S_2	3.13 ab	14.47 ab	31.53 d-g	27.53 d-g
A_1S_3	2.40 a-d	14.47 ab	43.20 a	39.13 bc
A_1S_4	2.60 a-d	13.73 ab	39.47 ab	43.27 b
A_1S_5	1.87 d	11.73 b	22.93 h-j	19.53 h
A_2S_1	2.80 a-d	14.27 ab	28.40 e-i	24.93 e-h
A_2S_2	3.13 ab	15.80 ab	30.33 d-g	29.07 d-f
A_2S_3	3.13 ab	15.53 ab	44.53 a	41.73 b
A_2S_4	3.33 a	15.20 ab	43.47 a	42.00 b
A_2S_5	2.73 a-d	16.00 ab	21.60 ij	18.87 h
A_3S_1	3.07 a-c	18.40 a	30.07 d-h	26.60 e-g
A_3S_2	2.33 b-d	15.93 ab	34.07 c-e	33.13 cd
A_3S_3	2.20 b-d	13.00 ab	41.93 ab	40.40 b
A_3S_4	2.13 cd	12.00 b	43.33 a	50.93 a
A_3S_5	2.33 b-d	13.40 ab	20.73 j	18.47 h
A_4S_1	1.93 d	12.27 ab	30.13 d-g	32.27 d-f
A_4S_2	2.00 d	13.60 ab	33.53 c-f	31.40 de
A_4S_3	2.20 cd	13.33 ab	39.87 a-c	41.67 b
A_4S_4	1.93 d	11.87 b	35.60 b-d	39.90 b
A_4S_5	2.60 a-d	16.73 ab	25.53 g-j	21.13 gh
$LSD_{(0.05)}$	0.987	6.323	7.165	6.514
CV(%)	23.47	26.40	12.92	12.23

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

4.3 Leaf area index

4.3.1 Seedling age

Ssignificant variation was recorded for leaf area index of *boro* rice at 30 DAT but at 60, 90 and 110 DAT it was non significant (Appendix V and Figure 3). The results revealed that at 30 DAT, the numerically maximum leaf area index (0.06) was recorded in A_3 (16 days old seedling) which was statistically similar (0.05) with A_1 (12 days old seedling) and A_2 (14 days old seedling) and the lowest leaf area index (0.04) was found in A_4 (30 days old seedling). At 60 DAT, the numerically maximum leaf area index (0.847) was found in A_4, whereas the minimum (0.734) was observed in A_3. At 90 DAT, the maximum leaf area index (5.19) was observed in A_3, while the minimum leaf area index (4.82) was recorded in A_1. At 110 DAT, the maximum leaf area index (3.46) was observed in A_3, while the minimum leaf area index (3.16) was recorded in A_2. Touhiduzzaman (2011) also recorded similar increment of leaf area index having variety BRRI dhan50. Krishna *et al.* (2008) reported that wider spacing of 40 × 40 cm found to have significant influence on leaf area index.

4.3.2 Plant spacing

Leaf area index of *boro* rice showed statistically significant differences at 30, 60, 90 and 110 DAT due to the different plant spacing (Appendix V and Figure 4). At 30 DAT, the numerical highest leaf area index (0.09) was found in S_5 (25 cm × 15 cm) which was similar (0.07) with S_1 (25 cm × 25 cm), while the lowest leaf area index (0.02) was recorded in S_4 (40 cm × 40 cm). At 60 DAT, the highest leaf area index (1.228) was recorded in S_5, which was followed (0.837) by S_2, while the lowest leaf area index (0.430) was recorded in S_3. At 90 DAT, the highest leaf area index (6.66) was observed in S_5 which was followed (5.10) by S_1, whereas the lowest leaf area index (4.14) was found in S_4. At 110 DAT, the highest leaf area index (4.49) was observed in S_5 which was followed (3.54) by S_1, whereas the lowest leaf area index (2.45) was found in S_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including leaf area index in SRI system.

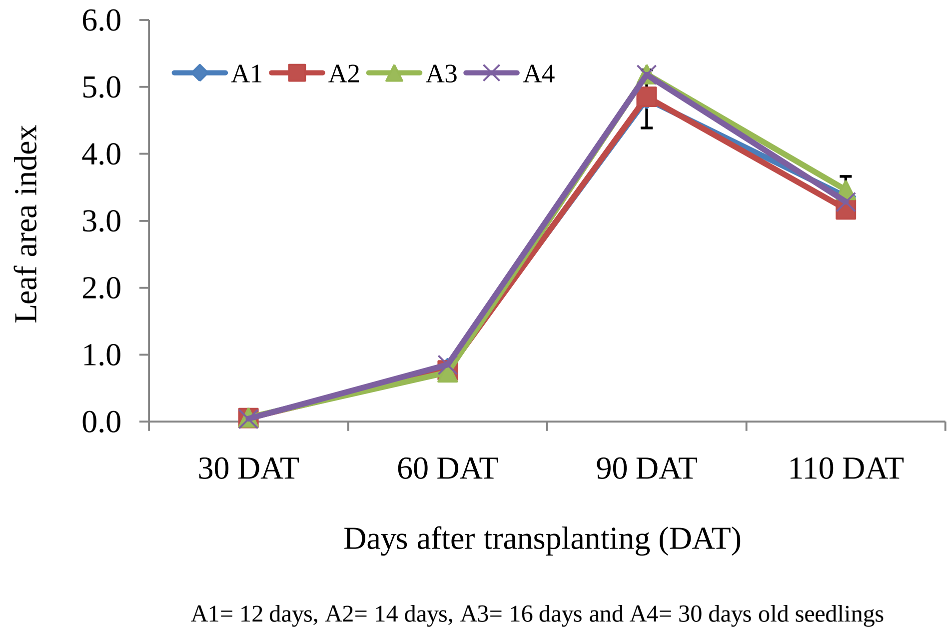


Figure 3. Effect of seedling age on leaf area index of *boro* rice (LSD(0.05)= 0.019for 30 DAT)

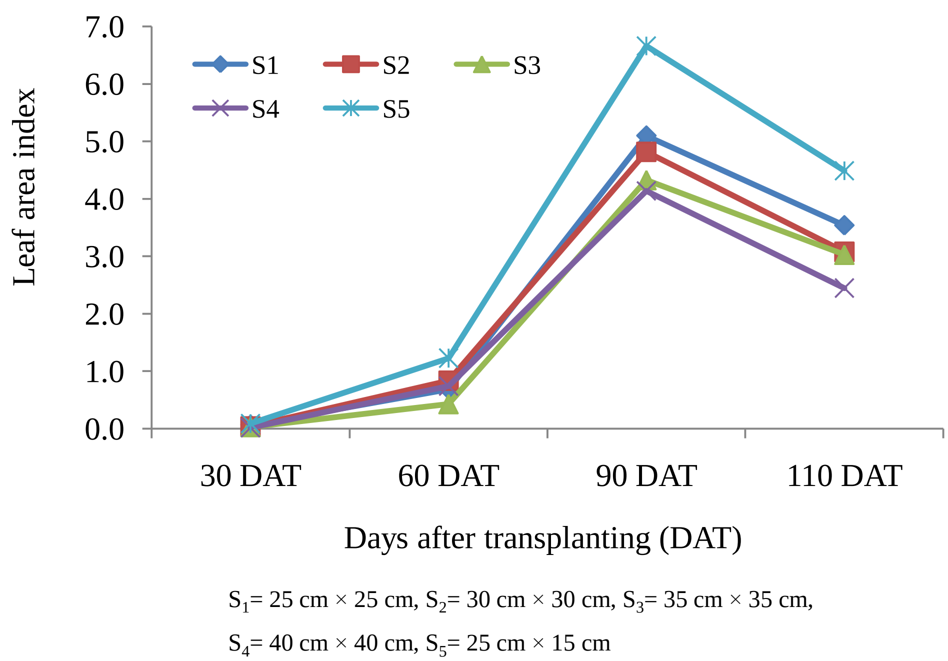


Figure 4. Effects of planting geometry on leaf area index of *boro* rice (LSD (0.05) = 0.032, 0.381, 0.547 and 0.69 for 30. 60, 90 and 110 DAT, respectively)

4.3.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for leaf area index of *boro* rice at 30, 60, 90 and 110 DAT (Appendix V and Table 6). At 30 DAT, the highest leaf area index (0.141) was found in the treatment combination of A_3S_1 (16 days old seedling and 25 cm × 25 cm plant spacing) and the lowest leaf area index (0.020) was observed in the treatment combination of A_4S_4 (30 days old seedling and 40 cm × 40 cm plant spacing). At 60 DAT, the highest leaf area index (1.552) was found in A_2S_5 and the lowest (0.332) was observed in the treatment combination of A_1S_3. At 90 DAT, the highest leaf area index (7.33) was found in the treatment combination of A_2S_5 and the lowest leaf area index (3.38) was observed in A_2S_4. At 110 DAT, the highest leaf area index (4.87) was found in the treatment combination of A_1S_5 and the lowest leaf area index (1.96) was observed in A_4S_4.

4.4 Dry matter hill^{-1}

4.4.1 Seedling age

Significant variation was recorded for dry matter hill^{-1} of *boro* rice at 40 and 100 DAT for different seedling age but it was non-significant for 70 DAT (Appendix VI and Table 7). The results revealed that at 40 DAT, the highest dry matter hill^{-1} (0.44 g) was recorded in A_1 (12 days old seedling) which was statistically similar (0.43 g and 0.42 g) with A_2 (14 days old seedling) and A_3 (16 days old seedling), respectively and the lowest dry matter hill^{-1} (0.30 g) was found in A_4 (30 days old seedling). The 12 days old seedlings showed 28.57, 30.23 and 31.82 % higher dry matter hill^{-1} compared to 30, 16 and 14 days old seedlings respectively. At 70 DAT, the numerically maximum dry mater hill^{-1} (29.89 g) was found in A_2, whereas the minimum (27.18 g) was observed in A_1. At 100 DAT, the highest dry matter hill^{-1} (106.48 g) was observed in A_2, which was statistically similar (101.21 g) with A_3, while the lowest (88.37 g) was recorded in A_4. The 14 days old seedlings showed 5.21, 12.14 and 20.49% higher dry matter hill^{-1} compared to 16, 12 and 30 days old seedlings, respectively. Touhiduzzaman (2011) recorded similar increment of dry matter content per hill having variety BRRI dhan50.

Table 6. Interaction effect of seedling age and plant spacing on leaf area index of *boro* rice

Treatments	Leaf area index at			
	30 DAT	60 DAT	90 DAT	110 DAT
A_1S_1	0.057 b-d	0.652 d	4.82 e-h	3.13 d-i
A_1S_2	0.044 b-d	0.750 bc	4.16 f-i	3.11 d-j
A_1S_3	0.027 cd	0.332 e	4.29 f-i	3.05 d-k
A_1S_4	0.030 cd	1.415 a-d	4.10 g-i	2.67 e-k
A_1S_5	0.091 a-c	0.831 a-d	6.71 ab	4.87 a
A_2S_1	0.070 b-d	0.658 d	4.74 f-h	3.71 b-f
A_2S_2	0.040 cd	0.617 e	4.52 f-i	2.57 g-k
A_2S_3	0.040 cd	0.524 e	4.29 f-i	2.95 d-k
A_2S_4	0.018 d	0.460 e	3.38 i	2.15 h-k
A_2S_5	0.107 ab	1.552 a	7.33 a	4.47 a-c
A_3S_1	0.141 a	0.954 a-d	5.53 b-f	3.72 b-e
A_3S_2	0.034 cd	0.488 e	4.34 f-i	3.44 c-g
A_3S_3	0.027 cd	0.469 e	4.49 f-i	3.11 d-k
A_3S_4	0.034 cd	0.732 cd	5.14 c-e	3.02 d-j
A_3S_5	0.085 a-c	1.028 a-e	6.46 a-c	4.03 a-c
A_4S_1	0.022 d	0.495 e	5.31 c-e	3.60 b-f
A_4S_2	0.047 b-d	1.484 a-c	6.27 a-d	3.19 d-h
A_4S_3	0.031 cd	0.394 e	4.28 f-i	3.02 d-k
A_4S_4	0.020 d	0.361 e	3.94 g-i	1.96 k
A_4S_5	0.076 a-d	1.499 ab	6.15 a-e	4.61 ab
$LSD_{(0.05)}$	0.065	0.763	1.39	1.09
CV(%)	74.50	58.42	16.68	19.82

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

Table 7. Effect of seedling age on dry matter hill^{-1} of *boro* rice

Treatments	Dry matter hill^{-1} (g) at		
	40 DAT	**70 DAT**	**100 DAT**
A_1	0.44 a	27.18	94.95 b-d
A_2	0.43 a	29.89	106.48 a
A_3	0.42 a	23.67	101.21 ab
A_4	0.30 b	27.74	88.37 c
$LSD_{(0.05)}$	0.109	NS	6.659
CV(%)	30.42	26.11	7.62

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

NS = Non significant

4.4.2 Plant spacing

Dry matter hill^{-1} of *boro* rice showed statistically significant differences at 70 and 100 DAT but non significant for 40 DAT due to the different plant spacing (Appendix VI and Table 8). At 40 DAT, the highest dry matter hill^{-1} (0.46 g) was found in S_2 (30 cm × 30 cm), while the lowest dry matter hill^{-1} (0.35 g) was recorded in S_3 (35 cm × 35 cm). At 70 DAT, the highest dry matter hill^{-1} (38.74 g) was recorded in S_3 which was statistically similar (35.15 g) with S_4 and followed (30.97 g) by S_2, while the lowest (14.77 g) was recorded in S_5. At 100 DAT, the highest dry matter hill^{-1} (156.18 g) was observed in S_4 which was followed (122.87 g) by S_3 whereas the lowest dry matter hill^{-1} (44.63 g) was found in S_5. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including dry matter hill^{-1} in SRI system. Sridhara *et al*. (2011) reported that significantly higher dry matter accumulation was recorded in BI-43 with 30 cm × 30 cm spacing under direct seeding.

Table 8. Effect of plant spacing on dry matter hill^{-1} of *boro* rice

Treatments	Dry matter hill^{-1} (g) at		
	40 DAT	**70 DAT**	**100 DAT**
S_1	0.44	15.98 d	50.84 d
S_2	0.46	30.97 bc	114.24 c
S_3	0.35	38.74 a	122.87 b
S_4	0.36	35.15 ab	156.18 a
S_5	0.40	14.77 d	44.63 e
$LSD_{(0.05)}$	NS	6.45	6.01
CV(%)	39.31	28.59	7.47

In a column, similar letter do not differ significantly at 0.05 level of probability

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

NS = Non significant

4.4.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for dry matter hill^{-1} of *boro* rice at 40, 70 and 100 DAT (Appendix VI and Table 9). At 40 DAT, the highest dry matter hill^{-1} (0.57 g) was found in the treatment combination of A_2S_4 (14 days old seedling and 40 cm × 40 cm plant spacing) and the lowest dry matter hill^{-1} (0.25 g) was observed in the treatment combination of A_4S_2 (30 days old seedling and 30 cm × 30 cm plant spacing). At 70 DAT, the highest dry matter hill^{-1} (52.56 g) was found in the treatment combination of A_1S_4 and the lowest dry matter hill^{-1} (9.90 g) was observed in the treatment combination of A_1S_1. At 100 DAT, the highest dry matter hill^{-1} (164.55 g) was found in the treatment combination of A_2S_4 and the lowest (37.03 g) was observed in the treatment combination of A_1S_5. Mazid *et al.* (2003) found that SRI method with 30 cm × 30 cm and 40 cm × 40 cm spacing and younger seedlings increased dry matter hill^{-1}.

Table 9. Interaction effect of seedling age and plant spacing on dry matter hill^{-1} of *boro* rice

Treatments	Dry matter hill^{-1} (g) at		
	40 DAT	70 DAT	100 DAT
A_1S_1	0.43 a-c	9.90 i	52.88 fg
A_1S_2	0.52 ab	28.51 c-g	107.92 de
A_1S_3	0.50 a-c	33.13 b-f	122.69 c
A_1S_4	0.33 a-c	52.56 a	154.25 a
A_1S_5	0.42 a-c	11.80 i	37.03 h
A_2S_1	0.41 a-c	15.76 g-i	55.88 f
A_2S_2	0.50 a-c	45.18 ab	123.83 c
A_2S_3	0.24 c	40.81 a-c	137.91 b
A_2S_4	0.57 a	27.23 d-g	164.55 a
A_2S_5	0.45 a-c	20.51 f-i	50.22 fg
A_3S_1	0.57 a	21.04 f-i	47.63 f-h
A_3S_2	0.56 a	24.88 f-h	119.87 cd
A_3S_3	0.33 a-c	38.15 b-e	125.25 c
A_3S_4	0.26 bc	20.99 f-i	165.30 a
A_3S_5	0.41 a-c	13.30 hi	47.99 f-h
A_4S_1	0.34 a-c	17.20 g-i	47.01 f-h
A_4S_2	0.25 c	25.32 e-h	105.32 e
A_4S_3	0.34 a-c	42.88 ab	105.61 e
A_4S_4	0.27 bc	39.81 a-d	140.61 b
A_4S_5	0.33 a-c	13.48 hi	43.28 gh
$LSD_{(0.05)}$	0.261	12.893	12.029
CV(%)	39.31	28.59	7.47

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

4.5 Effective tillers hill^{-1}

4.5.1 Seedling age

Non significant variation was recorded for number of effective tillers hill^{-1} of *boro* rice for different seedling age (Appendix VII and Table 10). The results revealed that the maximum number of effective tillers hill^{-1} (26.72) was recorded in A_4 (30 days old seedling), and the minimum number (26.27) was found in A_3 (16 days old seedling). Krishna *et al.* (2008) reported that the 12 days seedlings produced more productive tillers plant^{-1}. Touhiduzzaman (2011) also recorded similar increment of number of effective tillers hill^{-1} having variety BRRI dhan50.

Table 10. Effect of seedling age on yield contributing characters of *boro* rice

Treatments	Effective tillers hill^{-1} (No.)	Ineffective tillers hill^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)
A_1	26.44	2.48	93.08	25.97
A_2	26.52	2.39	100.95	24.71
A_3	26.27	2.88	93.46	27.56
A_4	26.72	2.59	100.69	24.47
$LSD_{(0.05)}$	NS	NS	NS	NS
CV(%)	2.75	45.84	11.77	25.30

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

NS = Non significant

4.5.2 Plant spacing

Number of effective tillers hill^{-1} of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VII and Table 11). The highest number of effective tillers hill^{-1} (36.30) was found in S_4 (40 cm × 40 cm) which was followed (31.93) by S_3 (35 cm × 35 cm), while the lowest number of effective tillers hill^{-1} (18.28) was recorded in S_5 (25 cm × 15 cm). The 40 cm × 40 cm spacing gave 13.69, 46.25, 72.04 and 98.58% higher number of effective tillers hill^{-1} than that of 35 cm × 35 cm, 30 cm × 30 cm, 25 cm × 25 cm and 25 cm × 15 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of effective tillers hill^{-1} in SRI system.

Table 11. **Effect of plant spacing on yield contributing characters of *boro* rice**

Treatments	Effective tillers hill^{-1} (No.)	Ineffective tillers hill^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)
S_1	21.10 cd	2.33 bc	93.97	26.13
S_2	24.82 c	2.70 ab	94.70	24.75
S_3	31.93 b	2.95 ab	96.13	26.26
S_4	36.30 a	3.27 a	98.93	26.47
S_5	18.28 d	1.67 c	101.5	24.78
$LSD_{(0.05)}$	4.126	0.727	NS	3.720
CV(%)	18.73	33.91	12.14	17.42

In a column, similar letter do not differ significantly at 0.05 level of probability

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

NS = Non significant

4.5.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for number of effective tillers hill^{-1} of *boro* rice (Appendix VII and Table 12). The highest number of effective tillers hill^{-1} (39.20) was found in the treatment combination of A_1S_4 (12 days old seedling and 40 cm × 40 cm plant spacing) that similar to A_2S_4 (38.40), A_3S_4 (34.87), A_4S_4 (32.73), A_4S_3 (32.53), A_3S_3 (32.27), A_1S_3 (31.60) and A_2S_3 (31.33) and the lowest number (16.20) was observed in the treatment combination of A_1S_5 (12 days old seedling and 25 cm × 15 cm plant spacing) that similar to A_3S_5 (16.80).

4.6 Ineffective tillers hill^{-1}

4.6.1 Seedling age

Non significant variation was recorded for number of ineffective tillers hill^{-1} of *boro* rice for different seedling age (Appendix VII and Table 10). The results revealed that the maximum number of ineffective tillers hill^{-1} (2.88) was recorded in A_3 (16 days old seedling), and the minimum number (2.39) was found in A_2 (16 days old seedling). Touhiduzzaman (2011) also recorded similar increment of number of ineffective tillers hill^{-1} having variety BRRI dhan50.

Table 12. Interaction effect of seedling age and plant spacing on yield contributing characters of *boro* rice

Treatments	Effective tillers hill^{-1} (No.)	Ineffective tillers hill^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)
A_1S_1	22.13 fg	2.27 b-e	94.70 a-c	24.23 ab
A_1S_2	23.07 e-g	2.33 b-e	93.37 a-c	26.13 ab
A_1S_3	31.60 a-d	2.27 b-e	92.80 a-c	25.33 ab
A_1S_4	39.20 a	3.93 a	85.13 c	27.23 ab
A_1S_5	16.20 g	1.60 de	99.40 a-c	26.93 ab
A_2S_1	20.00 fg	1.93 c-e	91.03 a-c	26.77 ab
A_2S_2	24.20 d-g	2.20 b-e	107.60 a	23.87 ab
A_2S_3	31.33 a-e	3.00 a-d	100.10 a-c	25.30 ab
A_2S_4	38.40 a	2.93 a-e	108.97 a	22.83 b
A_2S_5	18.67 fg	1.87 c-e	103.07 a-c	24.77 ab
A_3S_1	20.73 fg	2.93 a-e	84.60 c	30.87 a
A_3S_2	26.67 b-f	3.40 ab	87.67 bc	25.53 ab
A_3S_3	32.27 a-d	3.40 ab	94.13 a-c	28.37 ab
A_3S_4	34.87 ab	3.92 a	102.5 a-c	29.30 ab
A_3S_5	16.80 g	1.53 e	98.4 a-c	23.73 ab
A_4S_1	21.53 fg	2.20 b-e	105.53 ab	22.63 b
A_4S_2	25.33 c-f	2.87 a-e	96.17 a-c	23.47 ab
A_4S_3	32.53 a-c	3.13 a-c	97.50 a-c	26.03 ab
A_4S_4	32.73 a-c	3.07 a-c	99.10 a-c	26.50 ab
A_4S_5	21.47 fg	1.67 c-e	105.13 ab	23.70 ab
$LSD_{(0.05)}$	8.251	1.454	19.596	7.441
CV(%)	19.32	33.91	12.14	17.42

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

4.6.2 Plant spacing

Number of ineffective tillers $hill^{-1}$ of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VII and Table 11). The highest number of ineffective tillers $hill^{-1}$ (3.27) was found in S_4 (40 cm × 40 cm) which was statistically similar (2.95 and 2.70) with S_3 (35 cm × 35 cm) and S_2 (30 cm × 30 cm), while the lowest number of ineffective tillers $hill^{-1}$ (1.67) was recorded in S_5 (25 cm × 15 cm). The 40 cm × 40 cm spacing gave 10.85, 21.11, 40.34 and 95.81% higher number of ineffective tillers $hill^{-1}$ than that of 35 cm × 35 cm, 30 cm × 30 cm, 25 cm × 25 cm and 25 cm × 15 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of ineffective tillers $hill^{-1}$ in SRI system.

4.6.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for number of ineffective tillers $hill^{-1}$ of *boro* rice (Appendix VII and Table 12). The highest number of ineffective tillers $hill^{-1}$ (3.93) was found in the treatment combination of A_1S_4 (12 days old seedling and 40 cm × 40 cm plant spacing) that similar to A_3S_4 (3.92) and the lowest number (1.53) was observed in the treatment combination of A_3S_5 (16 days old seedling and 25 cm × 15 cm plant spacing).

4.7 Panicle length

4.7.1 Seedling age

Non significant variation was recorded for panicle length of *boro* rice for different seedling age (Appendix VII and Figure 5). The results revealed that the maximum panicle length (23.37 cm) was recorded in A_2 (14 days old seedling) and A_4 (30 days old seedling), again the minimum panicle length (22.92 cm) was found in A_3 (16 days old seedling). Touhiduzzaman (2011) also recorded similar increment of panicle length having variety BRRI dhan50. Thakur *et al*. (2010) observed measurable changes in longer panicles with transplanting single, young (10 days old) seedlings.

4.7.2 Plant spacing

Panicle length of *boro* rice showed statistically non significant differences due to the different plant spacing (Appendix VII and Figure 6). The numerical maximum panicle length (23.42 cm) was found in S_2 (30 cm × 30 cm), while the minimum panicle length (22.05 cm) in S_5 (25 cm × 15 cm). Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including panicle length in SRI system.

4.7.3 Interaction effect

Interaction effect of seedling age and plant spacing showed non significant differences for panicle length of *boro* rice (Appendix VII and Figure 7). The maximum panicle length (23.90 cm) was found in the treatment combination of A_2S_2 (14 days old seedling and 30 cm × 30 cm plant spacing) and the minimum panicle length (22.38 cm) was observed in the treatment combination of A_3S_1 (16 days old seedling and 25 cm × 25 cm plant spacing).

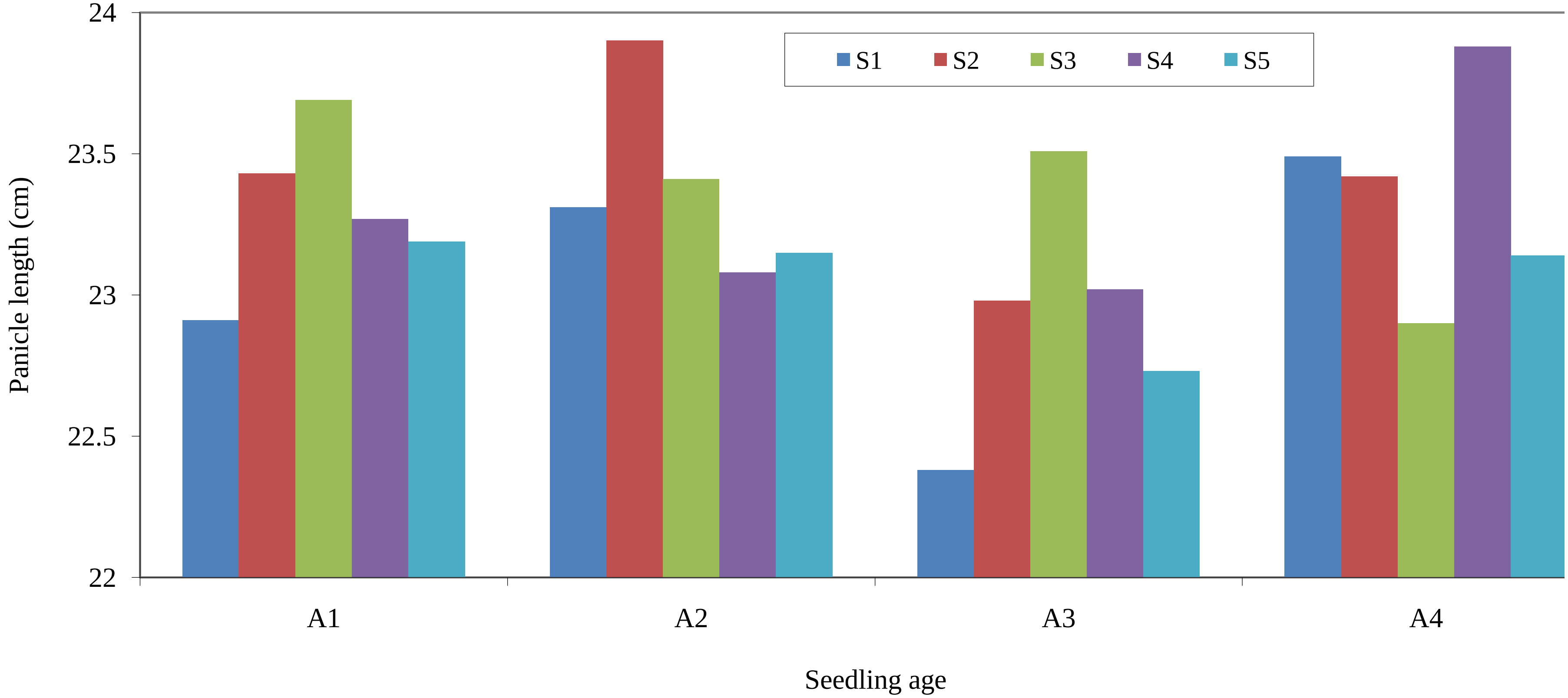
4.8 Filled grains panicle^{-1}

4.8.1 Seedling age

Non significant variation was recorded for number of filled grain panicle^{-1} of *boro* rice for different seedling age (Appendix VII and Table 10). The results revealed that the maximum number of filled grains (100.95) was recorded in A_2 (14 days old seedling), again the minimum number of filled grains (93.08) was found in A_1 (12 days old seedling). Touhiduzzaman (2011) also recorded similar increment of number of filled grain having variety BRRI dhan50. Thakur *et al*. (2010) observed more grains panicle^{-1} with transplanting single, young (10 days old) seedlings.

4.8.2 Plant spacing

Number of filled grain panicle^{-1} of *boro* rice showed statistically non significant differences due to the different plant spacing (Appendix VII and Table 11). The maximum number of filled grains (101.5) was found in S_5 (25 cm × 15 cm), while the minimum number of filled grains (93.97) was recorded in S_1 (25 cm × 25 cm). Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference in filled grain panicle^{-1} in SRI system.



A1= 12 days, A2= 14 days, A3= 16 days and A4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

Figure 7. Interaction effects of seedling age and planting geometry on panicle length of *boro* rice

4.8.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for number of filled grains panicle^{-1} of *boro* rice (Appendix VII and Table 12). The highest number of filled grains (108.97) was found in the treatment combination of A_2S_4 (14 days old seedling and 40 cm × 40 cm plant spacing) that similar to A_2S_2 (107.60) and the lowest number (84.60) in the treatment combination of A_3S_1 (16 days old seedling and 25 cm × 25 cm plant spacing) that similar to A_1S_4 (85.13).

4.9 Unfilled grains panicle^{-1}

4.9.1 Seedling age

Non significant variation was recorded for number of unfilled grains of *boro* rice for different seedling age (Appendix VII and Table 10). The results revealed that the maximum number of unfilled grains (27.56) was recorded in A_3 (16 days old seedling), and the minimum number of unfilled grains (24.47) was found in A_4 (30 days old seedling). Touhiduzzaman (2011) also recorded similar increment of number of filled grain having variety BRRI dhan50.

4.9.2 Plant spacing

Number of unfilled grains panicle^{-1} of *boro* rice showed statistically non significant differences due to the different plant spacing (Appendix VII and Table 11). Maximum number of unfilled grains (26.47) was found in S_4 (40 cm × 40 cm), while the minimum number (24.75) was recorded in S_2 (30 cm × 30 cm). Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference for unfilled grains in SRI system.

4.9.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for number of unfilled grains panicle^{-1} of *boro* rice (Appendix VII and Table 12). The maximum number of unfilled grains (30.87) was found in the treatment combination of A_3S_1 (16 days old seedling and 25 cm × 25 cm plant spacing) and the minimum number (22.63) was observed in the treatment combination of A_4S_1 (30 days old seedling and 25 cm × 25 cm plant spacing) that similar to A_2S_4.

4.10 Weight of 1000-grains

4.10.1 Seedling age

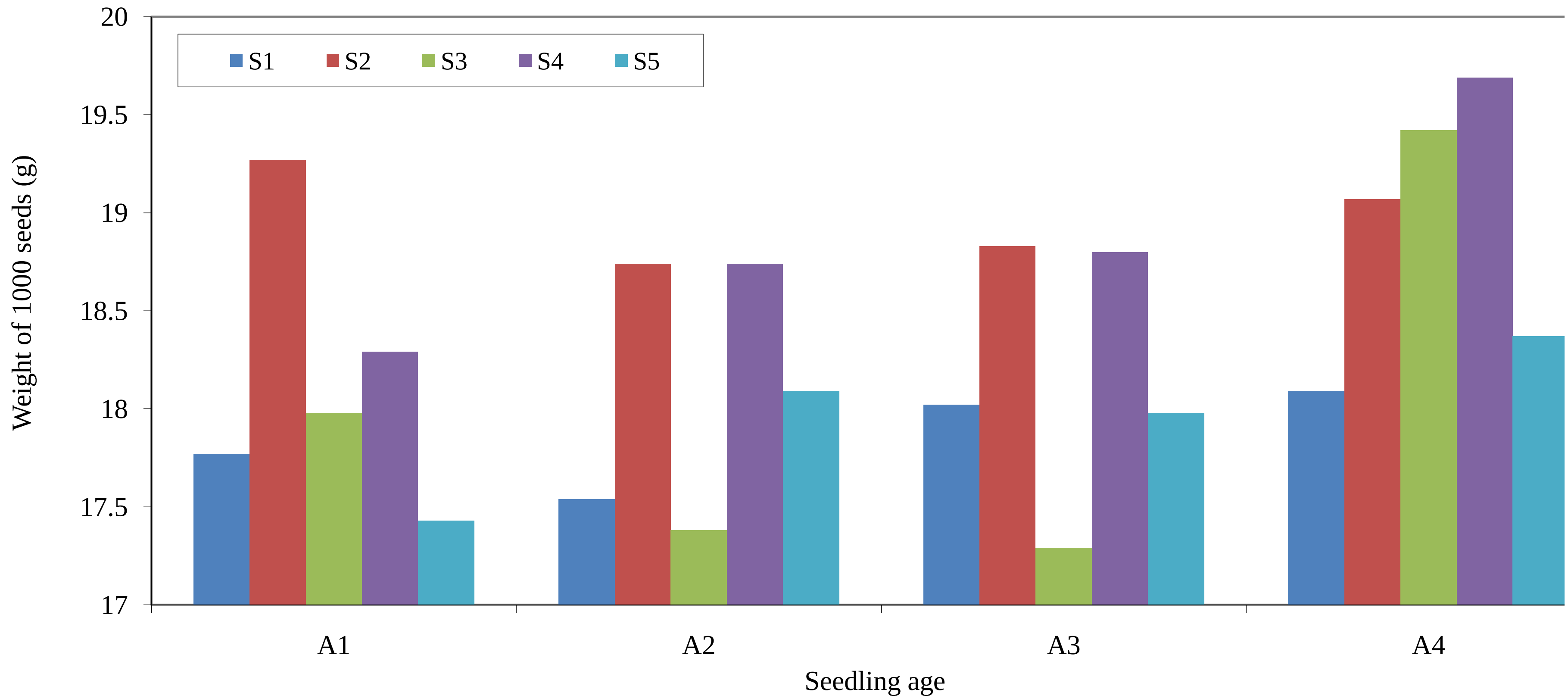
Non significant variation was recorded for weight of 1000 grains of *boro* rice for different seedling age (Appendix VIII and Figure 8). The results revealed that the maximum weight of 1000 grains (19.00 g) was recorded in A_2 (14 days old seedling) and the minimum weight of 1000 grains (18.15 g) was found in A_1 (12 days old seedling). Touhiduzzaman (2011) also recorded similar increment of weight of 1000 grains having variety BRRI dhan50. Datta and Goutam (1988) reported that 1000 grain weight were significantly higher with 30 and 40 days old seedlings than with 50 days old ones during the wet season.

4.10.2 Plant spacing

Weight of 1000-grains of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VIII and Figure 9). The highest weight of 1000-grains (18.98 g) was found in S_2 (30 cm × 30 cm) which was statistically similar (18.88 g) with S_4 (40 cm × 40 cm), while the lowest weight of 1000 grains (17.86 g) was recorded in S_1 (25 cm × 25 cm). The 30 cm × 30 cm spacing gave 0.53, 5.33, 5.62 and 6.27% higher weight of 1000 grains than that of 40 cm × 40 cm, 35 cm × 35 cm, 25 cm × 15 cm and 25 cm × 25 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including weight of 1000 grains in SRI system.

4.10.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for weight of 1000 grains of *boro* rice (Appendix VIII and Figure 10). The highest weight of 1000 grains (19.69 g) was found in the treatment combination of A_4S_4 (30 days old seedling and 40 cm × 40 cm plant spacing) and the lowest weight (17.29 g) was observed in the treatment combination of A_3S_3 (16 days old seedling and 35 cm × 35 cm plant spacing).



A1= 12 days, A2= 14 days, A3= 16 days and A4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

Figure 10. Interaction effects of seedling age and planting geometry on weight of 1000 seeds of *boro* rice [LSD(0.05)= 1.536]

4.11 Grain yield

4.11.1 Seedling age

Non significant variation was recorded for grain yield of *boro* rice for different seedling age (Appendix VIII and Table 13). The results revealed that the maximum grain yield (5.06 t ha^{-1}) was recorded in A_3 (16 days old seedling) and the minimum grain yield (4.58 t ha^{-1}) was found in A_2 (14 days old seedling). Krishna *et al.* (2008) recorded significantly higher seed yield ha^{-1} (3.19 t) from 12 days old seedlings. Touhiduzzaman (2011) also recorded similar increment of grain yield having variety BRRI dhan50.

Table 13. Effect of seedling age on yield of *boro* rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
A_1	4.91	4.71 a	9.62	51.17 bc
A_2	4.58	5.11 a	9.75	47.75 c
A_3	5.06	4.78 a	9.84	52.84 ab
A_4	4.94	3.80 b	8.73	56.21 a
$LSD_{(0.05)}$	NS	0.889	NS	3.48
CV(%)	13.86	21.62	16.24	7.49

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

NS = Non significant

4.11.2 Plant spacing

Grain yield of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VIII and Table 14). The highest grain yield (6.85 t ha^{-1}) was found in S_4 (40 cm × 40 cm) which was closely followed (5.23 t ha^{-1}) by S_5 (25 cm × 15 cm) and S_1 (25 cm × 25 cm), while the lowest grain yield (3.42 t ha^{-1}) was recorded in S_2 (30 cm × 30 cm). The 40 cm × 40 cm spacing gave 30.98, 44.21, 66.26 and 100.29% higher grain yield than that of 25 cm × 15 cm, 25 cm × 25 cm, 35 cm × 35 cm and 30 cm × 30 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including grain yield in SRI system.

Table 14. Effect of plant spacing on yield of *boro* rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	4.75 b	4.41 bc	9.16 c	52.00
S_2	3.42 d	3.20 d	6.62 d	51.96
S_3	4.12 c	4.07 cd	8.27 c	51.15
S_4	6.85 a	5.86 a	12.71 a	54.47
S_5	5.23 b	5.45 ab	10.68 b	50.28
$LSD_{(0.05)}$	0.576	1.109	1.40	NS
CV(%)	14.23	28.99	17.79	11.76

In a column, similar letter do not differ significantly at 0.05 level of probability

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

NS = Non significant

4.11.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for grain yield of *boro* rice (Appendix VIII and Table 15). The highest grain yield (7.11 t ha^{-1}) was found in the treatment combination of A_3S_4 (16 days old seedling and 40 cm × 40 cm plant spacing) that similar to A_1S_4 (7.07 t ha^{-1}) and A_4S_4 (6.36 t ha^{-1}) that similar to A_1S_4 (7.07 t ha^{-1}) and A_4S_4 (6.30 t ha^{-1}) and the lowest grain yield (3.21 t ha^{-1}) was observed from A_4S_2 (30 days old seedling and 30 cm × 30 cm plant spacing). Krishna *et al.* (2008) reported treatment combination of 12 days old seedling with wider spacing recorded maximum seed yield ha^{-1}.

4.12 Straw yield

4.12.1 Seedling age

Significant variation was recorded for straw yield of *boro* rice for different seedling age (Appendix VIII and Table 13). The results revealed that the highest straw yield (5.11 t ha^{-1}) was recorded in A_2 (14 days old seedling) which was statistically similar (4.78 t ha^{-1} and 4.71 t ha^{-1}) with A_3 (16 days old seedling) and A_1 (12 days old seedling), respectively and the lowest straw yield (3.80 t ha^{-1}) was found in A_4 (30 days old seedling). The 14 days old seedlings gave 6.90, 7.83 and 34.47% higher straw yield than that of 16 days old seedlings, 12 days old seedlings and 30 days old seedlings, respectively. Touhiduzzaman (2011) also recorded similar increment of straw yield having variety BRRI dhan50.

Table 15. Interaction effect of seedling age and plant spacing on yield of *boro* rice

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
A_1S_1	4.59 c-f	3.98 c-h	8.57 c-g	53.56 a-c
A_1S_2	3.34 hi	3.69 d-h	7.02 e-g	47.58 bc
A_1S_3	4.56 c-g	4.61 b-h	9.17 c-f	49.73 bc
A_1S_4	7.07 a	5.87 a-d	12.94 ab	54.64 a-c
A_1S_5	5.00 b-e	5.38 a-f	10.38 b-d	48.17 bc
A_2S_1	4.17 d-i	4.99 a-g	9.17 c-f	45.47 c
A_2S_2	3.25 hi	3.55 e-h	6.80 e-g	47.79 bc
A_2S_3	4.10 e-i	4.71 a-h	9.12 c-f	44.96 c
A_2S_4	5.86 b	6.71 ab	12.57 ab	46.62 bc
A_2S_5	5.50 bc	5.61 a-e	11.11 bc	49.50 a-c
A_3S_1	4.96 b-f	4.60 b-h	9.57 c-e	51.83 a-c
A_3S_2	3.88 f-i	2.70 h	6.57 fg	59.06 a
A_3S_3	4.40 c-h	3.78 c-h	8.18 d-g	53.79 a-c
A_3S_4	7.11 a	6.86 a	13.96 a	50.93 a-c
A_3S_5	4.96 b-f	5.96 a-c	10.91 b-d	45.46 c
A_4S_1	5.27 b-d	4.07 c-h	9.34 c-f	56.42 ab
A_4S_2	3.21 i	2.88 gh	6.09 g	52.71 a-c
A_4S_3	3.42 g-i	3.17 f-h	6.59 fg	51.90 a-c
A_4S_4	6.36 a	4.01 c-h	11.37 a-c	55.94 ab
A_4S_5	5.44 bc	4.86 a-h	10.30 b-d	52.82 a-c
$LSD_{(0.05)}$	1.153	2.218	2.80	10.18
CV(%)	14.23	28.99	17.79	11.76

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

4.12.2 Plant spacing

Straw yield of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VIII and Table 14). The highest straw yield (5.86 t ha^{-1}) was found in S_4 (40 cm × 40 cm) which was statistically similar (5.45 t ha^{-1}) with S_5 (25 cm × 15 cm) and closely followed (4.41 t ha^{-1}) by S_1 (25 cm × 25 cm), while the lowest grain yield (3.20 t ha^{-1}) was recorded in S_2 (30 cm × 30 cm). The 40 cm × 40 cm spacing gave 7.52, 32.88, 43.98 and 83.13% higher straw yield than that of 25 cm × 15 cm, 25 cm × 25 cm, 35 cm × 35 cm and 30 cm × 30 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including straw yield in SRI system.

4.12.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for straw yield of *boro* rice (Appendix VIII and Table 15). The highest straw yield (6.86 t ha^{-1}) was found in the treatment combination of A_3S_4 (16 days old seedling and 40 cm × 40 cm plant spacing) and the lowest straw yield (2.70 t ha^{-1}) was observed in the treatment combination of A_3S_2 (16 days old seedling and 30 cm × 30 cm plant spacing). Karmakar *et al*. (2004) reported that, conventional practice (25 cm ×15 cm spacing with 15 days old seedlings) gave higher yield that the SRI practices with wider spacing.

4.13 Biological yield

4.13.1 Seedling age

Non significant variation was recorded for biological yield of *boro* rice for different seedling age (Appendix VIII and Table 13). The results revealed that the maximum biological yield (9.84 t ha^{-1}) was recorded in A_3 (16 days old seedling), and the minimum biological yield (8.73 t ha^{-1}) was found in A_4 (30 days old seedling). Touhiduzzaman (2011) also recorded similar increment of biological yield having variety BRRI dhan50.

4.13.2 Plant spacing

Biological yield of *boro* rice showed statistically significant differences due to the different plant spacing (Appendix VIII and Table 14). The highest biological yield (12.71 t ha^{-1}) was found in S_4 (40 cm × 40 cm) which was closely followed (10.68 t ha^{-1}) by S_5 (25 cm × 15 cm), while the lowest biological yield (6.62 t ha^{-1}) was recorded in S_2 (30 cm × 30 cm). The 40 cm × 40 cm spacing gave 19.01, 38.76, 53.69 and 91.99% higher biological yield than that of 25 cm × 15 cm, 25 cm × 25 cm, 35 cm × 35 cm and 30 cm × 30 cm spacings respectively. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including biological yield in SRI system.

4.13.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for biological yield of *boro* rice (Appendix VIII and Table 15). The highest biological yield (13.96 t ha^{-1}) was found in the treatment combination of A_3S_4 (16 days old seedling and 40 cm × 40 cm plant spacing) and the lowest biological yield (6.09 t ha^{-1}) was observed in the treatment combination of A_4S_2 (30 days old seedling and 30 cm × 30 cm plant spacing).

4.14 Harvest index

4.14.1 Seedling age

Significant variation was recorded for harvest index of *boro* rice for different seedling age (Appendix VIII and Table 13). The results revealed that the highest harvest index (56.21%) was recorded in A_4 (30 days old seedling) which was statistically similar (52.84%) with A_3 (16 days old seedling) and closely followed (51.17%) by A_1 (12 days old seedling) and the lowest harvest index (47.75%) was found in A_2 (14 days old seedling). The 30 days old seedlings gave 6.38, 9.85 and 17.72% higher harvest index than that of 16, 12 and 14 days old seedlings, respectively. Touhiduzzaman (2011) also recorded similar increment of harvest index having variety BRRI dhan50. Roy *et al.* (1992) reported lower harvest index with younger seedlings compared to the older seedlings.

4.14.2 Plant spacing

Harvest index of *boro* rice showed statistically non significant differences due to the different plant spacing (Appendix VIII and Table 14). The numerical maximum harvest index (54.47%) was found in S_4 (40 cm × 40 cm), while the minimum (50.28%) was recorded in S_5 (25 cm × 15 cm). Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including harvest index in SRI system.

4.14.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for harvest index of *boro* rice (Appendix VIII and Table 15). The highest harvest index (59.06%) was found in the treatment combination of A_3S_2 (16 days old seedling and 30 cm × 30 cm plant spacing) and the lowest harvest index (44.96%) was observed in the treatment combination of A_2S_3 (14 days old seedling and 35 cm × 35 cm plant spacing).

4.15 Weed population

4.15.1 Seedling age

Significant variation was recorded for weed population m^{-2} at 30 DAT but non significant at 60 DAT for different seedling age (Appendix IX and Table 16). The results revealed that at 30 DAT, the highest weed population (58.87 m^{-2}) was recorded in A_1 (12 days old seedling) which was statistically similar (49.93 m^{-2} and 49.80 m^{-2}) with A_4 (30 days old seedling) and A_3 (16 days old seedling) and the lowest weed population (43.73 m^{-2}) was found in A_2 (14 days old seedling). The 12 days old seedlings showed 17.91, 18.21 and 34.62% higher number of weed population m^{-2} than that of 30, 16 and 14 days old seedlings, respectively. At 60 DAT, the highest weed population (88.40 m^{-2}) was recorded in A_3 (16 days old seedling) and the lowest weed population (63.13 m^{-2}) was found in A_2 (14 days old seedling).

Table 16. Effect of seedling age on weed population and weed dry matter of *boro* rice

Treatment	Weed population m^{-2} (No.) at		Weed dry matter (g m^{-2}) at	
	30 DAT	60 DAT	30 DAT	60 DAT
A_1	58.87 a	65.53	2.73	2.93
A_2	43.73 b	63.13	1.96	2.96
A_3	49.80 ab	88.40	2.31	3.53
A_4	49.93 ab	85.00	2.52	3.44
$LSD_{(0.05)}$	14.98	NS	NS	NS
CV(%)	33.15	69.88	68.89	64.19

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

NS = Non significant

4.15.2 Plant spacing

Weed population m^{-2} of *boro* rice varied significantly at 30 DAT but non significant for 60 DAT due to the different plant spacing (Appendix IX and Table 17). At 30 DAT, the highest number of weed population (61.25 m^{-2}) was found in S_2 (30 cm × 30 cm) which was statistically similar (55.92 m^{-2}) with S_5 (25 cm × 15 cm), while the lowest weed population (38.00 m^{-2}) in S_4 (40 cm × 40 cm). The 30 cm × 30 cm spacing showed 9.53, 24.59, 32.26 and 61.18% higher number of weed than that of 25 cm × 15 cm, 25 cm × 25 cm, 35 cm × 35 cm and 40 cm × 40 cm spacings respectively. At 60 DAT, the maximum number of weed population (84.25 m^{-2}) was found in S_3, while the minimum (65.83 m^{-2}) was recorded in S_1.

Table 17. Effect of plant spacing on weed population and weed dry matter of *boro* rice

Treatments	Weed population m^{-2} (No.) at		Weed dry matter (g m^{-2}) at	
	30 DAT	60 DAT	30 DAT	60 DAT
S_1	49.16 b	65.83	2.26	2.95
S_2	61.25 a	74.92	2.79	3.26
S_3	48.58 b	84.25	2.20	3.58
S_4	38.00 c	78.00	2.15	3.22
S_5	55.92 ab	74.58	2.49	3.07
$LSD_{(0.05)}$	9.09	NS	NS	NS
CV(%)	21.60	34.02	34.43	30.20

In a column, similar letter do not differ significantly at 0.05 level of probability

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

NS = Non significant

4.15.3 Interaction effect

Interaction effect of seedling age and plant spacing varied significantly for weed population at 30 and 60 DAT (Appendix IX and Table 18). At 30 DAT, the highest weed population (80.00 m^{-2}) was found in the treatment combination of A_1S_1 (12 days old seedling and 25 cm × 25 cm plant spacing) and the lowest weed population (31.00 m^{-2}) was found from A_3S_4 (16 days old seedling and 40 cm × 40 cm plant spacing). At 60 DAT, the highest weed population (106.33 m^{-2}) was found in the treatment combination of A_3S_5 (16 days old seedling and 25 cm × 15 cm plant spacing) and the lowest weed population (43.00 m^{-2}) was found in A_1S_5 (12 days old seedling and 25 cm × 15 cm plant spacing).

4.16 Weed dry matter

4.16.1 Seedling age

Non significant variation was recorded for weed dry matter m^{-2} at 30 and 60 DAT of *boro* rice for different seedling age (Appendix IX and Table 16). The results revealed that at 30 DAT, the maximum weed dry matter (2.73g m^{-2}) was recorded in A_1 (12 days old seedling) and the minimum weed dry matter (1.96 g m^{-2}) was found in A_2 (14 days old seedling). At 60 DAT, the maximum weed dry matter (3.44 g m^{-2}) was recorded in A_4 (30 days old seedling) and the minimum weed dry matter (2.93 g m^{-2}) was found in A_1 (12 days old seedling).

4.16.2 Plant spacing

Weed population m^{-2} of *boro* rice showed statistically non significant differences at 30 and 60 DAT due to the different plant spacing (Appendix IX and Table 17). At 30 DAT, the numerical maximum weed dry matter (2.79 g m^{-2}) was found in S_2 (30 cm × 30 cm), while the minimum weed dry matter (2.15 g m^{-2}) was recorded in S_4 (40 cm × 40 cm). At 60 DAT, the numerical maximum weed dry matter (3.58 g m^{-2}) was found in S_3 (35 cm × 35 cm), while the minimum weed dry matter (2.95 g m^{-2}) was recorded in S_1 (25 cm × 25 cm).

Table 18. Interaction effect of seedling age and plant spacing on weed population and weed dry matter of *boro* rice

Treatments	Weed population m^{-2} (No.) at		Weed dry matter (g m^{-2}) at	
	30 DAT	60 DAT	30 DAT	60 DAT
A_1S_1	80.00 a	51.33 de	2.73 a-d	2.48 ab
A_1S_2	56.67 b-d	59.00 b-e	2.33 b-d	2.82 ab
A_1S_3	59.33 b-d	76.00 a-e	2.79 a-d	3.13 ab
A_1S_4	45.67 d-g	98.33 a-c	2.41 a-d	3.94 a
A_1S_5	52.67 b-f	43.00 e	3.37 ab	2.29 b
A_2S_1	32.33 g	70.00 a-e	1.97 cd	3.49 ab
A_2S_2	56.00 b-e	52.33 de	1.79 d	2.30 b
A_2S_3	40.67 e-g	75.67 a-e	1.84 d	3.36 ab
A_2S_4	37.00 fg	60.00 b-e	1.94 cd	2.65 ab
A_2S_5	52.67 b-f	57.67 c-e	2.22 b-d	2.98 ab
A_3S_1	38.00 e-g	79.33 a-e	2.24 b-d	3.21 ab
A_3S_2	69.00 ab	87.33 a-d	3.75 a	3.85 ab
A_3S_3	46.33 d-g	88.00 a-d	1.76 d	3.84 ab
A_3S_4	31.00 g	81.00 a-e	1.77 d	3.12 ab
A_3S_5	64.67 a-c	106.33 a	2.00 cd	3.65 ab
A_4S_1	46.33 d-g	62.67 b-e	2.10 b-d	2.61 ab
A_4S_2	63.33 a-d	101.00 ab	3.26 a-c	4.07 a
A_4S_3	48.00 c-g	97.33 a-c	2.39 a-d	3.99 a
A_4S_4	38.33 e-g	72.67 a-e	2.47 a-d	3.17 ab
A_4S_5	53.67 b-f	91.33 a-d	2.35 b-d	3.37 ab
$LSD_{(0.05)}$	18.18	42.74	1.36	1.62
CV(%)	21.60	34.43	34.43	30.20

In a column, similar letter do not differ significantly at 0.05 level of probability

A_1= 12 days, A_2= 14 days, A_3= 16 days and A_4= 30 days old seedlings

S_1= 25 cm × 25 cm, S_2= 30 cm × 30 cm, S_3= 35 cm × 35 cm, S_4= 40 cm × 40 cm, S_5= 25 cm × 15 cm

4.16.3 Interaction effect

Interaction effect of seedling age and plant spacing showed significant differences for weed dry matter m^{-2} at 30 and 60 DAT of *boro* rice (Appendix IX and Table 18). At 30 DAT, the highest weed dry matter (3.75 g m^{-2}) was found in the treatment combination of A_3S_2 (16 days old seedling and 30 cm × 30 cm plant spacing) and the lowest weed dry matter (1.76 g m^{-2}) was observed in the treatment combination of A_3S_3 (16 days old seedling and 35 cm × 35 cm plant spacing). At 60 DAT, the highest weed dry matter (4.07 g m^{-2}) was found in the treatment combination of A_4S_2 (30 days old seedling and 30 cm × 30 cm plant spacing) and the lowest (2.29 g m^{-2}) was observed in the treatment combination of A_1S_5 (12 days old seedling and 25 cm × 15 cm plant spacing).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from December 2011 to May 2012 to study the growth and yield of *Boro* rice as affected by seedling age and planting geometry under System of Rice Intensification (SRI). BRRI dhan50 were used as the test crop of this experiment. The experiment comprised of two factors. Factor A: Seedling age (4 levels); A_1: 12 days old seedling, A_2: 14 days old seedling, A_3: 16 days old seedling & A_4: 30 days old seedling and Factor B: Plant spacing: (5 levels); S_1: 25 cm × 25 cm, S_2: 30 cm × 30 cm, S_3: 35 cm × 35 cm, S_4: 40 cm × 40 cm and S_5: 25 cm × 15 cm. The experiment was laid out in split-plot design with three replications. Data on different growth parameters, yield attributes and yield were recorded.

At 30 DAT, the longest plant (19.55 cm) was recorded in A_2 and the shortest plant (17.82 cm) in A_4. At 60 DAT, the maximum plant height (44.91 cm) was found in A_3, whereas the minimum plant height (43.30 cm) in A_1. At 90 DAT, the maximum plant height (65.59 cm) was observed in A_3, while the minimum plant height (64.07 cm) in A_4. The same trend of plant height was also observed at 110 DAT. At 30 DAT, the maximum number of tillers hill^{-1} (3.03) was recorded in A_2 and the minimum number (2.13) in A_4. At 60 DAT, the maximum number of tillers hill^{-1} (15.36) was found in A_2, whereas the minimum number (13.32) in A_4. At 90 DAT, the maximum number of tillers hill^{-1} (34.03) was observed in A_3, while the minimum number (32.77) in A_1. The same trend of number of tillers hill^{-1} was also observed at 110 DAT. At 30 DAT, the highest leaf area index (0.06) was recorded in A_3 and the lowest (0.04) in A_4. At 60 DAT, the highest leaf area index (0.847) was found in A_4, whereas the lowest (0.734) in A_3. At 90 DAT, the maximum leaf area index (5.19) was observed in A_3, while the minimum leaf area index (4.82) was recorded in A_1. At 110 DAT, the highest leaf area index (3.46) was observed in A_3, while the lowest (3.17) in A_2.

At 40 DAT, the highest dry matter hill^{-1} (5.46 g) was recorded in A_3 and the lowest (3.82 g) in A_4. At 70 DAT, the numerically maximum dry mater hill^{-1} (29.89 g) was found in A_2, whereas the minimum (27.18 g) was observed in A_1. At 100 DAT, the highest dry matter hill^{-1} (106.48 g) was observed in A_2, while the lowest (88.37 g) was recorded in A_4. The maximum number of effective tillers hill^{-1} (26.72) was recorded in A_4 and the minimum number (26.27) in A_3. The maximum number of ineffective tillers hill^{-1} (2.88) was recorded in A_3 and the minimum number (2.39) in A_2. The longest panicle (23.37 cm) was recorded in A_2 and the shortest panicle (22.92 cm) in A_3. The maximum number of filled grains panicle^{-1} (100.95) was recorded in A_2 and the minimum number (93.08) in A_1. The maximum number of unfilled grains panicle^{-1} (27.56) was recorded in A_3 and the minimum number (24.47) in A_4. The highest weight of 1000 grains (19.00 g) was recorded in A_2 and the lowest weight (18.15 g) in A_1. The highest grain yield (5.06 t ha^{-1}) was recorded in A_3 and the lowest (4.58 t ha^{-1}) in A_2. The highest straw yield (5.11 t ha^{-1}) was recorded in A_2 and the lowest (3.80 t ha^{-1}) in A_1. The highest biological yield (9.75 t ha^{-1}) was recorded in A_2 and the lowest (8.73 t ha^{-1}) in A_4. The highest harvest index (56.21%) was recorded in A_4 and the lowest (47.75%) in A_2. At 30 DAT, the highest weed population (58.87 m^{-2}) was recorded in A_1 and the lowest (43.73 m^{-2}) in A_2. At 60 DAT, the highest weed population (88.40 m^{-2}) was recorded in A_3 and the lowest (63.13 m^{-2}) in A_2. At 30 DAT, the highest weed dry matter (2.73g m^{-2}) was recorded in A_1 and the lowest (1.96 g m^{-2}) in A_2. At 60 DAT, the highest weed dry matter (3.44 g m^{-2}) was recorded in A_4 and the lowest (2.93 g m^{-2}) in A_1.

In consideration of planting geometry at 30 DAT, the maximum plant height (19.47 cm) was found in S_1, while the minimum plant height (18.49 cm) in S_4. At 60 DAT, the maximum plant height (44.99 cm) was recorded in S_2, while the minimum plant height (43.05 cm) in S_4. At 90 DAT, the longest plant height (65.98 cm) was observed in S_4, whereas the shortest plant height (63.85 cm) in S_5. At 110 DAT, the longest plant (76.92 cm) was recorded in S_3 and the shortest plant (75.17 cm) in S_1. At 30 DAT, the maximum number of tillers hill^{-1} (2.65) was found in S_1 and S_2, while the minimum number (2.38) in S_5. At 60 DAT, the maximum number of tillers hill^{-1} (15.30) was recorded in S_1, while the minimum number (13.20) in S_4. At 90 DAT, the maximum number of tillers hill^{-1} (42.38) was observed in S_3, whereas the minimum (22.70) in S_5. At 110 DAT, the maximum number of tillers hill^{-1} (44.03) was recorded in S_4 and the minimum (19.50) in S_5. At 30 DAT, the highest leaf area index (0.09) was found in S_5, while the lowest (0.02) in S_4. At 60 DAT, the highest leaf area index (1.23) was recorded in S_5, while the lowest (0.430) in S_4. At 90 DAT, the highest leaf area index (6.66) was observed in S_5, whereas the lowest leaf area index (4.14) was found in S_4. At 110 DAT, the highest leaf area index (4.49) was observed in S_5, whereas the lowest (2.45) in S_4. At 40 DAT, the highest dry matter hill^{-1} (10.44 g) was found in S_5, while the lowest (1.77 g) in S_4. At 70 DAT, the highest dry matter hill^{-1} (38.74 g) was recorded in S_3, while the lowest (14.77 g) was recorded in S_5. At 100 DAT, the highest dry matter hill^{-1} (156.18 g) was observed in S_4, whereas the lowest dry matter hill^{-1} (44.63 g) was found in S_5. The maximum number of effective tillers hill^{-1} (36.30) was found in S_4, while the minimum number (18.28) in S_5. The maximum number of ineffective tillers hill^{-1} (3.27) was found in S_4, while the minimum number (1.67) was recorded in S_5. The longest panicle length (23.42 cm) was found in S_2, while the shortest (22.05 cm) in S_5. The maximum number of filled grains panicle^{-1} (101.5) was found in S_5, while the minimum number (93.97) in S_1. The maximum number of unfilled grains panicle^{-1} (26.47) was found in S_4, while the minimum number (24.75) in S_2. The highest weight of 1000 grains (18.98 g) was found in S_2, while the lowest (17.86 g) in S_1. The highest grain yield (6.85 t ha^{-1}) was found in S_4, while the lowest (3.42 t ha^{-1}) in S_2. The highest straw yield (5.86 t ha^{-1}) was found in S_4, while the lowest (3.20 t ha^{-1}) in S_2. The highest biological yield (12.71 t ha^{-1}) was found in S_4, while the lowest (6.62 t ha^{-1}) in S_2. The highest harvest index (54.47%) was found in S_4, while the lowest (50.28%) in S_5. At 30 DAT, the highest number of weed population (61.25 m^{-2}) was found in S_2, while the lowest (38.00 m^{-2}) in S_4. At 60 DAT, the highest number of weed population (84.25 m^{-2}) was found in S_3, while the lowest (65.83 m^{-2}) in S_1. At 30 DAT, the highest weed dry matter (2.79 g m^{-2}) was found in S_2, while the lowest (2.15 g m^{-2}) in S_4. At 60 DAT, the highest weed dry matter (3.58 g m^{-2}) was found in S_3, while the lowest (2.95 g m^{-2}) in S_1.

In case of interaction effect of seedling age and planting geometry, at 30 DAT, the longest plant (21.82 cm) was found in the treatment combination of A_3S_1 and the shortest plant (16.85 cm) in A_1S_5. At 60 DAT, the longest plant (46.43 cm) was found in the treatment combination of A_3S_2 and the shortest plant (40.69 cm) in A_1S_4. At 90 DAT, the longest plant (69.07 cm) was found in the treatment combination of A_3S_2 and the shortest plant (63.00 cm) in A_4S_2. At 110 DAT, the longest plant (78.42 cm) was found in the treatment combination of A_1S_3 and the shortest plant (71.43 cm) in A_2S_1. At 30 DAT, the maximum number of tillers hill^{-1} (3.33) was found in the treatment combination of A_2S_4 and the minimum number (1.87) in A_1S_5. At 60 DAT, the maximum number of tillers hill^{-1} (18.40) was found in the treatment combination of A_3S_1 and the minimum number (11.73) in A_1S_5. At 90 DAT, the maximum number of tillers hill^{-1} (44.53) was found in the treatment combination of A_2S_3 and the minimum number (20.73) in A_3S_5. At 110 DAT, the maximum number of tillers hill^{-1} (50.93) was found in the treatment combination of A_3S_4 and the minimum number (18.87) in A_2S_5. At 30 DAT, the highest leaf area index (0.141) was found in the treatment combination of A_3S_1 and the lowest leaf area index (0.020) in A_4S_4. At 60 DAT, the highest leaf area index (1.552) was found in the treatment combination of A_2S_5 and the lowest (0.332) in A_1S_3. At 90 DAT, the highest leaf area index (7.33) was found in the treatment combination of A_2S_5 and the lowest leaf area index (3.38) was observed in A_2S_4. At 110 DAT, the highest leaf area index (4.87) was found in the treatment combination of A_1S_5 and the lowest leaf area index (1.96) in A_4S_4. At 40 DAT, the highest dry matter hill^{-1} (11.79 g) was found in the treatment combination of A_2S_5 and the lowest (1.28 g) in A_3S_4. At 70 DAT, the highest dry matter hill^{-1} (52.56 g) was found in the treatment combination of A_1S_4 and the lowest dry matter hill^{-1} (9.90 g) was observed in the treatment combination of A_1S_1. At 100 DAT, the highest dry matter hill^{-1} (164.55 g) was found in the treatment combination of A_2S_4 and the lowest (37.03 g) was observed in the treatment combination of A_1S_5. The maximum number of effective tillers hill^{-1} (39.20) was found in the treatment combination of A_1S_4 and the minimum number (16.20) in A_1S_5. The maximum number of ineffective tillers hill^{-1} (3.93) was found in the treatment combination of A_1S_4 and the minimum number (1.53) in

A_3S_5. The longest panicle (23.90 cm) was found in the treatment combination of A_2S_2 and the shortest (22.38 cm) in A_3S_1. The maximum number of filled grains panicle^{-1} (108.97) was found in the treatment combination of A_2S_4 and the minimum number (84.60) in A_3S_1. The maximum number of unfilled grains panicle^{-1} (30.87) was found in the treatment combination of A_3S_1 and the minimum number (22.63) in A_4S_1. The highest weight of 1000 grains (19.69 g) was found in the treatment combination of A_4S_4 and the lowest weight (17.29 g) in A_3S_3. The highest grain yield (7.11 t ha^{-1}) was found in the treatment combination of A_3S_4 and the lowest grain yield (3.21 t ha^{-1}) in A_4S_2. The highest straw yield (6.86 t ha^{-1}) was found in the treatment combination of A_3S_4 and the lowest straw yield (2.70 t ha^{-1}) in A_3S_2. The highest biological yield (13.96 t ha^{-1}) was found in the treatment combination of A_3S_4 and the lowest (6.09 t ha^{-1}) in A_4S_2. The highest harvest index (59.06%) was found in the treatment combination of A_3S_2 and the lowest (44.96%) in A_2S_3. At 30 DAT, the highest weed population (80.00 m^{-2}) was found in the treatment combination of A_1S_1 and the lowest weed population (31.00 m^{-2}) in A_3S_4. At 60 DAT, the highest weed population (106.33 m^{-2}) was found in the treatment combination of A_3S_5 and the lowest (43.00 m^{-2}) in A_1S_5. At 30 DAT, the highest weed dry matter (3.75 g m^{-2}) was found in the treatment combination of A_3S_2 and the lowest (1.76 g m^{-2}) in A_3S_3. At 60 DAT, the highest weed dry matter (4.07 g m^{-2}) was found in the treatment combination of A_4S_2 and the lowest (2.29 g m^{-2}) in A_1S_5.

Considering the findings of the present experiment, following conclusion may be drawn:

1. Lower seedling age of rice planted in wider spacing (SRI) revealed higher grain yield compared to that a conventional practice.

2. Before recommendation of seedling age and planting geometry to optimize *boro* rice production further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

REFERENCES

Akanda, W. (2003). SRI Extension through Department of Agricultural Extension. Report on National Workshop 2003 on System of Rice Intensification (SRI) Sub-Project of IRRI/PETRRA. 24th Dec. [http://ciifad.cornell.edu/sri/countries/bangladesh/bangriwspds.pdf].

Akbar, M.K. (2004). Response of hybrid and inbred rice varieties to different seedlings ages under system of rice intensification in transplant aman season. M.S. (Ag.) Thesis. Dept. Agron., BAU, Mymensingh.

Alauddin, M.H. (2004). Effect of methods of transplanting and seedlings per hill on the growth and yield of transplant aman rice cv. BRRI dhan39. M. Sc. (Ag) Thisis. Dept. of Agronomy. BAU, Maymensingh.

Ali, M.A., Ladha, J.K., Rickman, J. and Lales, J.S. (2006). Comparison of different methods of rice establishment and nitrogen management strategies for lowland rice. *J. Crop Improv*. **16**(1/2): 173-189.

Anbumani, S., Rajendran, K. and Kuppuswamy, G. (2000). Effect of planting methods and NPK levels on rice and rice fallow crops in single rice based cropping system. *J. Ecobiol*. **12**: 313-315.

Anonymous. (1992). Performance of Rice Hybrids under Bangladesh conditions. 1998-99 Boro Season. Agricultural Advisory Society (AAS). [www.knowledge bank.irri.org/regionalsites/bangladesh/docs/aas/performancericehybrid.doc].

Anonymous. (2001). More rice from less spacing. New Agriculturist. [http://www.new-agri.co.uk/01-4/newsbr.html].

Anonymous. (2004). Agricultural technologies for rural poverty alleviation. Jan. Report no. 13. M. Z. Abedin and M. R. L. Bool, (*eds.*). Flood-prone Rice Farming Systems Series. Technical Advisory Notes. IRRI. [www.irri.org/publications/ techbulletin/pdfs/technicaladvisorynotes.pdf].

Anonymous. (2005). Rice cultivation using drum seeder profitable. The Independent. [http://www.independent-bangladesh.com/news/jun/25/25062005ct.htm].

Ashraf, M. and Mahmood, S. (1989). Effect of seedling on Basmati growth and yield *Int. Rice Res. Newsl*. **14**(1): 8.

Aziz, M.B. and Hasan, R. (2000). Evaluation of System of Rice Intensification (SRI) in Bangladesh. Locally Intensified Farming Enterprises Project, CARE, Bangladesh. pp. 4-9.

Balasubramaniyan. P. (1987). Performance of long duration CR 1009 with aged seedlings. *Intl. Rice Res. Newsl*. **12**(4): 59.

Banarjee, R.N.S., Adhikary, B.K. and Bagchi, D.K. (1992). Effect of different cultural practices on long duration aman rice (*Oryza sativa)* in Bihar plateau. *Indian J. Agron*. **37**(2): 346-347.

Bari, S.M.W. (2004). Effect of method of planting and weeding on the yield and yield contributing characters of aman rice cv. BRRI dhan32. M.S. (Ag.) Thesis. Dept. Agron., BAU, Mymensingh.

Bautista, E.U. and Gagelonia, E.C. (1994). Rice Drum seeder Technology. Los Banos. **16**: 1-24.

Bhattacharya, P.C. (1993). Performance of tiller transplanted aman rice under different planting densities. M.S. (Ag.) Thesis. Dept. Agron., BAU, Mymensingh.

Bhuiyan, N.I., Paul, D.N.R. and Jabber, M.A. (2002). Feeding the extra millions by 2025-chalenges for rice research and extension in Bangladesh. A keynote paper presented on national workshop on rice research and extension. Jan. 29-31. BRRI. p. 9.

Biswas, P.K. and Salokhe, V.M. (2001). Effects of planting date, intensity of tiller separation and plant density on the yield of transplanted rice. *J. Agril. Sci. Camb.* **137**(3): 279-287.

Bo, I.M. and Min, H. (1995). Wet-seeded rice in Myanmar. Constraints, opportunities and innovations for wet-seeded rice. K. Moody (ed.). Intl. Rice Res. Inst., Manila, Philippines. pp. 59-62.

BRRI (Bangladesh Rice Research Institute). (2012). Adhunik Dhaner Chash. Joydebpur, Dhaka. p.10.

BRRI. (1981). Annual Report for 1978-79. Bangladesh Rice Research Institute. Joydebpur, Gazipur. p.13.

BRRI. (1983). Annual Report for 1982. Bangladesh Rice Research Institute. Joydebpur, Gazipur. p.16.

BRRI. (1985). Annual Report for 1984. Bangladesh Rice Research Institute Bangladesh. Joydebpur, Gazipur. pp.79-88.

BRRI. (1986). Annual Report for 1982. Bangladesh Rice Research Institute Bangladesh. Joydepur, Gazipur. pp. 3-4.

BRRI. (1991). Annual Internal Review for 1990-1991. Crop Soil Water Management Program. Agronomy Division. Bangladesh Rice Research Institute. Joydepur, Gazipur, Bangladesh. pp. 4-19.

BRRI. (2003). Adhunik Dhaner Chash (In bangle) 10th edition. Bangladesh Rice Research Institute, Joydepur, Gazipur. Booklet No. 5, pp.10-11.

Bruno, A. (2001). SRI experimentation in the Fianarantsoa region of Madagascar, FOFIFA Fianarantsoa. [www.ciifad.cornell.edu/sri/countries/madagascar.pdf].

Budhar, M.N. and Tamilselvan, N. (2001). Evaluation of stand establishment techniques in lowland irrigated rice. *Intl. Rice Res. Notes.* **26**(2): 72-73.

Cessay, M., Reid, W.S., Fernanades, E.C.M. and Uphoff, N.T. (2006). The effect of repeated soil wetting and drying on low land rice yield with System of Rice Intensification (SRI) methods. *Intl. J. Agril. Sust.* **4**(1): 5-14.

Chowhan, G. (2003). Verification and refinement of the System of Rice Intensification (SRI) project in selected areas of Bangladesh. Report on National Workshop 2003 on System of Rice Intensification (SRI) Sub-Project of IRRI/PETRRA. [http://ciifad.cornell.edu/sri/countries/bangladesh/ pdf].

DAE. (1992). Crop Production Manual through irrigation, Department of Agricultural Extension Khamarbari, Farmgate, Dhaka. pp.2-4.

Das, L. (2003). Verification and refinement of the System of Rice Intensification in selected areas of Bangladesh. Trial Monitoring Report. SAFE Development Group. [http://ciifad.cornell.edu/sri/countries/bangladesh/bangpetfrep.pdf].

Datta, M. and Goutam, R.C. (1988). Effect of seedling age and Zn application on yield of rice. *Intl. Rice Res. Newsl*. **13**(5): 29-30.

De Datta, S.K. (1981). Principles and Practices of Rice Production. Jhon Willey and Sons Inc, New York. p.102.

De Datta, S.K. and Nantasomsaran, P. (1991). Status and prospects of direct-seeded flooded rice in tropical Asia. In: Direct seeded flooded rice in the tropics. Intl. Rice Res. Inst., P. O. Bus 933. Manila. Philippines, pp.1-16.

Deichert, G. and Yang, S.K. (2002). Challenges to organic farming and sustainable land use in the tropics and subtropics. Experiences with System of Rice Intensification (SRI) in Cambodia. Conference on International Agricultural Research for Development. Deutscher Tropentag, Oct. 9-11. Witzenhausen. [http://www. tropentag.de/2002/abstracts/links/deichert_uvsfvyfm.php].

Devarajan, P. (2005). The foreign hand in Agartala. Financial Daily from The Hindu group of publications.

Dwivedi, D.K., Kumar, A., Singh, K.N. and Kumar, A. (1996). Efficacy of different rice planting methods under mid-upland ecosystem. *J. Appl. Biol.* **6**(1-2): 128-130.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p.118.

Elahi, N.E., Shaha, A., Bose, G.K. and Razzaque, M.A. (1995). Productivity of BR varieties as transplanted and direct wet-seeded late aman crop under rainfed conditions. *Bangladesh J. Agril. Sci.* **22**(2): 291-294.

FAO (Food and Agriculture Organization). (2009). FAO Production Yearbook, Food and Agriculture Organization, Rome, Italy. 63-78.

FAO. (1988). Production Year Book. Food and Agricultural Organizations of the United Nations Rome, Italy. **42**: 190-193.

Ganajaxi, A.V.V. and Rajkumara, S. (2000). Studies to develop appropriate techniques for growing direct seeded rice. *Adv. Agril. Res. India.* **13**: 197-200.

Garcia, F.V., Peng, S. and Cassaman, K.G. (1995). Yield potential of transplanted and wet seeded rice in high yield environments in the Philippines. In: Constraints, Opportunities and Innovations for Wet Seeded Rice. K. Moody (ed.). Intl. Rice Res. Inst., Philippines. pp.246-256.

Goel, A.C. and Verma, K.S. (2000). Comparative study of direct seeding and transplanting of rice. *Indian J. Agril. Res.* **34**(3): 194-196.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., *A Willey Int. Sci.*, pp.28-192.

Haden, V.R., Duxbury, I.M., DiTommaso, A. and Losey, J.E. (2007). Weed community dynamics in the system of rice intensification (SRI) and the efficacy of mechanical cultivation and competitive rice cultuvars for weed control on Indonesia. *J. Sust. Agril. Tech.* **1** (4): 21-29.

Hameed, K.A., Mosa, A.K.J. and Jaber, F.A. (2011). Irrigation water reduction using System of Rice Intensification compared with conventional cultivation methods in Iraq. *Paddy Water Environ.,* **9**(1): 121-127.

Harun, M. Eusuf, M.A., Mannan; M.R., Islam; B.A.A., Mustafi, A. and Siddique, S.B. (1991). Economic impact of seedling age of irrigated Rice. *Bangladesh Rice J*. **2**(1&2): 90-95.

Hien, N.L., Yoshihashi T. and Sarhadi, W.A. (2006). Evaluation of aroma in rice (*Oryza sativa* L.) using KOH method, molecular markers and measurement of 2-acetyl-1-pyrroline concentration. *Japanese J. Trop. Agric*. **50**:190-198.

Hirsch, R. (2000). La riziculture malgache revisitee: Diagnostic et perspectives (1993-1999). Antananarivo: Agence Francaise de Development.

Hong, C.S. and Park, P.S. (1992). Economic analysis on the demonstration farm for direct seeding of rice. Research Reports of the Rural Development Administration, Farm Management, Agricultural Engineering, Sericulture, and Farm Products Utilization. **34**(2): 1-8.

Hoon, J. and Kim, Y.K. (1997). Analysis of physiological and ecological characteristics of rice cultivated with direct seeding on dry paddy field. *Japanese J. Crop Sci.* **66**(3): 442-448.

Horie, T. (2004). Can yields of lowland rice resume the increases that they showed in the 1980s? New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress. Brisbane, Australia, 26 Sep. [http://www. cropscience.org.au/icsc2004/symposia/2/4/1869_horiet.htm].

Hossain, M. and Deb, U.K. (2003). Liberalization of Rice Sector: Can Bangladesh withstand Regional Competition? Poster paper presented at PETRRA Communication Fair 2003 held at Hotel Sheraton, Dhaka on Aug. 10-11.

Hossain, M.Z., Hossain, S.M.A., Anwar, M.P., Sarker, M.R.A. and Mamun, A.A. (2003). Performance of BRRI dhan32 in SRI and Conventional Methods and Their Technology Mixes. *Pakistan J. Agron.* **2**(4): 195-200.

Hossain, S.M.A. and Alam, A.B.M. (1991). Performance of different varieties of boro rice. In: Fact Searching and Intervention in two FSDP Sites. Activities 1989-90. Farming Syst. Res. and Dev. Prog. BAU, Mymensingh. pp. 19-20.

Husain, A.M.M., Barua, P. and Halder, S.R. (2003). Verification and refinement of the System of Rice Intensification (SRI) project in selected areas of Bangladesh. Trial Monitoring Survey Report on Chatkhil and Begumgonj in Noakhali District. BRAC. [http://ciifad.cornell.edu/sri/countries/bangladesh/ bangtrmon 03.pdf].

Islam, K.A. (1999). SRI - A Revolution Rice Production. Training Unit, GOLDA Project, CARE-Bangladesh. pp. 1-23.

Johnkutty, I., Mathew, G. and Mathew, J. (2002). Comparison between transplanting and direct seeding methods for crop establishment in rice. *J. Trop. Agril.* **40**(1/2): 65-66.

Kabir, H. and Uphoff, N. (2007). Results of disseminating the system of rice intensification with farmer field school methods in northern Myanmar. *Expt. Agril*. **43** (4): 463-476.

Karmakar, B., Ali, M.A., Mazid, M.A., Duxbury, J. and Meisner, C.A. (2004). Validation of System of Rice Intensification (SRI) practice through spacing, seedling age and water management. *Bangladesh Agron. J.* **10**(1&2): 13-21.

Kavitha, M.P., Ganesaraja, V., Paulpandi, V.K. and Subramanian, R.B. (2010). Effect of age of seedlings, weed management practices and Humic acid application on System of Rice Intensification. *Indian J. Agric. Res*. **44**(4): 294 – 299.

Kosta, L.D., Sachindanand, B., Raghu, J.S. and Upadhyaya, V.P. (1982). Effect of seedling age and soil submergence on the performance of paddy. *Oryza*. **24**(3): 226-230.

Kosta, P.J., Singh, H., Randhawa H.S., Joshi, D.P. and Ganneja, M.R. (1987). Sequential tiller separation- a method for rapid rice seed multiplication. *Intl. Rice Res. Newsl*. **12**(6): 9-15.

Krishna, A. and Biradarpatil, N.K. (2009). Influence of seedling age and spacing on seed yield and quality of short duration rice under systemof rice intensification cultivation. *Karnataka J. Agri. Sci*. **22**(1): 53-55.

Krishna, A., Biradarpatil, N.K., Manjappa, K. and Channappagoudar, B.B. (2008). Evaluation of System of Rice Intensification Cultivation, Seedling Age and Spacing on Seed Yield and Quality in Samba Masuhri (BPT-5204) Rice. *Karnataka J. Agri. Sci.* **21**(1): 20-25.

Kundu, D.K., Rao, K.V. and Pillai, K.G. (1993). Comparative yields and uptake in six transplanted and direct seeded low-land rice. *Intl. Rice Res. Notes*. **18**(3): 29-30.

Lal, P., Goutam, R.C. and Bisht, P.S. (1981). Success with old rice seedling. *Int. Rice Res. Newsl*. **6**(3): 26.

Latif, M.A., Islama, M.R., Alia, M.Y. and Salequeb, M.A. (2005). Validation of the system of rice intensification (SRI) in Bangladesh. *Field Crops Res.* **93**(2-3): 281-292.

Laulanie, H. (1993). Le systeme de riziculture intensive malgache. *Tropicultura (Brussels).* **11**: 110-114.

Longxing, T., Xi, W. and Shaokai, M. (2002). Physiological effects of SRI methods on the rice plant. China National Rice Res. Inst., Hangzhou. [http://ciifad.cornell.edu/sri/proc1/sri_29.pdf].

Mallick, A.H. (1994). Tiller removal and double transplanting effects on yield and grain filling characteristics of aman rice. M.S. (Agronomy) Thesis. Department of Agronomy, The Institute of Postgraduate Studies in Agriculture, Salna, Gazipur.

Mannan, M.A. Rahman, M.B., Choudhury, A.A. and Siddique, S.B. (1991). Yield of modern irrigated rice varieties under different population dynamics. *Bangladesh Rice J*. **2** (1&2): 59-62.

Maqsood, M., Hussain, A. and Akbar, N. (1997). Effect of planting methods and variable rates of nitrogen application on yield and components of yield of aman rice. *Pakistan J. Agric. Sci*. **34**(1-4): 89-93.

Martin, Y., Soto, F., Rodriguez, Y.E. and Morejon, R. (2010). The intensive rice growth system reduces seed amount for sowing, increases plant yields and saves irrigation water. *Cultivos Tropicales*. **31**(1): 70-73.

Matsuo, T. and Hoshikawa, K. (1993). Science of the rice plant. Vol. 1 (morphology). Food and Agriculture policy Research Center, Tokyo, Japan. p. 686.

Maurya, D.M. and Yadav, M.P. (1987). Performance of overage seedlings at different N levels. *Intl. Rice Res. Newsl*. **12**(4): 9.

Mazid, M.A., Karmakar, B., Meisner, C.A. and Duxbury, J.M. (2003). Validation of the System of Rice Intensification (SRI) through water management in conventional practice and bed-planted rice as experienced from BRRI Regional stations. Report on National Workshop 2003 on System of Rice Intensification (SRI) Sub-Project of IRRI/PETRRA. 24th Dec. [http://ciifad.cornell.edu/sri/countries/bangladesh/bangriwspds03.pdf].

McDonald, A.J., Hobbs, P. and Riha, S. (2005). Does the System of Rice Intensification outperform conventional best management? A synopsis of the empirical record. Reflections on Agricultural Development Projects. [http://crops.confex.com/crops/2005am/techprogram/p8132.htm].

McHugh, O.V., Steenhuis, T.S., Barison, J., Fernandes, E.C.M. and Uphoff, N.T. (2002). Farmer implementation of alternate wet-dry and nonflooded irrigation practices in the System of Rice Intensification (SRI). Proceedings of a thematic workshop on water-wise rice production, 8-11 April at IRRI headquarters in Los Banos, Philippines.

Mishra, A., Whitten. M., Ketelaar, J.W. and Salokhe, V.M. (2006). The system of rice intensification (SRI): a challenge for science and opportunity for farmers empowerment towards sustainable agriculture. *Intl. J. Agril. Sust*. **4** (3): 193-212.

Miyagawa, S., Konchan, S. and Kono, Y. (1998). Yielding ability in direct seeding rice culture in Northeast Thailand. *Japanese J. Trop. Agril.* **42**(4): 248-256.

Mondal, B.K. and Roy, P.K. (1984). Effect of age of seedling and nitrogen level on the growth and yield of Mashuri. *Indian J. Pl. physiol*. **27**(3): 303-306.

Nagappa, D.N. and Biradar, D.P. (2002). Drum seeding of sprouted rice seed in a farmer's field: an economic analysis. *Intl. Rice Res. Notes.* **27**(1): 54-55.

Naklang, K., Fukai, S. and Nathabut, K. (1996). Yield attributes in direct sowing than transplanting in low land conditions *Field Crops Res.* **48**(2-3): 115-123.

Naklang, K., Fukai, S., Cooper, M. and Salisbury, J. (1997). Direct seeding for rainfed lowland rice in Thailand. Breeding strategies for rainfed lowland rice in drought-prone environments: Proceedings of an International Workshop, Ubon Ratchathani, Thailand, 5-8 Nov. ACIAR Proceedings. **77**: 126-136.

Nissanka, S.P. and Bandara, T. (2004). Comparison of productivity of system of rice intensification and conventional rice farming systems in the dry-zone region of Sri Lanka. New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress. Brisbane, Australia, 26 Sep. 1 Oct. [http://www.cropscience.org.au/icsc2004/poster/1/2/1177_nissankara.htm].

Ogura, A. (2002). A new farming system based on no-tillage direct sowing and transplanting technology using long mats of hydroponically grown rice seedlings. *J. Japanese Soc. Agril. Machinery*. **64**(4): 14-16.

Padalia, C.R. (1981). Effect of age of seedlings on the growth and yield of transplanted rice. *Oryza*. **18**(3): 165-167.

Paris, T.R. and Chi, T.T.N. (2005). The impact of row seeder technology on women labor: A case study in the Mekong Delta, Vietnam. Gender. *Technol. Develop*. **9**(2): 157-184.

Park, P.S., Kim, S.Y. and Jo, S.J. (1995). Economic analysis on the direct seeding in rice cultivation. *RDA J. Agril. Sci.*. **37**(1): 568-577.

Park, S.T., Kim, S.C., Lee, S.K. and Chung, G.S. (1989). Rice growth and yield for direct seeding of rice in the Southern area. Research Reports of the Rural Development Administration, *Rice*. **31**(4): 36-42.

Paul, S.K., Sarkar, M.A.R. and Ahmed, M. (2003). Leaf production, leaf and culm dry matter yield of transplant aman rice as affected by row arrangement and tiller separation. *Asian J. Plant Sci.* **2**(2): 161-166.

Rafaralahy, S. (2002). An NGO perspective on SRI and its origin in Madagascar. In: Assessments of the System of Rice Intensification SRI): Proceedings of the International Conference, Sanya, China, April 1-4, 2002. pp. 17-22.

Rahman, M.M. (2001). Effect of seedling age and spacing on the productivity of hybrid rice Sonarbangla-1. M.S. Thesis, Dept. Agron., BAU, Mymensingh.

Rajaonarison, J.D.D. (2000). Preliminary results of factorial analysis of SRI yield components in Morondave region. Personal communication of data from research from mémoire de fin d'études. Ántananarivo: Ecole Supérieure des Science Agronomiques, Univ. Antananarivo.

Rajkhowa, D.J. and Gogoi, A.K. (2004). Effect of planting methods and weed management on transplanted summer rice. *Indian J. Weed Sci.* **36**(1/2): 119-121.

Rajput, R.L. and Yadav, K.S. (1993). Effect of different planting methods on yield and yield attributes of aman rice in Chattisgarh Plains of Madhya Pradesh. *Bhartiya Krishi Anusandhan Patrika*. **8**(1): 47-52.

Rao, R.V., Satyanarayana, V. and Reddy, G.H.S. (1981). Studies on the effect of local method of planting as compared to transplanting in 15 cm × 10 cm spacing on growth and yield of rice under puddle condition. *Andhra Agric. J*. **21**(1): 87-91.

Rao, S.P. (1990). Influence of sequential planting of tillers on high density grain in rice. *Oryza.* **27**(3): 331-333.

Reddy, G.K. (2005). More rice with fewer inputs. Education Plus Visakhapatnam. Online Edn of India's National Newspaper. Mon. Mar. 14. [www.hindu.com/edu/2005/03/14/stories/2005031408320500.htm].

Reddy, T.M.M., Raghavolu, A.V., Ramaiah, N.V. and Reddy, G.V. (1987). Effect of methods of planting and nitrogen levels on growth, yield attributes and yield of aman rice under late conditions. *J. Res. APAU.* **15**(1): 56-58.

Roknuzzaman, M. (1997). Effect of row management and number of seedling per hill on the growth and yield of transplanted rice cv. BR 11. M.S.(Ag.) Thesis. Dept. Agron., BAU, Mymensingh. p.41.

Roy, S.K., Biswas, P.K. and Quasem, A. (1992). Effects of tiller removal and replanted tillers on the yield of the main and the subsequent rice crops. *Bangladesh J. Agril.* **15**(1): 11-18.

Saina, T. (2001). More rice with less water. *Approp. Technol.* **28**(3): 8-11.

Sarkar, R.K., Sanjukta, D. and Das, S. (2003). Yield of rainfed lowland rice with medium water depth under anaerobic direct seeding and transplanting. *Trop. Sci*. **43**(4): 192-198.

Sarker, G., Rahman, M., Hassan, R. and Roy, S.C. (2002). System of Rice Intensification; Yield and economic potential in boro rice at different locations of Bangladesh. LIFE-NOPEST Project, CARE-Bangladesh. pp.1-5.

Sattar, M.A. and Khan, M.A.K. (1995). An assessment of the wet-seeded rice cultivation method in Bangladesh. Constraints, opportunities and innovations for wet-seeded rice. K. Moody (ed.). Intl. Rice Res. Inst., Manila, Philippines. pp.186-198.

Sattar, S.A., Rashid H.A. and Islam, A.J.M.A. (1986). Effect of seed rate and seedbed management on seedling quality and its carryover effect on rice production. *Bangladesh J. Bot*. **15**(1): 33-39.

Satu, S. (2006). An evaluation of the System of Rice Intensification (SRI) in eastern Indonesia for its potential to save water while increasing productivity and profitability. Paper for International Dialogue on Rice and Water: Exploring Options for Food Security and Sustainable Environments, held at IRRI, Los Banos, Philippines, Mar. 7-8.

Sheehy, J.E., Peng, S., Dobermann, A., Mitchell, P.L., Ferrer, A., Yang, J., Zou, Y., Zhong, X. and Huang, J. (2004). Fantastic yields in the system of rice intensification: fact or fallacy? *Field Crops Res.* **88**(1): 1-8.

Singh, K.K., Yadav, S.K., Tomar, B.S., Singh J.N. and Singh, P.K. (2004). Effect of seedling age on seed yield and seed quality attributes in rice cv. Pusa Basmati-1. *Seed Res*. **32**: 5-8.

Sorour, S.G.R., El Keredy, M.S., Mosalem, M.E. and Hegazy, A.M. (1998). Evaluation of planting methods on two rice cultivars Proceedings, Seventh conference of agricultural development research, Cairo, Egypt, 15-17 Dec. Volume 3. *Annals Agril. Sci*. Special issue. pp. 645-661.

Sridhara, C.J., Ramachandrappa, B.K., Kumarswamy, A.S. and Gurumurthy, K.T. (2011). Effect of genotypes, planting geometry and methods of establishment on root traits and yield of aerobic rice. *Karnataka J. Agric. Sci.* ***24***(2):129-132.

Stoop, W.A., Uphoff, N. and Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. *Agril. Sys.* **71**:(3): 249-274.

Subbaiah, S.V., Balasubramanian, V. and Krishnaiah, K. (2002). Evaluation of drum seeder in puddled rice fields. *AMA, Agril. Mech. Asia, Africa Latin America*. **33**(4): 23-26.

Sundersingh, K.K., Subramanium, A. and Kolandaisamy, S. (1983). Studies on methods of planting under different levels of nitrogen and their influence on yield of IR8 rice. *Madas Agric. J.* **7**(8): 741-745.

Supaad. M.A. and Cheong, A.W. (1995). Wet seeded cultivations m the North-west Selangor project, Malaysia. In: Constraints, opportunities and innovations for wet seeded rice. K. Moody (ed.). Intl. Rice Res. Inst., Manila, Philippines. pp. 6-21.

Talukder, M.A.B.H. (1996). Performance of transplanted and direct wet seeded rice in late aman season. M.S. Thesis. Dept of Agronomy, BAU, Mymensingh.

Thakur, A. K., Uphoff, N. and Antony, E. (2010). An assessment of physiological effects of System of Rice Intensification (SRI) practices compared with recommended rice cultivation practices in India. *Expt. Agri*. **46** (1): 77-98.

Tohiduzzaman (2011). Screening of rice varieties responsive to system of rice intensification (sri) in *boro* season. M. Sc. (Ag) Thesis. Dept. of Agronomy. Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Uphoff, N. (1999). Agroecological implications of the System of Rice Intensification (SRI) in Madagascar. *Envir. Dev. Sus*. **1**(3-4): 297-313.

Uphoff, N. (2002). Questions and answers about the system of rice intensification (SRI) for raising the productivity of land, labor, and water. CIIFAD Writings on SRI. [http://ciifad.cornell.edu/sri/qanda.pdf].

Uphoff, N. (2004). SRI - the system of rice intensification: an opportunity for raising productivity in the 21st century. Paper for the International Year of Rice Conference, FAO, Rome, Feb. 12-13. [http://www.earthinstitute.columbia.edu/ cgsd/documents/uphoff.pdf].

Uphoff, N. (2005). Agroecologically sound agricultural systems: Can they provide for the world's growing populations? The global food & product chain-dynamics, innovations, conflicts, strategies. Deutscher Tropentag, Oct. 11-13. Hohenheim. [www.tropentag.de/2005/abstracts/links/uphoff_sdkbqnqq.pdf].

Valarmathi, G. and Leenakumary, S. (1998). Performance analysis of high yielding rice varieties of Kerala under direct seeded and transplanted condition. *Crop Res. Hisar.* **16**(2): 284-286.

Vallois, P. (1996). Discours de la methode du riz: Rapport sur la nouvelle riziculture Malgache, considérée sous ses aspects techniques, théoriques, economiques, sociologiques et culturelles. Institut de Promotion de la Nouvelle Riziculture. 3ème Edn. [http://www.anthropologieenligne.com/pages/rizm.html].

Varughese, A., Nair, S.S. and Pillai, K.B. (1993). Transplanting rice by broadcasting seedlings. *Kerala J. Agril. Sci.* **31**(2): 252-258.

Venkatachalapathy, V. and Veerabadran, V. (2002). Technical package for lowland direct seeded rice. *J. Ecobiol.* **14**(1): 43-50.

Wang, S., Cao, W., Jiang, D., Dai, T. and Zhu, Y. (2002). Physiological characteristics and high-yield techniques with SRI rice. In: Assessments of the System of Rice Intensification. Proc. Intl. Conf., Sanya, Chaina. Apr. 1-4. pp. 116-124.

Ye, D.C. and Ye, D.C. (1997). Utilization of tillers in early hybrid rice with different planting methods. *China Rice*. **2**: 13-15.

Yoshida, S. (1981). Fundamentals of Rice Crop Science, IRRI, Philipines. pp. 1-41.

Zheng, J., Lu, X., Jiang, X. and Tang, Y. (2004). The System of Rice Intensification (SRI) for super-high yields of rice in Sichuan Basin. New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep-1 Oct. [http://cropscience.org.au/icsc2004/poster/2/3/319_zhengjg.htm].

APPENDICES

Appendix I. Physical characteristics of field soil analyzed in Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine of the experimental site during the period from December 2011 to May 2012

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
December, 2011	22.4	13.5	74	00	6.3
January, 2012	24.5	12.4	68	00	5.7
February, 2012	27.1	16.7	67	30	6.7
March, 2012	31.4	19.6	54	11	8.2
April, 2012	34.2	23.4	61	112	8.1
May, 2012	34.7	25.9	70	185	7.8

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Means square values for plant height of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*			
		30 DAT	*60 DAT*	*90 DAT*	*110 DAT*
Replication	2	26.3063	8.05450	14.3055	20.8708
Seedling age (A)	3	7.36253*	8.18819^{NS}	6.70863^{NS}	5.90036^{NS}
Error (a)	6	2.69283	19.3201	6.54782	4.61185
Plant spacing (S)	4	2.08244^{NS}	8.62196^{NS}	9.02600*	5.23795^{NS}
A×S	12	4.27145*	7.35355*	8.77084*	8.75987*
Error (b)	32	5.85833	10.4830	4.95140	9.63857

* Significant at 5% level; NS = Non significant

Appendix IV. Means square values for number of tillers hill^{-1} of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*			
		30 DAT	*60 DAT*	*90 DAT*	*110 DAT*
Replication	2	4.87467	26.7440	241.262	214.536
Seedling age (A)	3	2.09244*	8.59911^{NS}	5.32156^{NS}	33.9659^{NS}
Error (a)	6	0.495111	24.6658	35.1642	37.9779
Plant spacing (S)	4	0.160000^{NS}	7.97167^{NS}	801.114*	1262.43*
A×S	12	0.454667*	10.8863*	19.6138*	19.9254*
Error (b)	32	0.352500	14.4562	18.5612	15.3425

* Significant at 5% level; NS = Non significant

Appendix V. Means square values for leaf area index of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*			
		30 DAT	*60 DAT*	*90 DAT*	*110 DAT*
Replication	2	0.00447	0.02837	1.4278	2.5605
Seedling age (A)	3	0.00164^{NS}	0.03509^{NS}	0.6368^{NS}	0.2344^{NS}
Error (a)	6	0.00121	0.45467	1.9352	0.8362
Plant spacing (S)	4	0.00931*	1.0064*	11.909*	6.9434*
A×S	12	0.00169*	0.4363*	1.2634*	0.3708*
Error (b)	32	0.00150	0.21029	0.6985	0.4327

* Significant at 5% level; NS = Non significant

Appendix VI. Means square values for dry matter hill^{-1} of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*		
		40 DAT	*70 DAT*	*100 DAT*
Replication	2	0.00928167	32.6238	182.419
Seedling age (A)	3	0.0626017*	48.4323^{NS}	663.078*
Error (a)	6	0.0148017	26.1593	95.7623
Plant spacing (S)	4	0.0270642^{NS}	229.8009*	452.2034*
A×S	12	0.0332753*	34.9679*	206.924*
Error (b)	32	0.0247238	26.6141	149.044

* Significant at 5% level; NS = Non significant

Appendix VII. Means square values for yield contributing characters of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*				
		Effective tillers hill^{-1} (No.)	*Ineffective tillers hill^{-1} (No.)*	*Panicle length (cm)*	*Filled grains panicle^{-1} (No.)*	*Unfilled grains panicle^{-1} (No.)*
Replication	2	234.085	2.42467	1.46921	324.201	9.81617
Seedling age (A)	3	0.530666^{NS}	0.686889^{NS}	0.685411^{NS}	285.551*	30.1998^{NS}
Error (a)	6	20.0580	1.39889	0.730123	130.564	42.2299
Plant spacing (S)	4	675.202*	4.55333*	0.434184^{NS}	117.563^{NS}	8.46058^{NS}
A×S	12	13.6401*	0.534667*	0.355194*	103.091*	12.1016*
Error (b)	32	24.6147	0.765333	0.834927	138.841	20.0167

* Significant at 5% level; NS = Non significant

Appendix VIII. Means square values for yield of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*				
		Weight of 1000 grains (g)	*Grain yield (t ha^{-1})*	*Straw yield (t ha^{-1})*	*Biological yield (t ha^{-1})*	*Harvest index (%)*
Replication	2	1.02871	0.460712	3.06633	5.74912	24.6379
Seedling age (A)	3	2.33033*	0.641717^{NS}	4.77051*	3.88178^{NS}	186.074*
Error (a)	6	1.43118	0.465567	0.989138	2.37278	15.1988
Plant spacing (S)	4	3.51354*	20.1895*	13.7598*	64.8646*	29.4453^{NS}
A×S	12	0.612294*	0.669303*	1.00467*	1.35689*	49.3111*
Error (b)	32	0.852893	0.480247	1.77838	2.84990	37.3568

* Significant at 5% level;

Appendix IX. Means square values for weed population and weed dry matter of *boro* rice at different growth duration

Sources of variation	*Degrees of freedom*	*Mean square*			
		Weed population m^{-2} (No.) at		*Weed dry matter (g m^{-2}) at*	
		30 DAT	*60 DAT*	*30 DAT*	*60 DAT*
Replication	2	317.317	2762.02	0.809807	1.90582
Seedling age (A)	3	582.861 ^{NS}	2544.64^{NS}	1.61748^{NS}	1.48505^{NS}
Error (a)	6	281.161	2785.57	2.68242	4.26700
Plant spacing (S)	4	919.708*	532.308^{NS}	0.825686^{NS}	0.683906^{NS}
A×S	12	323.042*	786.819*	0.803848*	0.925678*
Error (b)	32	119.408	659.892	0.670061	0.945036

* Significant at 5% level; NS = Non significant

PLATES

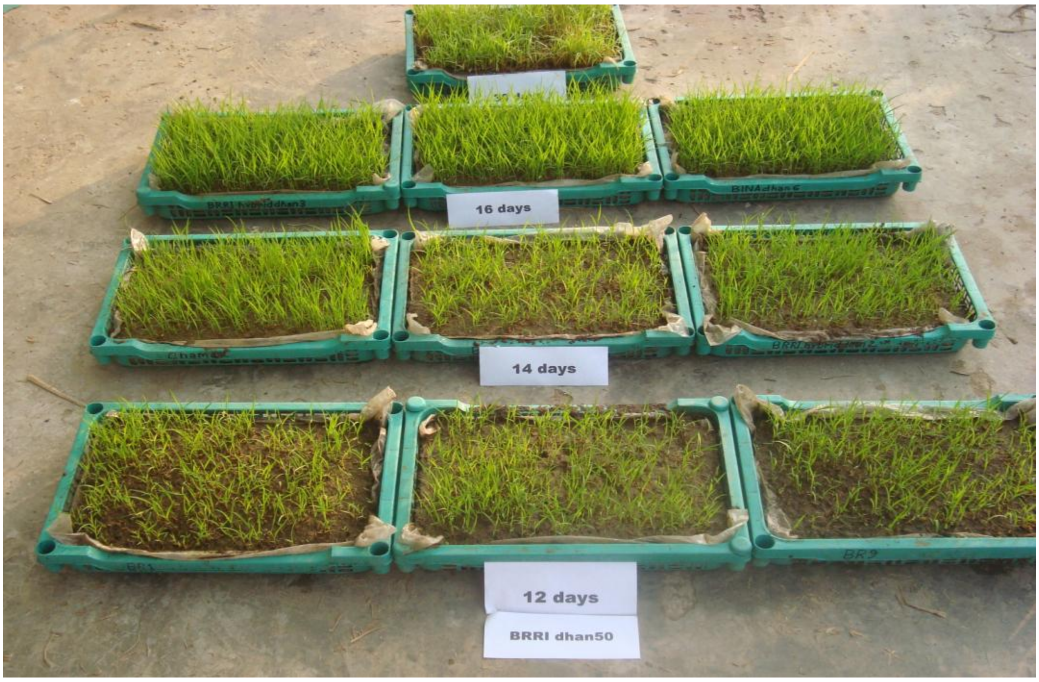


Plate 1. Young seedlings of different ages

Plate 2. Field preparation

Plate 3. Field cracking due to AWD

Plate 4. Field view of the plot after mulching

Plate 5. Early vegetative stage of seedlings

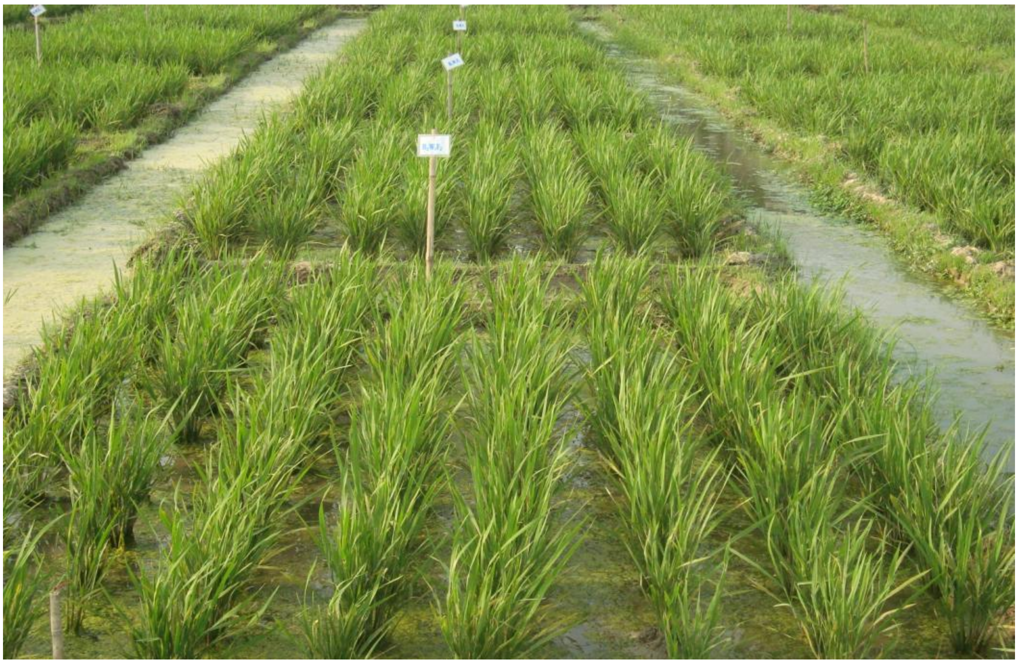


Plate 6. Vegetative stage of seedlings

Plate 7. Rice hill produce profuse and vigorous tillers

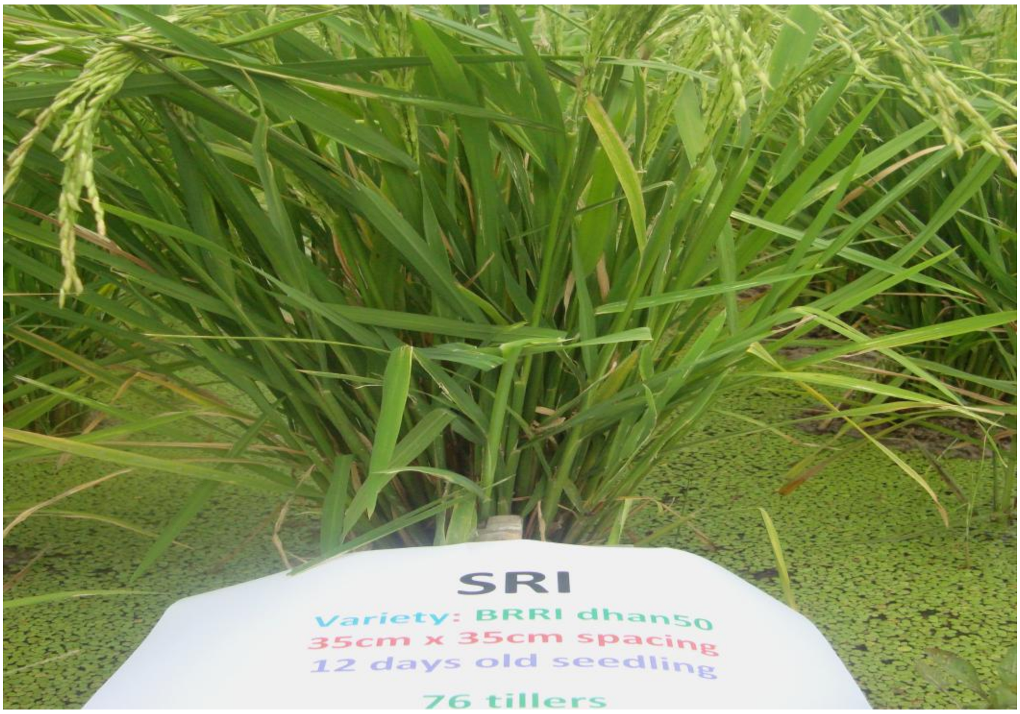


Plate 8. Single hill produces 76 tillers

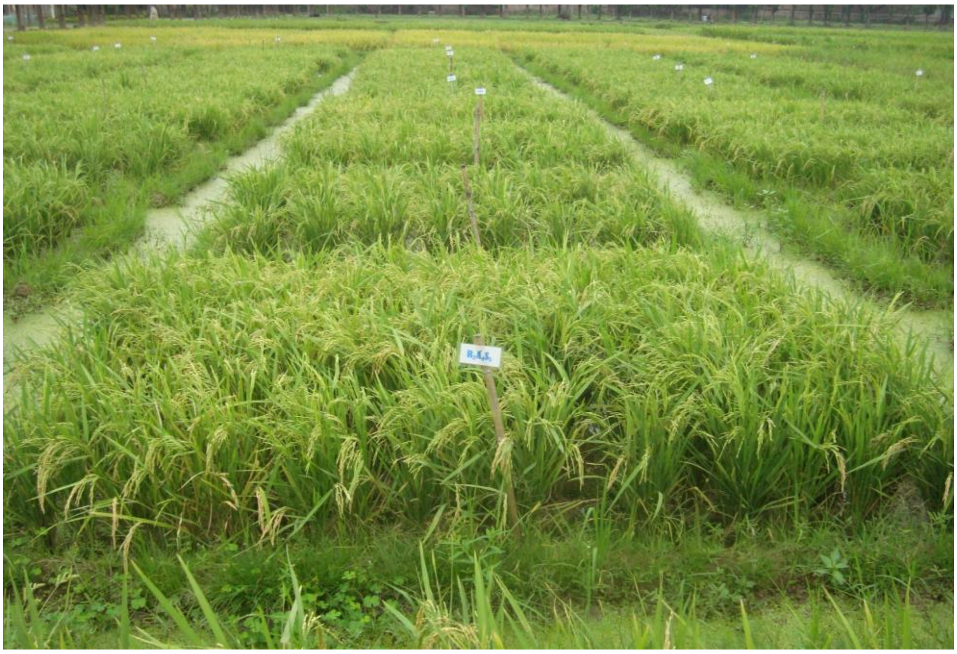


Plate 9. Field view of the experiment at ripening phase

Plate 10. Field view of the experiment before maturity