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Optimizing the Yield of Rice (Variety: BRRI Dhan29) Through Appropriate Agronomic Practices to Ensure Food Security

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OPTIMIZING THE YIELD OF RICE (VARIETY: BRRI DHAN29) THROUGH APPROPRIATE AGRONOMIC PRACTICES TO ENSURE FOOD SECURITY

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DEDICATED

To the memory of my father
Mr. Zillur Rahman
And
To my mother Mrs. Zohora Khatun

And

To my wife Shamima Pervin and
Children Ibnat and Ieanat

The love, encouragement and support of my parents,
Wife and children have been exemplary.

DECLARATION

I **do hereby** declare that the whole work submitted as a Dissertation entitled **"Optimizing the Yield of Rice (variety: BRRI dhan29) through Appropriate Agronomic Practices to Ensure Food Security"** in the Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh, for the degree of Doctor of Philosophy is the result of my own investigation and was carried out under the supervision of Dr. M. Aminul Hoque, Professor, Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh. The Dissertation has not been submitted in the substance for any other degree.

30/06/09

Date: 30/06/2009

Abul Basar Mohammad Ziaur Rahman

CERTIFICATE

This is to certify that Mr. **Abul Basar Mohammad Ziaur Rahman** has worked under my supervision. I am pleased to forward his Dissertation entitled **"Optimizing the Yield of Rice (variety: BRRI dhan 29) through Appropriate Agronomic Practices to Ensure Food Security"** which is the record of bonafied research carried out at the Agronomy and Agricultural Extension Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh. He has fulfilled all the requirements of the regulations relating to the nature and prescribed period of research for submission of Dissertation for the award of Ph.D degree.

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June, 2009 — The author

ABSTRACTS

Five individual experiment was conducted at the Research and Development Farm of Syngenta Bangladesh Limited (Multinational Plant Science Company, former Ciba-Geigy) Birgram, Bogra, Bangladesh during two consecutive Boro season from November'2006 to May'2007 and November'2007 to May'2008 in order to optimizing the yield of rice (cv. BRRI dhan29) through appropriate agronomic practices like spacing, time of transplanting, nitrogen rate, seedling age, seedling number hill^{-1} and method of weed control. Each experiment included a set of treatment and experiment 1, 2, 3, 5 was laid out in a randomized complete block design with three replication and experiment 4 was laid out in a randomized complete block design (factorial) with three replication. The result revealed that spacing, planting time, nitrogen application rate, seedling age and seedling number hill^{-1} and weeding method has significant effect on yield and yield contributing character of BRRI dhan29. Highest grain yield (7.32 t ha^{-1}) and biological yield (14.36 t ha^{-1}) was obtained from 25cm x 20cm spacing due to higher number of effective tiller per m^2, highest fertile spikelet panicle^{-1} and lowest sterile spikelet panicle^{-1}. Planting of 10th January gave the highest grain yield (7.18 t ha^{-1}) and biological yield (14.10 t ha^{-1}) due to highest number of effective tiller per hill, highest fertile spikelet panicle^{-1} and highest 1000 grain weight. Application of nitrogen @ 110 kg/ha produced the highest grain yield (7.18 t ha^{-1}), straw yield (7.31 t ha^{-1}) and biological yield (14.49 t ha^{-1}) due to higher number of effective tiller per hill, highest panicle length and highest fertile spikelet panicle^{-1}. Planting at 40 days old seedling obtained highest grain yield (6.77 t ha^{-1}) and planting 2 seedling hill^{-1} gave highest grain yield (6.28 t ha^{-1}) but the highest grain yield (7.64 t ha^{-1}) was obtained in BRRI dhan29 due to the interaction effect of 40 days old seedling and 2 seedling hill^{-1}. The result summarized that the spacing of 25cm x 20cm coupled with 40 days old seedling and 2 seedling hill^{-1} transplanting at 10th January, application of nitrogen @ 110 kg/ha and controlling of weeds by applying Rifit @ 1.0 l ha^{-1} showed better performance in respect of growth, yield and yield component of rice (cv. BRRI dhan29) that will increase the rice production and contribute to the food security in Bangladesh.

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LIST OF ABBREVIATIONS

%	=	Percent
AEZ	=	Agro-ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BAU	=	Bangladesh Agricultural University
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
cv.	=	Cultivar
DMRT	=	Duncan's Multiple Range Test
et al.	=	and others
FAO	=	Food and Agriculture Organization
Fig.	=	Figure
g	=	Gram
ha	=	Hectare
HYV	=	High Yielding Variety
i.e.	=	That is
m	=	Meter
m^2	=	Square meter
NS	=	Non significant
t	=	Ton
viz.	=	Namely

Chapter 1

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop for more than one third of the world's population. On a global scale it provides 21% of the total caloric intake. In Asia, where 3.1 billion people live, it provides an average 35% of total calories consumed, ranging up to 80% in Cambodia (IRRI, 1995). In Bangladesh, 76% of the people's average caloric intake and 66% of protein intake comes from rice (FAO, 2000). Majority of food grains come from the rice where cent percent of its population use as staple food and food security means rice security in Bangladesh. About 80% of cropped area of this country is used for rice production, with annual production of 25.18 million tons from 10.29 million ha of land (IRRI, 2006). Bangladesh is an agro-based country, earns about 23.46% of her gross domestic products (GDP) from agriculture (Kiron, 2003) and rice contributes 9.05% of the national GDP (BBS, 2004). Geographical and agro climatic conditions of Bangladesh are favorable for rice cultivation. Rice is grown under diverse ecosystems subject to irrigated, rainfed and deep water conditions in three distinct seasons, namely, Aus, Aman and Boro. Among the seasons, boro rice covered about 3.94 million hectares with a production of 12.83 million metric tons of rice (BBS, 2004).

The average yield of rice in Bangladesh is very low, only 2.45 t ha^{-1} (BRRI, 2007). This average yield is almost less than 50% of the world average rice grain yield. On the other hand, rice production area is decreasing day by day due to high population pressure. The agricultural land of Bangladesh is being reduced by about 1% per annum (Husain *et al.*, 2006) while the population is increasing at an alarming rate of 1.43% (Economic Review, 2006). The demand of rice will be increasing in future because of increasing population size. The projected population will be about 169 millions by the year 2025. We need to produce about 27.8 million metric tons of clean rice (41 million metric ton paddy) to feed the population by the year 2025, which is about 21% higher than the production level of 2000 (Bhuiyan *et al.*, 1996). To meet the rice demand of the over increasing population and to ensure food security, improvement in agronomic practices along with introduction of high yielding cultivars would be the most logical way to increase the total production at national level (Shrestha and Ladha, 1998; Kundu and Ladha, 1999). At present BRRIdhan29 is one of the most common modern rice variety developed by BRRI which is cultivating widely during boro season in Bangladesh. It becomes popular due to its high yield potential and well adaptation across the environment. Proper management practices are the most effective means for increasing yield of rice. Among different management practices, especially use of optimum age of seedling, appropriate spacing, accurate number of seedling per hill, optimum time of transplanting, optimum nitrogen application and effective weed control methods are most important way of increasing yield of rice per unit area.

Seedling transplanting at optimum age ensures better rice yield because it has a tremendous influence on plant height, tiller production, panicle length, grain formation, grains per panicle and other yield contributing characters (BRRI, 1981). The farmers of Bangladesh do not give much attention regarding the age of seedlings at transplanting and often they use aged seedlings. In order to get optimum yield, age of seedlings at transplanting for a variety at a particular season may not be similar for other varieties at the same season or at other season. Age of seedling at the time of transplanting is an important factor for uniform stand establishment of rice (Paddalia, 1981). So, it is very important to find out the optimum age of seedling of a suitable variety for a particular season.

Among cultural practices, application of best planting space is the important ones (Barari, 2005). The growth of rice plant is greatly affected both qualitatively and quantitatively by planting density (Hoseini, 2004). Optimum plant density ensures the plant to grow properly with their aerial and under ground parts by utilizing more solar radiation and soil nutrients (Miah *et al.*, 1990). In a densely populated crop, the inter-space competition between the plants is very high which usually results in mutual shading, lodging and thus favors more straw yield than grain yield. The maximum benefit of rice can be obtained from a field, if it is properly spaced between plants and rows.

Number of seedling hill^{-1} is another important factor for successful rice production because it affects plant population per unit area, availability of sunlight, competition for nutrients, photosynthesis and respiration which ultimately influence the yield and yield contributing characters of rice (Chowdhury *et al.*, 1993). Optimum number of seedlings $hill^{-1}$ may enable the rice plant to grow properly both in its aerial and under ground parts by utilizing maximum radiant energy, nutrient, space and water. Excess number of seedlings $hill^{-1}$ may produce higher number tillers $hill^{-1}$ resulting shading and lodging and thus favor the production of straw instead of grain, while the least number of seedling $hill^{-1}$ may cause insufficient tiller growth and thus keeping space and nutrients unutilized in soils and at the end, total panicles per unit area will be reduced resulting in poor yield. It is, therefore, necessary to determine the optimum number of seedlings $hill^{-1}$ for obtaining higher yield especially for the improve variety like BRRI dhan29.

Planting time is also an important factor to maximize yield and there is an optimum planting time to obtain higher yield of a crop (Bhuiyan, 1992). Generally boro rice is transplanted from early December to mid March (BRRI, 1984). Early transplantation of boro rice prolongs field duration due to low temperature and involves higher cost of production, particularly for management practices including irrigation, while delayed planting reduces the yield in some cases (BRRI, 1985). Therefore, optimum time of planting is necessary to ensure high yield.

Rice plants solely depend on soil and applied source of N for maximum yield. Nitrogen plays a key role in supporting plant activity and increasing the rice yield (BRRI, 1997 and Behera, 1998). Different varieties may have varying response to N-fertilizer depending on their genetic and agronomic traits. Many workers have reported a significant response of rice to nitrogen in different soils in Bangladesh (Islam *et al.*, 1990). The application of nitrogen fertilizer either in excess or less than optimum rate affects both yield and quality of rice to a remarkable extent. Hence proper management of crop nutrition is of immense value.

Weed is another major constraints in the rice production which share or compete to nutrients, light and water with rice. Also harbor pest resulting poor yield. Moreover, farmers of the tropics spend more time, energy and money on weed control than any other aspects of crop production. Poor weed control is one of the major factors for yield reduction of rice depending on the type of weed flora and their intensity (Amarjit *et al.*, 1994). The climate as well as the edaphic condition of Bangladesh is favorable for growth of weeds. In Bangladesh, weed infestation reduces the grain yield by 70-80% in Aus rice (early summer), 30-40% for Transplanted Aman rice (late summer) and 22-36% for modern Boro rice cultivars (winter rice) (BRRI, 2006; Mamun, 1990). In boro rice field, weeds of terrestrial, semi-aquatic and aquatic habitats grow throughout the season. For their competitive abilities weeds form a serious negative effect in crop production and responsible for marked losses in crop yield (Mamun *et al.*, 1993). Thus effective weed management system needed to optimize the boro rice yield.

In the view of above discussion, the present study were undertaken with the following objectives:

i. To evaluate different plant spacing, seedling age, seedling number per hill, time of planting, doses of nitrogen application and different weed control method on the yield and yield contributing character of rice (cv. BRRI dhan29)

ii. To identify the best practice among the different treatment for higher yield of BRRI dhan29.

iii. To increase rice yield that will contribute to the country's food security.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1: Effect of spacing on yield and yield components of rice

Chandrakar and Khan (1981) studied the effect of spacing of 10 x 10 cm, 15 x 10 cm and 20 x 10 cm on the grain yields on early, medium and late duration tall growing indica rice varieties and found that the spacing of 20 x 10 cm gave the highest yields for medium and late varieties, while the spacing of 10 x 10 cm gave higher yield in case of early maturing varieties.

BRRI (1981) carried out a field experiment on different spacing of BR3 rice variety and found in minimum plant spacing, 5cm × 5cm, the plant population was the highest but yield not high and in maximum plant spacing, 40cm × 40cm plant population was the lowest but was not found sufficient yield. The highest yield found in 25cm × 20cm spacing with optimum plant population.

Singh *et al.* (1983) studied the effect of row spacing in combination with nutrient supply on grain yield of semi-dwarf upland rice variety Narendra 1 (IET 2232). The crop was grown by direct seeding in rows at three spacing of 15, 20 and 25 cm. The grain yield was more with 20 cm spacing as compared to other spacing.

Bari *et al.* (1984) studied the effect of plant density of 15 x 15 cm and 25 x 25 cm between hill and rows and compared for their effect on grain yield and yield components of two standard varieties IR 6 and IR 8 and two mutant strains of rice Shadab and Shua-92. The plant density at spacing of 20 x 20 cm was more effective and gave significantly higher grain yield per plot than the other plant densities at other spacing and was, therefore, most suitable for obtaining maximum yields.

Bhab *et al.* (1987) reported that in 25cm × 15cm spacing the harvest index was maximum. Ghosh *et al.* (1988) noticed that at a spacing of 30cm × 30cm the highest number of grains panicle^{-1} obtained than those of closer spacing of 20cm × 20cm and 20cm × 25cm, respectively. Kim *et al.* (1990) also reported that harvest index was increased by dense planting.

Mannan *et al.* (1991) carried out an experiment with modern rice varieties, BR1, BR3, BR12, BR14 and BR20 planted at 25cm × 30cm, 25cm × 20cm, 25cm × 15cm, 25cm × 10cm and 15cm × 10cm spacing. The number of tillers and grains yield per unit area increased with the increase in plant density. The grain yield was significantly higher in planting at 25cm ×10cm and 15cm × 10cm spacing.

Ramakrishna *et al.* (1992) conducted an experiment with rice cv. Jaya transplanted at 10cm × 10cm, 20cm × 10cm and 20cm x15cm spacing and observed that grains yield decreased with increasing plant spacing. Karim *et al.* (1992) noticed that number of panicles m^{-2} was increased and number of grains/panicle and 1000 grain weight were decreased with increasing plant density.

Om *et al.* (1993) studied the effect of spacing on grain yield of rice cv. Bashmati and found that transplanted at 15cm × 22.5cm and 30cm × 15cm spacing produced grain yields of 4.80 and 3.91 t ha^{-1}, respectively.

Krishna *et al.* (1994) carried out a field experiment in rice cv. IR 20 at spacing of 20 cm × 10cm, 15cm × 10cm and found that grain yield was higher with wider spacing.

Padmajarao (1995) reported that rice cv. Basmati 370 and IET 8580 when transplanted at 20cm × 20cm, 20cm × 15cm or 20cm × 10cm spacing (25, 33 and 50 plants m^{-2}, respectively) grain yield was the highest at the closest plant spacing.

Hegazy *et al.* (1995) conducted a field experiment in rice and transplanted at 15cm × 15cm, 20cm × 20cm and 25cm × 25cm spacing. They observed that the yield was the highest at the 20cm x 20cm row spacing. Rafiq *et al.* (1998) carried out an experiment in rice cv. Basmati 385 and transplanted at 30 cm × 25 cm, 30 cm × 20 cm, 30 cm × 16 cm and 20 cm × 20cm spacing. They noticed that the 20cm × 20cm spacing produced the highest grain yield of 4.88 t ha^{-1}.

Shah (1998) conducted field experiments at the Bangladesh Rice Research Institute (BRRI) Regional Station, Habiganj in the dry season in 1996 to determine the contribution of tillering times to grain yield as influenced by plant densities and

Nitrogen levels. Three spacing (20 x 20 cm, 20 x 10 cm, 10 x 10 cm) and three N levels 0, 60, 120 kg ha^{-1} was used as a treatment and result showed that a spacing of 20 x 10 cm and 60 kg N kg^{-1} was optimum in fertile soil.

Mia (2001) reported that a higher dry matter accumulation was observed in the widest spacing (20cm × 25cm) up to 90 DAT and it was the lowest in the closest spacing (16cm × 20.8cm).

Reddy *et al.* (2001) noticed that rice transplanting at a closer spacing of 15cm × 10cm produced higher grain yield (4.1 and 4.8 t ha^{-1} during 1996 and 1997, respectively) as compared to normal planting at a spacing of 20cm × 10cm (4.0 and 4.3 t ha^{-1} during 1996 and 1997, respectively) and recorded a mean increase of 7.6% higher in yield over the normal spacing. Among the yield components, number of panicles per unit area and grains/panicle affected significantly by closer planting. Closer planting at seedlings (15cm × 10cm) also significantly increased the number of panicles m^{-2} (463) compared to the other treatments.

Baloch *et al.* (2002) carried out a field experiment at the experimental farm of Nuclear Institute of Agriculture, Tandojam, Sindh, Pakistan with three mutant strains Basmati 370-32, Jajai 77-30 and Sonahri Sugdasi-6 along with their respective mother varieties Basmati 370, Jajai 77, Sonahri Sugdasi and check variety Basmati 385 were evaluated under different plant population (spacing, 20 x 20 cm, 22.5 x 22.5 cm and 25 x 25 cm between plant and rows) for grain yield and yield contributing parameters. An increase in spacing induced vigorous plant growth as well as increased the number of panicles per hill, grain yield per hill, filled grains per panicle and 1000 grain weight. The spacing 22.5 x 22.5 cm proved more appropriate because it produced better plant stand, gave more panicle density and higher grain yield than other two spacing.

Haque (2002) conducted an experiment during boro season with cv. BINA dhan6 and found that the highest biological yield (14.24 t ha^{-1}) was obtained from the spacing of 30cm × 30cm and the lowest (7.51 t ha^{-1}) was obtained from the spacing of 40cm × 40cm.

Paul *et al.* (2002) reported that high density reduced total tiller number per hill but fertile tiller number was improved by high density.

Verma *et al.* (2002) carried out a field experiment to study the effect of spacing (20cm × 20cm, 20cm × 15cm and 20cm × 10cm) and crop density (1, 2 and 3 seedling hill^{-1}) during the rainy season of 1998-99. Seedlings planted at 20cm × 20cm, 20cm × 15cm produced higher number of productive tillers, grain yield and harvest index than seedlings planted at 20cm × 10cm. Closer spacing (20cm × 10cm) gave higher sterility percentage than wider spacing.

Haque (2002) conducted an experiment with 20cm × 20cm, 30cm × 30cm, 30cm× 40cm and 40cm× 40cm spacing and observed the tallest plant obtained from wider spacing. Chris (2002) noticed that among three plant spacing (20cm × 20cm, 30cm × 30cm and 40cm × 40cm) the higher number of tillers hill^{-1} was recorded in case of 20cm × 20cm spacing.

Hossain *et al.* (2003) carried out an experiment during 30 June – 6 December, 2001 in Bangladesh, to study the effect of cultivar (Sonar Bangla 1, BRRI dhan39 and Nizershail) and spacing (10cm × 15cm, 10cm × 20cm, 15cm × 25cm, 20cm × 30cm and 25cm × 35cm) on weed infestation and performance of transplanted aman rice. Spacing had a significant effect on all the characteristics, except panicle length and 1000 grain weight. The highest grain yield was obtained from 15cm × 25cm spacing, while the lowest grain yield was obtained from 25cm × 25cm spacing. Sonar Bangla 1 produced the highest grain yield in 15cm × 25cm spacing where as Nizersail produced the lowest yield in 25cm × 35cm spacing.

Akhter (2003) conducted an field experiment where three seedlings ages viz. 8, 12 and 16 days old, three hill spacing viz. 20 cm × 20cm, 30cm× 30cm and 40cm × 40cm and two number of seedling hill^{-1} viz. 1 and 2 seedling hill^{-1} were included as experimental treatment. It was observed that the widest spacing of 40cm × 40cm produced the tallest plants, the highest number of tillers hill^{-1} and the lowest number of non-effective tillers hill^{-1}.

Ming *et al.* (2004) studied on the effects of spacing (20cm × 20cm, 30cm × 30cm, 40cm × 40cm and 50cm × 50cm) on the performance of small panicle type conventional rice cv, Yuexiangzhan and big-panicle-type rice cv. Yuezal 22. Dense spacing prolonged the growth duration and increased the number of tillers hill^{-1}, number of ear bearing tillers, number of grains/panicle, 1000 grain weight, leaf area index and dry matter production. The performance of the cultivars significantly varied.

Mobasser *et al.* (2007) carried out an experiment in the field of Ghaemshahr Islamic Azad University, Iran to study the effects of seedling age and planting spaces on yield and yield components of rice (Neda variety). Seedling age in three levels (25, 35, 45 days) and transplanting spaces (15 x 15 cm, 20 x 20 cm, 25 x 25 cm, 30 x 30 cm) used as a treatment and some agronomical trails were measured. Results showed that planting spaces had a significant effect on total tiller, fertile tiller, panicle per m^2, total spikelet per panicle and grain yield. 25 day old seedling along with 15 x 15 cm planting space was the best performance of yield attributes.

2.2: Effect of time of planting on yield and yield components of rice

Ishiy (1986) carried out an experiment with 6 cultivars and 12 lines sown on 13 September, 14 October, 14 November, 13 December or 13 January and reported that early sowing at low temperature prolonged the growth cycle and reduced plant height and number of grains panicle^{-1} but late sowing increased spikelets sterility and reduced the length of growth cycle.

Maity and Mahapatra (1988) conducted an experiment with four transplanting dates, at 10 days interval, starting from 5 December 1985 and 14 January 1986. Time of planting affected yield significantly and transplanting on 25 December 1985 and 4 January 1986 produced the highest yield but late and early planting reduced yield, perhaps because of temperature.

Mazumder and Prasad (1989) conducted an experiment in 1987-88 with 6 rice cultivars grown on saline soils. Crops transplanted on 1 January gave the highest paddy yield of 1.12 t ha^{-1} compared with 0.81-0.92 t ha^{-1} for crops transplanted on 15 December 15 January or 1 February. CSR-4 and IR56 produce the highest grain yields of 1.11 t ha^{-1} and 1.45 t ha^{-1} respectively, compared with 0.75-0.88 t ha^{-1} for other four cultivars.

The date of planting of a crop within a cropping season is a most important factor for obtained higher yield; usually, there is a range of optimum planting dates for a crop (Bhuiyan, 1992). Boro crop grown at low temperature to start with, mature at high temperature and similar conditions prevail in the temperate areas. Therefore, high yield are obtained in this particular cropping season.

BRRI (1993) carried out an experiment to find out the optimum planting time of 14 advanced lines in boro season. Forty-day old boro seedlings were transplanted between 25 December and 12 March in the boro' season at 15 days intervals. Among the tested promising lines/varieties, BR4828-2-21 yielded the highest (5.18 t ha^{-1}) when planted on 25 December. On the other hand, BR4828-50-1-2 yielded the highest (5.18 t ha^{-1}) when planted on 9 January. The yield of all the promising lines/varieties decreased progressively with the advancement of planting dates beyond 9 January.

BRRI (1994) carried out an experiment with 40 day old seedlings of sixteen promising lines, including one cheek variety BR26 during Boro season. Seedlings were transplanted between 25 December 1993 to 12 March 1994. Results showed that BR4824-17-2-3 yielded significantly the highest yield. Significantly the highest yield was obtained when planted on 25 December and 9 January followed by 25 January planting. After 25 January planting the grain yield declined significantly.

BRRI (1995) carried out a field experiment to study the optimum planting date of boro rice planting at 15 day interval from 25 December to 12 March. All lines produced satisfactory yield up to 9 February after that, yield reduced drastically and field duration of the tested lines decreased with the advancement of planting dates. BR14 gave the highest (5.14 t ha^{-1}) yield and the lowest (2.24 t ha^{-1}) yield was obtained from 9 January and 12 March, respectively and required 117 and 92 days from planting to harvesting, respectively.

BRRI (1995) carried out an experiment with four promising lines with the check BR14 planting at 15 day intervals starting from 20 December up to 5 February at Gazipur using 40 days old seedlings for all the planting. Among the tested lines, RWBC-6-5 yielded the highest (($5.75\ t\ ha^{-1}$) from 5 January planting followed by BR6161-R1-3 ($5.08\ t\ ha^{-1}$). Grain yields and maturity of all the lines and varieties decreased considerably after 20 January planting.

Chowdhury and Guha, (2000) conducted a field trial during boro season, 1996 in India with 55 day old seedlings of 5 short duration (Calturel, IR 50, Govind, China and Jagilu) and 3 medium duration (Joymati, Mala and Mahsuri) rice cultivars planting on 20 January, 4 and 19 February 1996. Among the short duration cultivars, Govind gave the best results, followed by china, while among medium duration cultivars Mahsuri was the best followed by Joymati. Planting on 20 January produced the highest yield among all the cultivars except Mala, which showed better performance with planting on 4 February.

Pirdashty *et al*. (2000) conducted an experiment at the Iran Rice Research Institute in Amol during 1998 to study the effect of transplanting date on yield and yield components in four rice cultivars. Treatments comprised: four genotypes Tarom, Nemat, Shel (7325 line) and Fajr (7328 line) and their transplanting dates with 10 days intervals from 13 March to 1 June 1998. Traits such as grain yield, biomass, harvest index, tiller number, grain number per ear, ear fertilized percentage and 1000 grain weight at different transplanting dates were evaluated. The delay in transplanting date decreased tiller number, ear fertilized percentage, grain number per ear, the grain yield and harvest index, but the different transplanting dates did not show any significant differences in 1000 grain weight and biomass. Nemat had higher tiller number and 1000 grain weight compared to the other cultivars. Among the yield components, tillers number per plant, 1000 grain weight and grain number per ear had a positive and significant correlation with yield.

Pattar *et al*. (2001) carried out a field experiment to determine the effect of planting date and seedling age on rice (cv. Sonamasuri) yield. Seedlings of 25, 35 and 45 days old were planted on the first and second fortnight of August and the first fortnight of September. Planting on the first fortnight of August had higher yield than those planted on later dates. Planting on 35 or 45 day old seedlings produced significantly higher grain yield, grain weight and number of filled grains per panicle compared to 25 day old seedlings. When transplanting was delayed to the second fortnight of August, the performance of both 35 and 45 day old seedling was greater than that of 25 day old seedling. In general, there was a drastic reduction in yield when planting was done in the first fortnight of September.

2.3: Effect of nitrogen on yield and yield components of rice

Plant height

Nitrogen plays the key role in the growth of rice plant especially for plant height. Lenka and Behara (1967) reported that application of higher doses of N (120 kg ha^{-1}) significantly increased the plant height.

Idris and Matin (1990) found that plant height increased while increasing N dose up to 120 kg N ha^{-1} compared to the control and there after it declined at 140 kg N ha^{-1}. Reddy *et al.* (1990) observed that nitrogen has positive effect on plant height of rice.

Hussain and Sharma (1991) reported that application of nitrogen up to 140 kg ha^{-1} increased plant height. At 80 kg and 120 kg N ha^{-1}, the change in this parameter was non-significant. The highest plant height was observed from 120 kg N ha^{-1}. Thakur (1993 a) noticed that the highest plant height was observed from 120 kg N ha^{-1} and the lowest one obtained from the control (0 kg N ha^{-1}) .

Kumar *et al.* (1995) found that there was a significant effect of increasing levels of nitrogen on the increasing of the plant height. Sahrawat *et al.* (1999) observed that nitrogen level significantly affect plant height. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Number of tillers hill^{-1}

Nitrogen has strong influences on tiller production of rice. Rao *et al.* (1986) reported that split application of nitrogen increased total tillers/hill compared to entire nitrogen applied as basal.

Reddy *et al.* (1988) observed that nitrogen application in three split from 0 to 120 kg ha^{-1} increase total tillers/hill. Idris and Matin (1990) noticed that the maximum tillers hill^{-1} was obtained from 140 kg N ha^{-1} which was statistically similar to 60, 80, 100 and 120 kg N ha^{-1} and the minimum tillers hill^{-1} was observed from the control treatment (0 kg ha^{-1}).

Kumar *et al.* (1995) reported that increasing level of N from 80 to 120 kg N ha^{-1} significantly increased total tillers hill^{-1}. Maske *et al.* (1997) concluded that number of tiller/hill increased significantly with increased N level. Sahrawat *et al.* (1999) also noticed that nitrogen level significantly influenced tiller number.

Number of Effective tillers hill^{-1}

Nitrogen stimulates the cellular activities during panicle formation and development, which lead to increase number of effective tillers/hill.

Balasubramaniya (1984) summarized that increasing nitrogen application increased the number of effective tillers/hill with the highest at 120 kg N ha^{-1}.

Akanda *et al.* (1986) reported that nitrogen application in three doses such as 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation stage produce the highest number of panicle hill^{-1}. Dubey *et al.* (1991) noticed that application of 90 kg N ha^{-1} resulted in higher number of effective tillers/hill. Thakur (1991a) reported that increasing level of nitrogen increase the number of panicle/hill significantly up to 120 kg ha^{-1}. Thakur (1991b) concluded that the yield attributes like number of effective tillers/m^2 and grain weight/panicle increased with increasing level of nitrogen.

Chander and Pandey (1996) found that application of 120 kg N ha^{-1} resulted in significant increase in number of effective tillers/hill compared to 60 kg N ha^{-1}.

Hari *et al.* (1997) carried out a field experiment with rice hybrids PMS2, AIR 30802 to study the effect of different level of nitrogen and observed that productive tillers/hill increase significantly with increasing level of N from 0 to 150 kg ha^{-1}.

Panicle length

Nitrogen contributes panicle formation and elongation of rice. Kumar *et al.* (1986) noticed that the highest panicle length was observed from 80 kg N ha^{-1} which was significantly superior to 40 kg N ha^{-1}. Sharma and Mishra (1986) reported that maximum length of panicle and maximum number of tillers/hill was observed from the highest nitrogen rate.

Idris and Matin (1990) noticed that the panicle length influenced positively due to the increasing rate of nitrogen. The highest panicle length was observed from 60 kg N ha^{-1} and the lowest one from control (0 Kg N ha^{-1}). Singh and Singh (1993) reported that panicles/m^2, panicle length and grains/panicle increased due to application of 60 Kg N ha^{-1}. Azad *et al.* (1995) noticed that panicle length increased significantly with the increasing level of nitrogen from 0 to 75 kg ha^{-1}.

Total spikelets/panicle

Devi and Nair (1984) reported that with the increasing N level from 0 to 40 Kg N ha^{-1} the total spikelets/ panicle in four drought resistant tall upland rice varieties increased. Ghosh *et al.,* (1991) noticed that N level increased the total spikelets/panicle. Hussain and Sharma (1991) reported that the nitrogen application increased total spikelets/panicle up to 140 Kg N ha^{-1}.

Number of filled spikelets/panicle

Bhuiyan *et al.* (1989) found that the nitrogen application positively influenced the filled spikelets/panicle. Hussain and Sharma (1991) noticed that application of nitrogen increased number of filled spikelets/panicle up to 80 kg N ha^{-1} and the 120 kg N /ha did not significantly affect the filled spikelets/panicle. The highest number of filled spikelets/panicle produced at 80 kg N ha^{-1} and the lowest was produced in the control. Chander and Pandey (1996) found that a significant increase in filled spikelet/panicle, tiller/m^2 and grain yield was obtained from 120 kg N ha^{-1} compared to 60 kg N ha $^{-1}$.

Rajarathinam and Balasubrananiyan (1999) reported that there was no remarkable change in filled spikelets/panicle due to higher dose of N above 150 kg ha^{-1}. They also noticed that an appreciable reduction in filled spikelets/panicle at 250 Kg N ha^{-1}.

1000 grain weight

Rahman *et al*. (1985) reported that doses of nitrogen had no significant effect on grains $panicle^{-1}$ and 1000 grains weight of rice. However, Mondal *et al*. (1987) found that increasing level of nitrogen from 40 to 160 kg ha^{-1} significantly increased 1000 grain weight. Similarly Bhuiyan *et al*.(1989) noticed that application of N at 0-60 Kg ha^{-1} increased the weight of 1000 grains. The Weight of 1000 grains was the highest at 60 Kg N ha^{-1} and the lowest at 0 Kg N ha^{-1}. Islam *et al*. (1990) found that there was an increasing trend of 1000 grain weight with an increase in levels of nitrogen up to 80 Kg ha^{-1}.

Ali *et al*. (1993) concluded that 1000 grains weight was higher when 100 Kg N ha^{-1} was applied in three equal splits at basal, 30 days and 60 days after transplanting.

Grain yield

Nitrogen has remarkable influence both on yield and yield attributes of rice. Grain yield increased significantly at each successive level of N, due to increase in the number of panicles/m^2, length of panicle, spikelets/panicle and weight of 1000 grain (Dalai and Dixit, 1987). Mishra *et al*. (1988) concluded that N rates at 0, 30 and 60 Kg N ha^{-1} produced aus rice yield of 3.46, 4.84 and 5.24 t ha^{-1}, respectively and no further increase in yield was achieved by N application up to 90 kg ha^{-1}.

Mirza and Reddy (1989) concluded that increase in N level from 30 to 90 kg ha^{-1} significantly increased the grain yield of rice. Islam *et al*. (1990) observed that the grain yield of rice increased significantly up to 80 Kg N ha^{-1} but decreased at 120 Kg N ha^{-1}. Sadeque *et al*. (1990) carried out a field experiment to study the effect of different levels of N (50, 100 and 200 kg ha^{-1}) on transplant aman rice (cv .BR11) and observed that N had no significant effect on grain yield. Pandey *et al.* (1991) reported that significant increased in yield with increased in N level.

BRRI (1992) reported that grain yield of rice increased positively up to 80 Kg N ha^{-1}. Nitrogen application from 120 Kg to 160 Kg ha^{-1} significantly reduced the yield which was assumed to be due to excessive vegetative growth followed by lodging after flowering. Thakur (1993 a) noticed that increasing levels of N increased the growth and yield attributes of rice significantly. Thakur (1993 b) concluded that most of the yield contributing characters specially panicles/m^2 and spikelets/panicle increased with increase N level and followed this trend to the grain yield.

Singh and Pillai (1994) observed that grain yield increased significantly up to 90 Kg ha^{-1} nitrogen application and after which it declined. Hossain *et al.* (1995) found that application of nitrogen up to 120 Kg ha^{-1} increased the grain yield of rice. Increased in yield with 40, 80 and 120 Kg N ha^{-1}over the control was 24, 33 and 34%, respectively. They noticed significantly higher yield was obtained with 80 and 120 Kg N ha^{-1} than 0 and 40 Kg N ha^{-1}. Hari *et al.* (1996) pointed out that grain yield increased as nitrogen application increased from 0 to 150 Kg ha^{-1}, although a further increase up to 200 Kg ha^{-1} did not increase grain yield.

Muthukrishnan *et al.* (1997) showed that incremental dose of N increased the grain yield by up to 80 kg N ha^{-1} (4.5 t ha^{-1}). Singh *et al.* (1998) evaluated the performance of three F_1 hybrid rice cultivars (KRH1, Pro. Agro. 103 and MGR1) using Jaya and Rasi as standard checks giving four levels of N (0, 60, 120,180 kg ha^{-1}) and noticed that grain yield increased linearly with increased N levels up to 120 kg ha^{-1}. Gopal *et al.* (1999) found that rice yield cv. Yerramallelu increased with N up to 100 kg N ha^{-1} and then decreased with 140 kg N ha^{-1}. Yield was not significantly affected by different split application. Sahrawat *et al.* (1999) noted that N level significantly affected the grain and straw yields. Chopra and chopra (2000) reported that nitrogen application at the rate of 80 kg ha^{-1} improved the entire yield attributes compared with control.

Sarker *et al.* (2001) investigated the effect of N level on the yield, yield contributing characters, physiological parameters of Iratom rice variety and observed significant effect of N on yield and other crop characters. The highest grain yield (6.45 t ha^{-1}), 1000 grain weight (27.49 g) and number of grains/panicle were produced at 120 kg N ha^{-1} for Iratom rice variety.

Harvest index

Prasad (1981) noticed that the increasing rate of N application from 0 to 120 and 200 kg ha^{-1} increased biological yield but decreased harvest index. Similar observation was also noted by Park (1987).

Pandey (1999) conducted a field experiment with 6 rice cultivars fertilized with 0, 40, 80, 120, 160 Kg N ha^{-1} and observed that harvest index and yield were the highest in cv. IET 7633. Grain yield increased with increasing N rates, while harvest index decreased. Mondal and Swamy (2003) concluded that application of N (120 Kg ha^{-1}) as urea in four equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest number of panicles, number of grains/panicle, 1000 grain weight, straw yield and harvest index.

2.4:Effect of seedling age and seedling number $hill^{-1}$ on yield and yield components of Rice

Plant height

Theetharappan and Palaniappan (1984) summarized that increasing seedling age from 25 to 55 days, plant height was decreased. Kostha *et al.* (1987) found that seedling age of rice affected different plant characteristics including plant height. They observed that 20 days old seedlings gave the tallest plant compared to seedling age of 28 and 36 days old. Seedling age has remarkable influence on the yield of rice.

Kim *et al.* (1990) noticed that 10 days old seedlings were more vigorous and had taller plant height and higher tillering ability compared to 15 and 40 days old seedling. Hossain (2001) concluded that in seedbed, the higher height of old seedling caused higher plant height in main field. But young seedlings grow faster than older ones (35 to 65 days old seedling).

Haque (2002) reported that seedling age had considerable effect on plant height. He noticed that 15 days old seedlings produced the tallest plant compared to 25, 35 and 45 days old seedlings. The shortest plant was found from 45 days old seedlings. He also reported that the plant height decreased with the increasing of seedling age.

Total tillers hill^{-1}

Ramasamy *et al.* (1987) noticed that increasing seedlings hill^{-1} made an adverse effect on yield parameters of rice. All yield parameters were reduced with more than two seedlings hill^{-1}.

Hossain and Haque (1988) noticed that more number of basal tillers/hill produced at 30 days old seedlings than 60 days old seedlings. Aragones and Wada (1989) reported that young seedling planting had a positive effect in increasing the number of tillers, promoted the early occurrence of the maximum tillers but decrease the percentage of bearing tillers to total tillers with aged seedlings.

Roy and Sattar (1992) noticed that the tillering rate was more in younger seedling and as the seedling age increased, the tillering rate decreased. They also observed that within a variety the number of total tillers decreased with seedling age. Rahman (2001) reported that younger seedlings produced more number of tillers /hill than older ones. Haque (2002) carried out an experiment with 15, 25, 35, and 45 days old seedlings and observed that younger seedlings produced more tiller than older ones.

Number of Filled spikelets panicle^{-1}

Datta and Gautam (1988) observed that with increasing in seedling age the number of filled grains panicle^{-1} was decreased. Ashraf and Mahammod (1989) studied the influence of over aged seedlings of two Basmati rice varieties and noticed that yield attributes declined significantly with the increasing of seedling age.

Bhagat *et al.* (1991) noticed that 50% flowering days and sterile spikelets number per panicle increased with the seedling age at transplanting and plant height at maturity, number of panicles/m^2, panicle length, number of filled spikelets $panicle^{-1}$ and 1000 grain weight decreased.

Roy *et al.* (1992) found that filled spikelets number was decreased slightly as seedling age increased in BR14 and IR50. IR50 produced higher panicles but less number of grains/ panicle than BR14. The highest grains per panicle was observed from 60 days old seedling for both the varieties.

Bisht *et al.* (1999) conducted a field experiment of hybrid variety PRH 1 transplanting with 1, 2, 3 seedlings $hill^{-1}$ and reported that number of panicles and filled spikelets increased with 2 or 3 seedlings $hill^{-1}$.

1000 grain weight

Datta and Gautam (1988) carried out an experiment with rice cv. BR4 and seedlings of 30, 40 or 50 days old were transplanted with 2-3 seedlings $hill^{-1}$ and found that 1000 grain weight decreased with increasing seeding age.

Raju *et al*. (1989) noticed that 30, 45 and 60 days old seedling produce yield of 4.85, 4.40 and 4.19 t ha^{-1}, respectively. Panicle number/m^2, grains number/panicle and 1000 grain weight was the highest at 30 days old seedlings. Mohapatra and Kar (1991) conducted an experiment with 30, 35 and 60 days old seedlings and they observed that 30 days old seedlings had significant effect on 1000 grain weight.

Kamdi *et al.* (1991) reported that 1000 grains weight was decreased with aged seedlings used at transplanting. Mori *et al.* (1994) reported that grain yield and 1000 grain weight were slightly higher with the younger seedlings than aged seedlings.

Grain Yield

BINA (1987) reported that seedling number/hill (1 to 4 seedling $hill^{-1}$) had no significant response on yield of IRATOM24, IRATOM38 and BR3 in aus. However, the highest yield was recorded in 4 seedling/hill and that was almost similar with 3 seedling hill^{-1}.

Karim *et al.* (1987) reported that the highest grain and straw yield (2748 kg ha^{-1} and 4574 kg ha^{-1}) by 4 seedlings hill^{-1} while 1 seedlings hill^{-1} yielded the lowest. Pande *et al.* (1987) conducted an experiment with 4 rice cultivars transplanted at 1, 2, 3 and 4 seedlings hill^{-1} and obtained average paddy yield of 3.78, 5.09, 5.00 and 4.94 tha^{-1}, respectively.

Muhammad *et al.* (1987) observed that when rice cv. Basmati 370 was grown at 2 seedlings hill^{-1} and 6, 11, 25 or 44 hill^{-1} m^{-2} then the number of tillers hill^{-1}, the number of panicle bearing tillers hill^{-1} and 1000 grain weight decreased with increasing plant density but plant height, number of grains m^{-2} and grain yield remained unaffected.

Kim *et al.* (1990) conducted a field experiment with three rice cultivars, namely Namweonbyeo (early maturing), Hwaseongbyeo (medium maturing) and Donjinbyeo (medium late maturing) which were transplanted at three different seedling ages to identify their growth habits in the southern plain of Hionam. The 10 days old seedlings had more vigorous elongation of plant height and higher tillering ability but lower effective tiller rate when compared with 35 or 40 days old seedlings. Panicle number/m^2 was the highest from 10 days old seedlings, while spikelets number/panicle was the highest from transplanting 40 days old seedling. There was no significant effect on milled rice yield with seedling age at planting.

BRRI (1991) carried out a field experiment at the Regional Station of Barisal to know the effect of seedling number (2, 3, 4 and 5 seedlings hill^{-1}) on the yield and yield components of BR3, BR9 and BR14. The results observed that there was no significant effect of seedling numbers on the yield of BR3 and BR14. Planting 4-5 seedlings hill^{-1} gave significantly higher yield of BR9, than 2-3 seedlings hill^{-1} although such differences were not apparent in yield components.

BRRI (1992) reported from a trial that the highest grain yield (5.75 t ha^{-1}) was obtained from the planting 44 hills m^{-2} followed by 33 hills m^{-2} (5.42 t ha^{-1}) and 25 hills m^{-2} (5.02 t ha^{-1}). Singh *et al.* (1992) carried out an experiment with 2, 4 or 6 seedlings $hill^{-1}$ to study their effect on the yield and yield components of rice cv. Madhukar and found 4 seedlings $hill^{-1}$ were better for grain yield. Prasad *et al.* (1992) conducted a field experiment with 2, 3, 4 and 5 seedlings $hill^{-1}$ to know their effect on the yield and yield components of rice cv. Sarjoo - 52 and found that for all factors 4 seedlings $hill^{-1}$ were better for grain yield.

Roy *et al.* (1992) concluded that grain weight of two rice varieties BR14 and IR50 decreased with increase of seedling ages. Reddy and Reddy (1994) carried out an experiment with rice cv. Surrekha transplanted at 30, 45 or 60 days old seedlings and the result indicated that the highest grain yield was obtained from 30 days old seedlings. Bali *et al.* (1995) reported that grain yield was higher with 5 week old seedlings when 5 and 7 week old seedlings were transplanted.

Chowdhury *et al.* (1993) conducted a field experiment with 2, 4 and 6 seedlings $hill^{-1}$ to know their effect on the yield and yield components of rice cv, BR23 and pajam during the aman season. They noticed that the highest grain and straw yield were produced from 6 seedling $hill^{-1}$.

Channabasappa *et al.* (1997) conducted an experiment with rice cv. Sonamashuri and IR64 by transplanting 25, 35 or 45 days old seedlings and noticed that there was no significant yield difference between cultivars, but was the highest with 35 days old seedlings. Banik *et al.* (1997) conducted an experiment on rice cv. Pankaj and Potanaion with 30, 40 50 or 60 days old seedlings and noticed that yield did not differ significantly between the cultivars and mean grain yield was the highest (4.74 t ha^{-1}) with transplanting 40 days old seedlings.

Banik *et al.* (1997) carried out a field experiment in 1993-95 in Bihar with 30.40.50 or 60 day old rice cv. Pankaj and patnation seedlings were transplanted at 2, 4, 6 or 8 seedlings $hill^{-1}$. There was no significant variation in yield between the cultivars.

Mean grain yield was the highest (4.74 t ha^{-1}) from plots transplanted with 40 day old seedlings; yield was the highest with 4 seedling $hill^{-1}$ (4.22 t ha^{-1}).

Asif *et al.* (1997) conducted an experiment with rice cv. Basmati-385 grown at 1, 2 or 3 seedlings $hill^{-1}$ and found that grain yield was the highest at 2 seedlings $hill^{-1}$ but grain quality parameters in terms of percentage of sterility number of aborted, opaque and normal kernels were not significantly affected by planting density.

Singh and Singh (1998) carried out an experiment on 25, 35 and 45 days old seedling transplanting and found that yield was decreased with increase of seedlings age. Rajendra *et al.* (1998) noticed in a field trail with two hybrid rice cv. Pusa 834 and Pusa HR3 and grown at 1, 2 or 3 seedlings $hill^{-1}$ and found that the highest grain yield of 3.5 and 5.6 t ha^{-1} was obtained from 2 and 3 seedlings $hill^{-1}$, respectively.

Shi *et al.* (1999) conducted an experiment with 25, 30, 35, 40 or 45 days old seedling of rice in regards of grain yield. They observed that yield was negatively correlated with seedlings age at transplanting. Mean yields were 6.7, 6.5, 5.9 & 4.5 t ha^{-1} with transplanting 25, 30, 35 and 40 days old seedlings, respectively. Yield with 25 or 30 days old seedlings was positively higher than that of 35 or 40 day old seedlings.

Singh and Singh (1999) reported that 4.92, 4.64 and 4.22 t ha^{-1} grain yield was obtained from transplanting of 25, 35 and 45 days old seedlings, respectively. Sanbagavali *et al.* (1999) noticed that 4.98, 5.95 and 5.90 t ha^{-1} grain yield was obtained from 20, 30 and 40 days old seedlings, respectively. Lu *et al.* (1999) carried out an experiment with hybrid rice cv. You 2070 transplanted with 20, 25, 30, 40, 45, 50 or 55 days old seedlings and observed that yield was decreased with increasing seedling age.

Molla (2001) carried out an experiment during 1998 and 1999 wet season in west Bengal, India to observe the performance of rice hybrids and high yielding cultivars (HYV) with different seedling age and number of seedling $hill^{-1}$ and found that 28 days old seedlings produced more grain yield than 21 days old seedlings.

Chris (2002) evaluated a field trial with rice var. Taichung-176 and observed that among three seedling ages (10, 20 and 30 days old), 30 days old seedling had very high tillering (259 tillers/m^2) rate. Haque (2002) found that seedling age was positive effect in respect of the entire yield and yield contributing characters except filled grains/panicle. The highest value of plant height, total tillers $hill^{-1}$, total tillers/m^2, effective tillers $hill^{-1}$, spikelets $panicle^{-1}$, and straw yield (t ha^{-1}) were found significantly positive from the younger seedlings.

Harvest index

Zhang and Huang (1990) conducted a field experiment to study the effects of seedlings number $hill^{-1}$ for medium duration rice variety EW an 5 transplanting at 1-5 seedlings $hill^{-1}$. They found that two or three seedlings $hill^{-1}$ produce the best yield with increasing grain yield, total weight and panicles $plant^{-1}$ but 1000-grain weight, plant height, panicle length and harvest index were unaffected by the number of seedlings $hill^{-1}$.

BINA (1993) carried out a research work with three rice varieties during boro season viz., IRATOM24, BR14 and BR3 and three number of seedlings $hill^{-1}$ viz., 1, 2, and 3 seedlings $hill^{-1}$and observed that number of seedlings $hill^{-1}$ produced significant effect on grains $panicle^{-1}$, grain and straw yield. Increased seedlings number $hill^{-1}$ produced significantly higher grain and straw yield with higher harvest index but other characters did not differed significantly.

Shrirame *et al.* (2000) conducted a field experiment during the kharif 1996 in Nagpur, Maharashtra, India on rice cv. TNRH10, TNRH13 and TNRH18 were grown at 1, 2 or 3 seedlings $hill^{-1}$. Two seedlings $hill^{-1}$ produce significantly higher number of tillers $hill^{-1}$ and straw yield than other seedlings $hill^{-1}$. One seedlings $hill^{-1}$ produce significantly higher harvest index (HI) but plant height , number of functional leaves, leaf area and grain yield were not affected by seedling number $hill^{-1}$.

2.5:Effect of method of weeding on yield and yield component of rice

Weed vegetation in rice

Venkataraman and Gopalan (1995) observed that in transplant lowland rice the most important weed species were *Echinochloa Colonum*, *E. crusgalli*, *Cyperus difformis*, *C. iria*, *Fimbristylis miliace*, *Scirpus spp.*, *Ammania baccifera*, *Brachiaria spp.*, *Cyanotis axillaries*, *Eclipta alba*, *Ludwigia parviflora*, *Marsilea quadrifolia*, *Monochoria vaginalis*, *Ratala densiflora* and *Sphaeranchus indicus*.

Shahdeva *et al.* (1998) reported from an experiment that *Echinochloa colonum* and *Echinochloa crusgalli* dominated the dry and wet season rice, respectively while *Eclipta alba* and *Alternenthera sesilis* were the most prevalent broad leaves species, particularly in wet season.

Gogoi *et al.* (2001) conducted a field experiment in Assam, India during kharif seasons of 1995 and 1996 to know the effective weed management practices in transplanted rice. Close spacing (15 cm x 15 cm) + pre-emergence application of butachlor @ 0.5 kg ha^{-1} or anilofos @ 0.2 kg ha^{-1} reduced the weed growth effectively and increased the yield components and grain yield of rice and was comparable with the use of rotary weeder at 25 days after transplanting.

Hossain *et al.* (2003) found thirteen weed species infested the experimental field. The cultivar significantly affected all the characteristics studied, except panicle length.

Ranasinghe (2003) observed that dominant weed were *Monochoria vaginalis* and *Ludwigia octavalvis* in moderately-to-poorly-drained soils, and *Echinochloa crusgalli*, *Ischaemum nugosum*, *Leptochloa chiriensis*, *Cyperus iria*, *Fimbristylis miliacea* and *Cyperus difformis* in well to moderately drained soils.

Sathyamoorthy *et al.* (2004) observed the major weeds on the experimental rice field were *Cyperus iria*, *Echinochloa crusgalli*, *E. colonum*, *elipta alba* and *Ludwigia parviflora*.

Major weeds of boro rice crop

Twenty six species of weeds were found in Boro (Mamun, 1988). Out of them in AEZ-9 *Echinochloa crusgalli*, *Scripus juncoides* and *Monochoria hastate* were the major.

Mamun *et al.* (1987) reported 19 weed species namely *Echinochloa crusgalli*, *Echinochloa colonum*, *Monochoria hastata*, *Commelina bengalensis*, *Jussiaea repens*, *Atternanthera sessilis*, *Ipomoea aquatica*, *Cyperus strigosus*, *Enhydra fluckluana*, *Fimbristylis miliacea* and *Eleocharis plantagiuea* in Boro rice.

Mamun (1990) found 27 Species of Weeds belongs to 13 families to grow in association with modern boro rice. Of these species, 7 belonged to Cyperaceae, 6 to Gramineae, 2 to each of Onagracene, Amaranthac and Commelinaceae and 1 to each of Onagraceae, polygonaceae, Verbenaceae, Lythraceae, Lentibulariaceae, Convolvulaceae, Acanthaceae and Compositae. The most important species weed was *Cyprus iria* and followed by in order of importance as *Cyperus difformis, Ludwigia adscendens*, *Amaranthus sessilies,* *Echinochloa crusgalli* and *Amaranthus philoxeroides.* Annuals were dominant over perennials and broadleaves weeds were more important than grasses and sedges.

Effect of weeding method on yield and yield component of rice

Goyi and Pathak (1996) carried out an experiment during the monsoon season during 1991 at Titaban, Assam on rice cv. Pankaj and reported that grain yield was higher from weeding with a weeder at 25 and 45 DAT compared with unweeded control.

Bhattachary *et al.* (1996) observed that although the hand weeding treatment produce the highest yield and the result indicated that this was laborious, time consuming and costly. Hand weeding can be replaced by the application of butachlor 50 EW @ 10 kg a.i.ha^{-1}, cinmethylin @ 100 g a.i. ha^{-1} or butachlor 50 EW 0.5 kg a.i. ha^{-1}, at 10 DAT.

Ahmed *et al.* (1998) carried out an experiment in Pakistan to study the effects of weed control on rice yield and its components. Six treatments were included in this research work: no weed control, continuous weeding, weed control by herbicide and weed removal at 30, 45 and 60 DAT. They found weed control treatments were significantly affected number of tillers and bundle weight. The highest number of tillers m^{-2} (331) was recorded under continuous weeding followed by weed control at 30 DAT and herbicide. The highest yield was found 5.14 t ha^{-1} in continuous weeding.

Singh *et al.* (1999) reported that application of herbicide or hand weeding resulted significant effect in total number of weeds and their dry matter as compared to weedy check. Maximum weed density and dry weight were recorded with weedy check treatment. Crop received weed free treatment up to 60 DAT recorded the minimum weed density and weed dry weight. Pre-emergence application of Anilofs @ 0.4 kg a.i. ha^{-1} supplemented with one hand weeding at 40 DAT was found most effective in controlling density and dry weight of weeds.

Jena *et al.* (1999) observed that grain yield significantly differed due to weed infestation. The yield was 0.98 t ha^{-1} in unweeded control plots, 1.56 t ha^{-1} with herbicide and 2.24 t ha^{-1} in manual weed control plot.

Gul-Hassan *et al.* (2002) reported that grain yield was the highest in hand weeded and Basagran EC (post emergence) treated plots (2560 and 3256 kg ha^{-1}), respectively.

Ranasinghe (2003) noticed that the average grain yield obtained under farmers' weed management practice was lower by 12.6% than that recorded under researcher's weed management choice as high weed growth.

Effect of hand and mechanical weeding on weed infestation and performance of boro rice

Rafiquddualla (1999) found that the weed dry weight at 20, 40 and 60 DAT was significantly affected by the weeding regimes. No weeding regimes produced the highest weed density and weed dry weight. He also observed that maximum number of effective tillers, panicle length, grains $panicle^{-1}$, grain yield and straw yield from the weed free condition which was similar to three weeding. Maximum non-effective tillers and sterile spikelets grains were found from the no weeding regimes.

Islam (2003) carried out a research work to evaluated the effect of five weeding regimes viz. no weeding, one weeding at 20 DAT, two weedings at 20 and 40 DAT, three weedings at 20, 40 and 60 DAT and always weed free and observed that the highest grain yield and effective tillers hill^{-1} were obtained under always weed free condition, which was statistically similar to that obtained from three weedings at 20, 40 and 60 DAT. However, Chowdhury *et al.* (1998) noticed that the highest number of tillers hill^{-1}, grains panicle^{-1} and grain yield were observed in the weed free condition in rice.

Effect of herbicides on weeds and rice

Gul-hassan *et al.* (2002) reported that weed control treatments reduced weed infestation and elevated rice yield. Hand weeding followed by Basagran EC (post-emergence) and Rilof EC (pre-emergence) were most effective in reducing weed infestation to 6.13 and 17 weed plants m^{-2}, respectively.

Singh *et al.* (2004) found that Butachlor at 1.5 kg (pre- emergence) + 0.5 kg 2, 4 D ha^{-1} (post- emergence) treatment produce grain yield similar to hand weeding done 2 times (30 and 50 days after transplanting).

Effect of rifit 500 EC/pretilachlor on weed and rice

Achlderon *et al.* (1987) observed selectivity of rifit (pretilachlor) in both direct seeded and transplanted rice. The herbicide gave good control of most major broad leaves and sedge weeds of low land rice. Application of 20 g Prêtilachlor ha^{-1} 3- 5 days after transplanting is recommended for optimum efficiency.

Guerra *et al.* (1989) observed that rifit 500EC controlled a broad range of weeds of rice including *Alismatacae*, *Cyperaceae* (both annual and perennial), *Potamogetonaceae*, *Elatinaceae* and *Lythraceae* without injuring rice. Some activity was evident against *Echinochloa* at early growth stages. Set-off 20 WG was effective when applied at the 1-2 leaf stage of rice up to tillering. A rate of 80 g a.i.ha^{-1} proved aquatic weed control. It showed low toxicity to mammals and fishes.

Cabanilla, (1993) reported that rifit 500 EC mixture with sand offer excellent weed control efficacy. This mixture provides long lasting, broad-spectrum weed control with one- short treatment. Rifit 500EC mixture with sand gives superior control of grasses, sedges and broad leaved weeds with variable water management.

Mondal *et al.* (1995) investigated the efficiency of rilot H and rifit 500 EC as herbicides in comparison of hand weeding in BR11 variety of aman rice. The major weeds in the rice were *Cyperus iria* L., *Scirpus macronatus* L. and *Monochoria*. Plots treated with rilot H @ 3 L ha^{-1} produced the highest grain yield (6.0 t ha^{-1}) which was identified with the treatments of hand weeding at 21, 38 and 55 DAT and rifit 500 EC 2 L ha^{-1}. The lowest doses of both rilot H 1 L ha^{-1} and rifit 500 EC 1 L ha^{-1} failed to kill the weeds properly. The highest doses of both rilot H and rifit 500 EC had phytotoxic effects on the rice plant and the grain yield reduction due to weed infestation was 20.3 %.

Chowdhury and Thakuria (1998) evaluated a few herbicides for the performance in wet-seeded rice (*Oryza sativa* L.). They found that rifit 500 EC/pretilachlor either at 0.45 or 0.60 kg ha^{-1}, combination of butachlor and pretilachlor at 1.00 and 0.50 kg ha^{-1}, respectively in 1992 and butachlor 1.00 kg ha^{-1} followed by hand weeding 25 days after sowing in 1993 recorded comparable yields as that of hand weeding 20 and 40 days after sowing. The weed control efficiency of these treatments ranged from 30 to 75% compared with 65 to 72 % of hand weeding 20 and 40 days after sowing.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiments were conducted at the Research and Development Farm of Syngenta Bangladesh Limited (Multinational Plant Science Company) located at Birgram, Kharna Union, Bogra, Bangladesh (Fig. 1) during two consecutive Boro season [Boro'2006-2007 (Nov'2006-May'2007) and Boro'2007-2008 (Nov'2007-May'2008)].

Details of the different materials and methods are presented in this chapter.

3.1 Description of the experimental site

3.1.1 Geographical location

The experimental site is located at 24.51°N latitude and 89.18°E longitude at an elevation of 17 m above the sea level.

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological Zone (AEZ-25) of the Level Barind Tract.

3.1.3 Soil

The land was medium high and the soil was clay loam in texture, poorly drained and developed on shallowly weathered Madhupur clay. The predominant soil had a grey, silty and puddle top soil with plough pan below. The soil having low moisture holding capacity, very low in organic matter (0.8 %) and low in most of the available nutrient. The pH of the soil ranged from 5.0-5.7.

3.1.4 Climate

The research station had a variable pre-monsoon rainfall and occasional dry breaks. The mean annual rainfall was 1553 mm, most of which fall during June to September. Water balance was negative from November to April. The warmest and coldest month were April (35°C maximum) and January (11.6°C minimum), respectively.

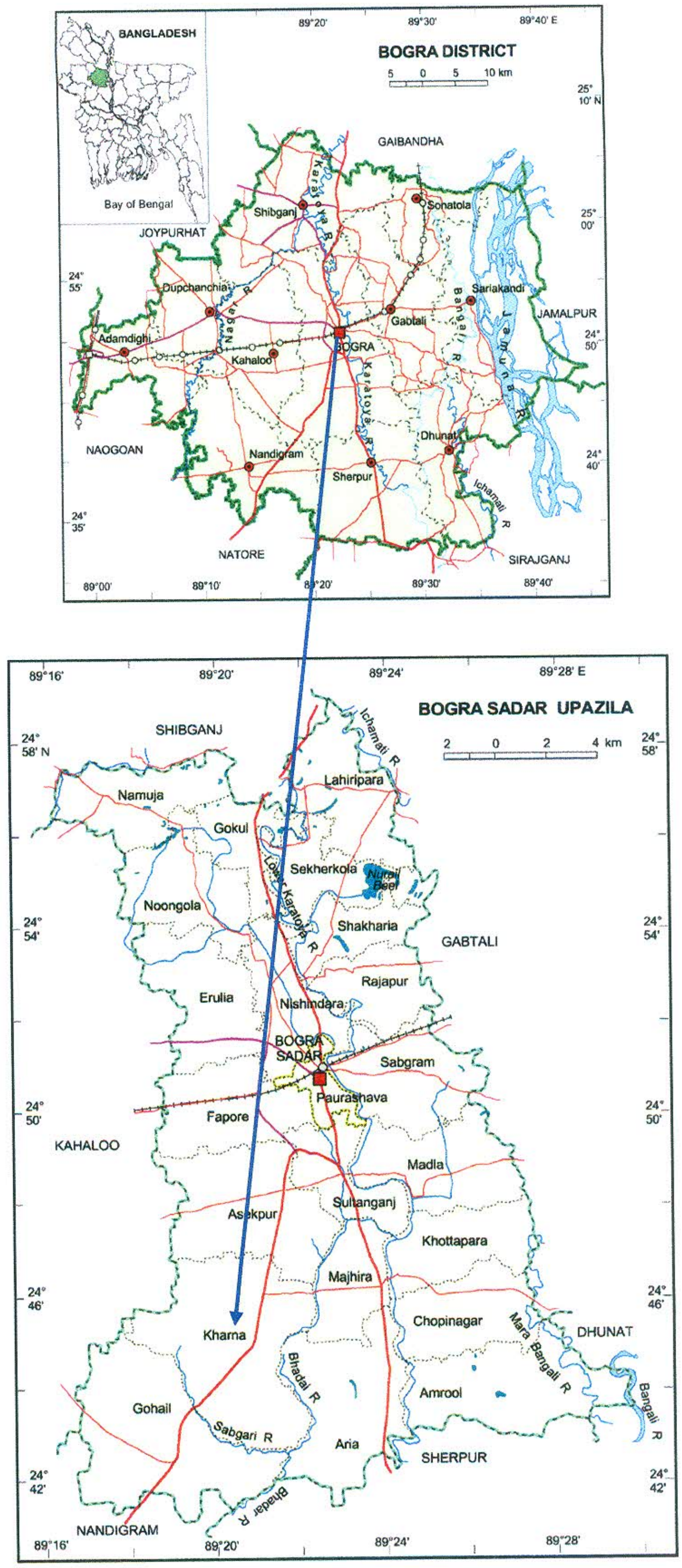

Fig. 1: Geographic location of the experimental site

3.2 Details of the experiment

3.2.1Effect of spacing on yield and yield component of rice (Var: BRRI dhan29)

Objective: To know the appropriate spacing on yield and yield attributes of rice (var:BRRI dhan29)

Design: RCBD with 3 replications.

Treatment

The study was comprised of the following treatments

Sp_1 : 25 x 10 cm, Sp_2 : 25 x 15 cm, Sp_3 : 25 x 20 cm, Sp_4 : 25 x 25 cm, Sp_5 : 25 x 30 cm

Experimental layout

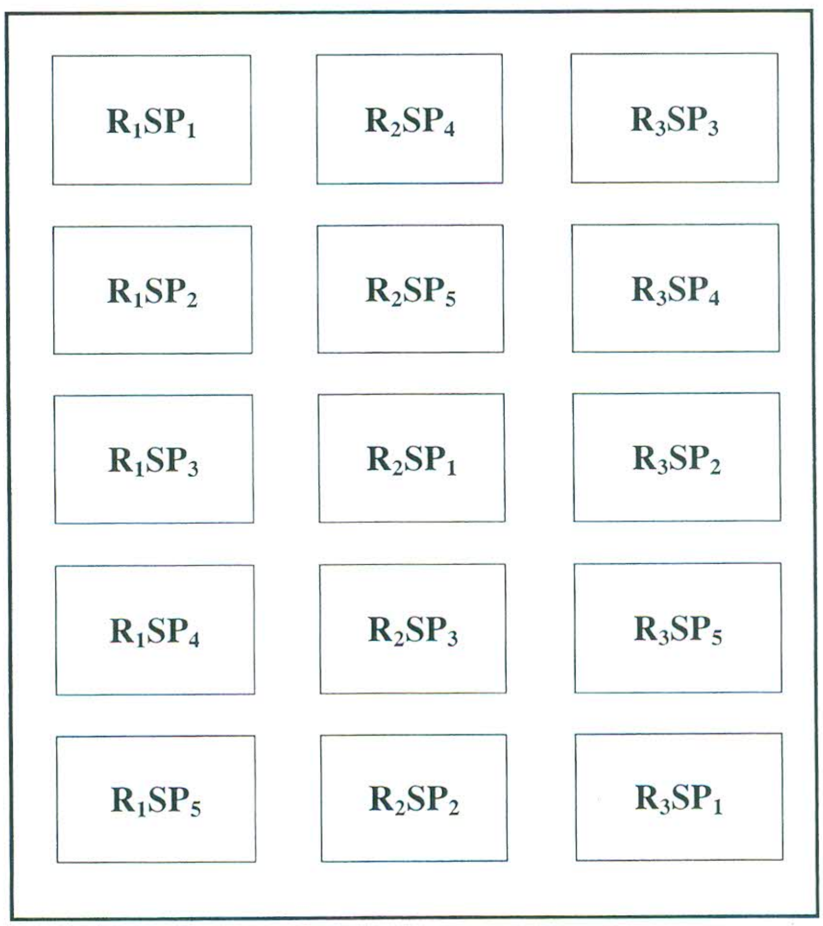

Fig. 2: Experimental layout

3.2.2Effect of time of transplanting on yield and yield component of rice (Var:BRRI dhan29)

Objective: To know the optimum time of transplanting on yield and yield attributes of BRRI dhan29.

Design: RCBD with 3 replications.

Treatment:T_1 :10th December, T_2 :25th December, T_3 :10th January, T_4 :25th January, T_5 :10th February

Experimental layout

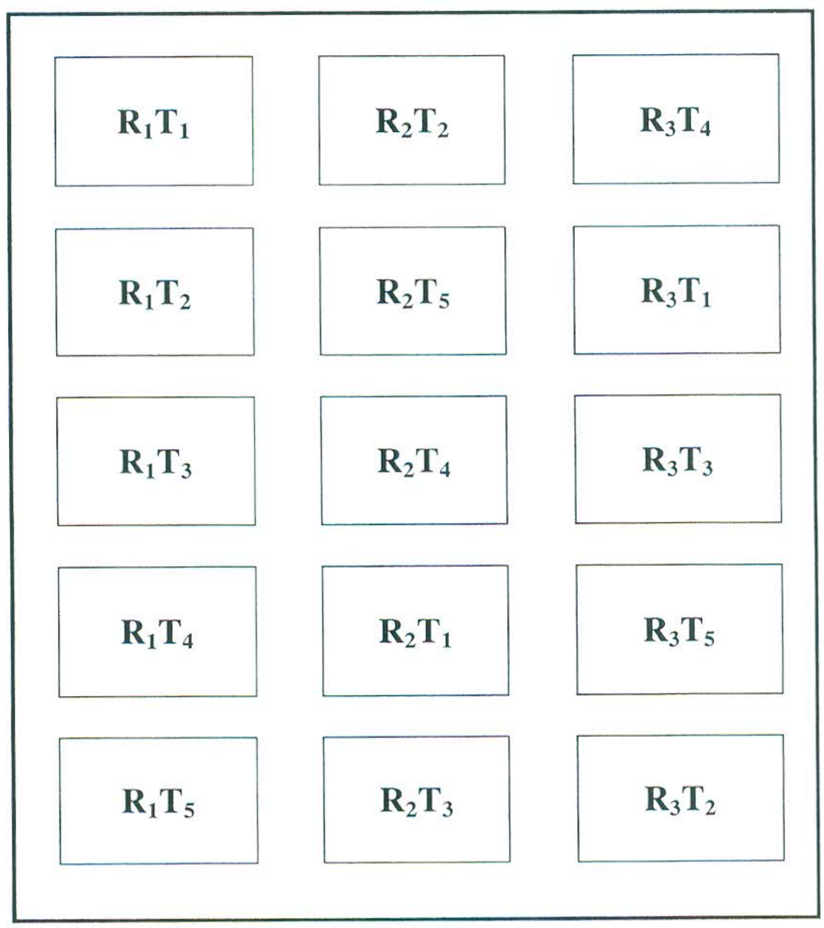

Fig. 3: Experimental layout

3.2.3 Effect of nitrogen on yield and yield component of BRRI dhan29

Objective: To determine the optimum dose of nitrogen on yield and yield attributes of BRRI dhan29.

Design: RCBD with 3 replications.

Treatment:

The study was comprised of the following treatments

N_1= 0 kg/ha , N_2= 90 kg/ha , N_3= 110 kg/ha , N_4= 130 kg/ha , N_5=150 kg/ha

Experimental layout

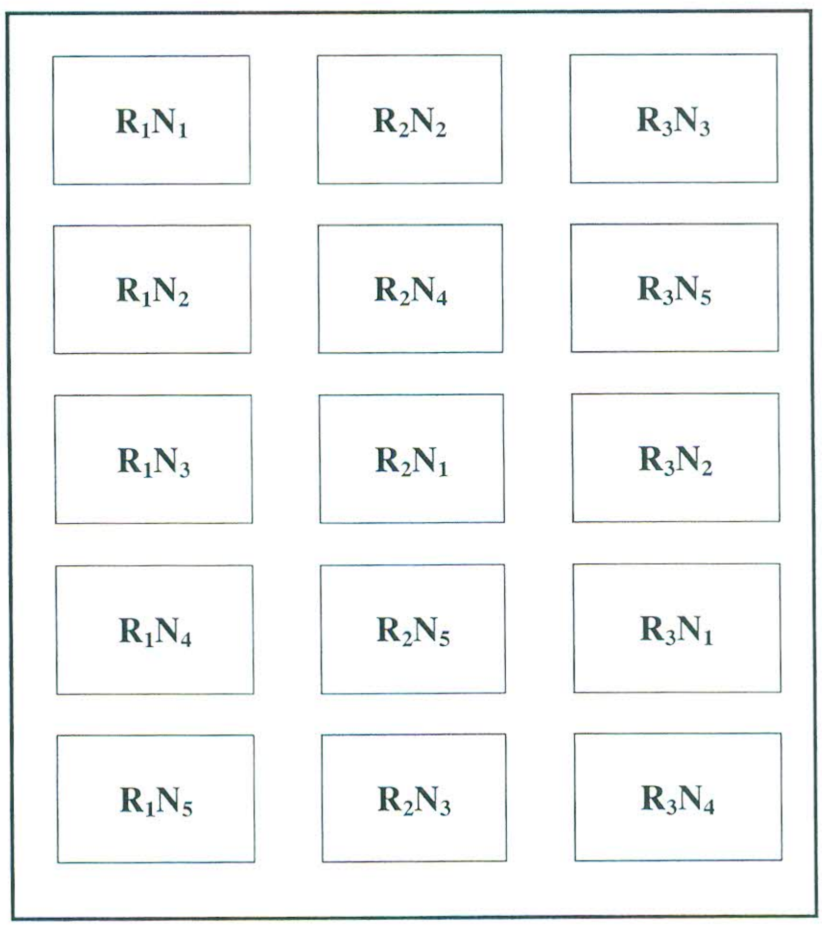

Fig. 4: Experimental layout

3.2.4Effect of seedling age and seedling number per hill on yield and yield component of rice (cv.BRRI dhan29)

Objective:

1. To find out the optimum seedling age and number for higher yield.

2. To see the interaction between seedling age and number of seedlings $hill^{-1}$.

Design: RCBD (factorial) with 3 replications.

Treatment:

Factor1: Seedling age

SA_1: 30 days old, SA_2: 40 days old, SA_3: 50 days old, SA_4: 60 days old

Factor2: Number of Seedling $hill^{-1}$

SN_1: 2 seedlings/hill, SN_2: 4 seedlings/hill, SN_3: 6 seedlings/hill

Treatments :

SA_1SN_1 ,	SA_2SN_1 ,	SA_3SN_1 ,	SA_4SN_1 ,
SA_1SN_2 ,	SA_2SN_2 ,	SA_3SN_2 ,	SA_4SN_2 ,
SA_1SN_3 ,	SA_2SN_3 ,	SA_3SN_3 ,	SA_4SN_3 ,

Experimental layout

$R_1SA_1SN_1$	$R_2SA_2SN_1$	$R_3SA_3SN_1$
$R_1SA_1SN_2$	$R_2SA_2SN_2$	$R_3SA_3SN_2$
$R_1SA_1SN_3$	$R_2SA_2SN_3$	$R_3SA_3SN_3$
$R_1SA_2SN_1$	$R_2SA_4SN_1$	$R_3SA_1SN_1$
$R_1SA_2SN_2$	$R_2SA_4SN_2$	$R_3SA_1SN_2$
$R_1SA_2SN_3$	$R_2SA_4SN_1$	$R_3SA_1SN_3$
$R_1SA_3SN_1$	$R_2SA_1SN_1$	$R_3SA_2SN_1$
$R_1SA_3SN_2$	$R_2SA_1SN_2$	$R_3SA_2SN_2$
$R_1SA_3SN_3$	$R_2SA_1SN_3$	$R_3SA_2SN_3$
$R_1SA_4SN_1$	$R_2SA_3SN_1$	$R_3SA_4SN_1$
$R_1SA_4SN_2$	$R_2SA_3SN_2$	$R_3SA_4SN_2$
$R_1SA_4SN_3$	$R_2SA_3SN_3$	$R_3SA_4SN_3$

Fig. 5: Experimental layout

3.2.5 Effect of method of weeding on the performance, yield and yield component of rice (cv.BRRI dhan29)

Objective:

1. To investigate the relative efficiency of different weed control method.
2. To select the best weed control option for obtaining high yield.

Design : RCBD with 3 replications.

Treatment :

The study was comprised of the following treatments

W_0= No weeding , W_1= One hand weeding , W_2= Two hand weeding , W_3= Application of Pretilachlor 500 EC @ 0.5 litre ha^{-1} (Under dose), W_4= Application of Pretilachlor 500 EC @ 1.0 litre ha^{-1} (Optimum dose) , W_5 =Application of Pretilachlor 500 EC @ 1.5 litre ha^{-1} (Over dose)

Experimental layout

R_1W_0	R_2W_4	R_3W_3
R_1W_1	R_2W_2	R_3W_0
R_1W_2	R_2W_5	R_3W_4
R_1W_3	R_2W_0	R_3W_1
R_1W_4	R_2W_1	R_3W_5
R_1W_5	R_2W_3	R_3W_2

Fig. 6: Experimental layout

3.2.6 Experimental Design

Experiment 1, 2, 3 and 5 was laid out in a randomized complete block design with three replications and Experiment 4 was laid out in a randomized complete block design (factorial) with three replications. Each replication represented a block in the experiment. Each block was divided into unit plots where the treatments were allocated at random. The size of unit plot was 4.0 m x 2.5 m. The spaces between replications and between unit plots were 1.0 m and 0.5 m, respectively.

3.2.7 Plant material

BRRI dhan29 was used as plant material.

3.2.8 Description of Variety : BRRI dhan29

BRRI dhan29, a high yielding inbred variety of boro season developed by the Bangladesh Rice Research Institute (BRRI). This variety with the pedigree number BR 802-118-4-2 was developed by crossing breeding line BG 90-2 with BR-51-46-5. Then the line BR 802-118-4-2 was released for boro season as BRRI dhan29 in 1994. Life cycle of this variety ranges from 155 to 160 days. It attains a plant height of 95-100 cm at maturity. The grains are medium slender with light golden husks and kernels are white in color. The cultivar gives a grain yield of 7.5 ton/ha. It is resistant to damping off and moderately resistant to sheath blight and bacterial blight. In terms of yield, this is the best variety so far released by BRRI (BRRI, 1991).

3.3 Crop Management

3.3.1 Raising of seedling

3.3.1.1 Seed collection

Healthy seeds of BRRI dhan29 was collected from the Genetic Resource and Seed Division, BRRI, Gazipur, Bangladesh.

3.3.1.2 Seed sprouting

Seeds were soaked in water in bucket for 24 hours. Then seeds were taken out of water and kept densely in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing after 72 hours.

3.3.1.3 Preparation of seedling nursery and seed sowing

A piece of high land was selected in the east side of pump house of Syngenta R & D farm, Birgram, Bogra for raising of seedling. The land was puddled with harrow and country plough, cleaned and leveled by ladder. Then the sprouted seeds were sown in the nursery beds as per experimental schedule. Proper care was taken to raise the seedling in the nursery bed. Weeds were removed and irrigation was given in the seedling nursery as and when necessary.

3.3.2 Preparation of experimental land

The experimental land was first open with a tractor drawn disc plough 15 days before transplanting. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a tractor plough and leveled by laddering. The field layout were prepared on schedule date according to experimental specification, immediately after final land preparation. Weeds and stubble were cleaned off from individual plots and finally plots were leveled properly by wooden plank so that no water pocket were remained in the puddle field.

3.3.3 Fertilizer application

Cowdung was applied in unit plots at the rate of 5 t/ha. and chemical fertilizers such as urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate were applied at the rate of 270-130-120-70-10 kg/ha in order to supply of N,P,K,S and Zn respectively (BRRI,1991). Whole triple superphosphate, muriate of potash, gypsum, zinc sulphate and cowdung were applied as basal dose at final land preparation in individual plots. Urea was top-dressed in three equal installments on 10, 30 and 50 days after transplanting (DAT).

3.3.4 Uprooting of seedlings

Seedlings were uprooted from the nursery bed carefully as per the experimental schedule.

3.3.5 Transplanting

Seedlings were transplanted in the well-puddle experimental plots as per experimental treatments in the schedule. Soil of the plots were kept moist without allowing standing water. Seedlings (as per treatment) were transplanted into the soil very gently and close to soil; so that, its root lies horizontally in moist soil.

3.3.6 Intercultural operations

3.3.6.1 Gap filling

One week after transplanting, gap filling was carried out as and where needed with seedlings from the same source.

3.3.6.2 Weeding

In order to keep the crop weed free, manual weeding was done in three times during entire growing season except the experiment-5. The first weeding were done on 20 DAT and the crop were subsequently weeded out at every 15 days interval.

3.3.6.3 Water management

After transplanting, standing water was kept in the plots up to 2-3 inch for transplanting shock recovery and during tillering stage, the plots were kept saturated for good tillering and from panicle initiation (PI), 2-3 cm standing water was maintained until hard daugh stage. Again water was drained out from the plots during ripening stage.

3.3.6.4 Plant protection measures

If any remarkable infestation either by insect or by disease were noticed in the field, appropriate plant protection measures were taken.

3.3.7 Harvesting and processing

The crop of each plot were harvested separately at full maturity when 90% of the grains turn golden yellow in color on different dates. Hills from the central 5 m^2 area of each plot were harvested for collecting data on crop yield. The harvested crop of each plot were bundled separately, tagged and brought to the clean threshing floor. The crops were threshed by pedal thresher and then grains were cleaned. The grain and straw weight for each plot were recorded after proper sun drying and then converted at 14% moisture level. Prior to harvesting, ten plants were selected randomly from each plot and uprooted carefully for collecting data on yield contributing characters.

3.4 Data collection

3.4.1 Collection of data on growth parameters at vegetative stage

Data were recorded on the following parameters:

- Plant height (cm)
- Total tillers $hill^{-1}$

3.4.2 Data recording at harvest on yield and yield components

- Plant height (cm)
- Total number of tillers $hill^{-1}$
- Number of bearing tillers $hill^{-1}$
- Panicle length (cm)
- Number of filled spikelets per panicle
- Number of sterile spikelets per panicle
- Number of total spikelets per panicle

- 1000 grain weight (gm)
- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest Index (%)

3.5 Data recording

A brief outline on data recording procedure were followed during the study was given below:

3.5.1 Growth characters

Growth characters viz. plant height, and number of tillers $hill^{-1}$ were recorded at 35, 50, 65 and 80 days after transplanting (DAT).

Plant height and number of tillers $hill^{-1}$

Ten hills were randomly selected and marked with bamboo sticks in each unit plot excluding border rows to record the data on plant height and number of tillers $hill^{-1}$. The plant height were measured from the collar zone of the plant to the tip of the longest leaf. Plant height and number of tillers $hill^{-1}$ were recorded at 15 days interval beginning at 35 DAT up to 80 DAT.

3.5.2 Yield and yield components

Ten plants sample $plot^{-1}$ other than those from the central 5 m^2 area were selected randomly. The sample plants were harvested and tagged separately. Data on yield components were collected from the sample plants of each plot.

Plant height

The plant height were measured from ground level to the tip of the upper most panicle.

Total tillers hill^{-1}

Tillers with at least one visible leaf were counted. It included both bearing and non bearing tillers.

Bearing tillers hill^{-1}

The tillers which had at least one grains panicle^{-1} were considered as bearing tillers.

Panicle length

Panicle length were measured from the first node of the rachis to the tip of each panicle.

Total spikelets panicle^{-1}

Number of all spikelets of each panicle were counted.

Number of filled spikelets panicle^{-1}

Presence of food material in the spikelet were considered as grain and total number of grains present on each panicle were counted.

Sterile spikelets panicle^{-1}

Spikelets having no food material inside were considered as sterile spikelets and the number of such spikelets present on each panicle were counted.

1000 grain weight (g)

One thousand clean dried grains from the seed stock of each plot were counted separately and weight was taken by an electrical balance at 14% moisture.

Grain yield

Grains obtained from the central 5 m^2 area of each plot were sun dried, cleaned and weighed carefully at 14% moisture. Dry weight of grains of each plot were converted into grain yield ton hectare^{-1}.

Straw yield

Straw obtained from the central 5 m^2 area of each plot were sun dried and weighed separately in kg $plot^{-1}$ and finally converted into straw yield ha^{-1}.

Biological yield

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

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

Harvest index (%)

It is the ratio of economic yield to biological yield and were calculated with the following formula:

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

3.6 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and the mean differences were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Chapter 4

RESULTS

RESULTS

4.1: Effect of Spacing on yield and yield component of rice (cv.BRRI dhan 29)

The crop plant depends largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional requirements. A thick population crop may have limitations in the maximum availability of these factors. It is, therefore, necessary to determine the optimum density of plant population per unit area for obtaining maximum yields. A number of workers have reported that maintenance of a critical level of rice plant population in field was necessary to maximize grain yields. Results on the effects of different plant spacing on different growth parameters, yield and yield components of boro rice cultivar BRRI dhan29 have been presented and discussed in this chapter. The results have been presented in tables, figures, plate and appendices. A general view of the experimental plot has been shown in plate 1.

Plate 1: A General view of the experimental plot at tillering stage

4.1.1 Growth parameters before harvest at vegetative phase

4.1.1.1Plant height

There was no significant effect on plant height at all the sampling dates of BRRI dhan29 due to different plant spacing (Appendix 3). At 35 days after transplanting (DAT) the tallest plant(40.05 cm) was obtained with 25 cm x 20cm spacing and shortest plant(37.82 cm) with 25cm x 15cm. At 50 DAT, the tallest plant (56.73 cm) was observed with 25cm x 25cm spacing and shortest (53.80 cm) with 25cm x 15cm. At 65 DAT, the tallest plant (61.05 cm) was observed with 25cm x 25cm spacing and shortest (58.51 cm) with 25cm x 15cm. At 80 DAT, the tallest plant (70.23 cm) was produced with 25cm x 10cm and shortest (67.85 cm) with 25cm x 15cm (Table 1).

4.1.1.2 No. of tiller hill^{-1}

Spacing had significant effect on number of tiller hill^{-1} at 5% level of probability except at 35 DAT (Appendix 3). At 35 DAT highest tiller (11.47) found with 25cm x 20cm and the lowest tiller (9.07) with 25cm x 10cm. The highest number of total tiller hill^{-1} (16.20, 29.73 and 23.00 at 50, 65 and 80 DAT respectively) was observed from wider spacing 25cm x 30cm and the lowest number of total tiller (10.07, 13.73 and 10.53 at 50, 65 and 80 DAT respectively) was obtained with closer spacing 25cm x 10cm (Table 1).

4.1.2.Yield and yield contributing characters at harvest

4.1.2.1. Plant height

There was no significant effect on plant height in respect of plant spacing (Appendix 4). The highest plant (91.99 cm) was obtained at 25cm x 20cm spacing followed by 25cm x 25cm spacing and the wider spacing (25cm x 30cm) produced the lowest plant height (84.91 cm). (Appendix 5)

4.1.2.2. No. of effective, non-effective and total tiller hill^{-1}

It was observed that the spacing was significant effect in producing effective tiller hill^{-1}(Appendix 4). The highest number of effective tiller hill^{-1} (19.07) was obtained with spacing 25cm x 30cm and the lowest number of effective tiller hill^{-1} (9.53) was found with 25cm x 10cm spacing. There was no significant effect on number of non effective tiller hill^{-1}. The highest number of non-effective tiller hill^{-1} (0.67) was produced at 25cm x 30cm and 25cm x 20cm spacing. The lowest number of non effective tiller hill^{-1} (0.20) was obtained at 25cm x 10cm spacing. The different plant spacing had the significant effect on number of total tiller hill^{-1}. The highest number (19.73) of total tiller hill^{-1} was obtained at 25cm x 30cm spacing and the lowest (9.73) was 25cm x 10cm spacing (Fig. 7 and Appendix 5).

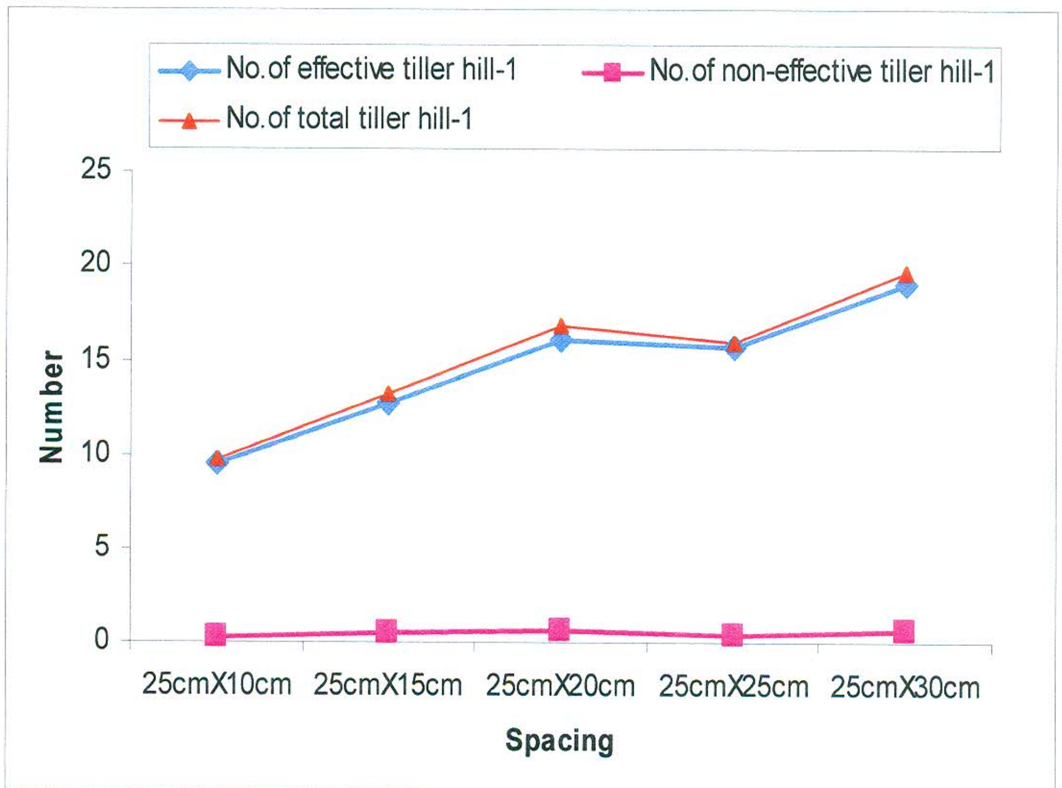

Fig. 7: Effect of spacing on number of effective, non-effective and total tiller per hill of BRRI dhan29

4.1.2.3. Panicle length

Spacing had no significant effect on panicle length (Appendix 4). The longest (22.93cm) panicle length was obtained at 25cm x 15cm spacing followed by 25cm x 20 cm and the shortest panicle length (22.27cm) was found with 25cm x 25cm spacing (Appendix 5).

4.1.2.4. Number of fertile, sterile and total spikelet panicle^{-1}

It was observed that number of fertile spikelet panicle^{-1} varied significantly due to spacing (Appendix 4). The plant grown in 25cm x 20cm spacing obtained the highest number of grains panicle^{-1} (160.7) which was statistically similar to 25cm x 30cm (149.3) and 25cm x 15cm (136.3) and the lowest one (109.36) was observed when the plant was transplanted at 25cm x 10cm spacing. Number of sterile spikelet penicle^{-1} was significantly affected by spacing. The plant grown under 25 cm x 10 cm spacing produce the highest number of sterile spikelet panicle^{-1} (81.47) and the lowest one (45.80) was produced at 25 cm x 20 cm spacing which was statistically identical to 25 cm x 30 cm spacing (49.13).There was no significant effect on number of total spikelet panicle^{-1} due to different plant spacing.The highest number of total spikelet panicle^{-1} (206.47) was obtained at 25 cm x 20 cm spacing and the lowest one (190.93) obtained at 25 cm x 10 cm spacing (Fig. 8 and Appendix 5).

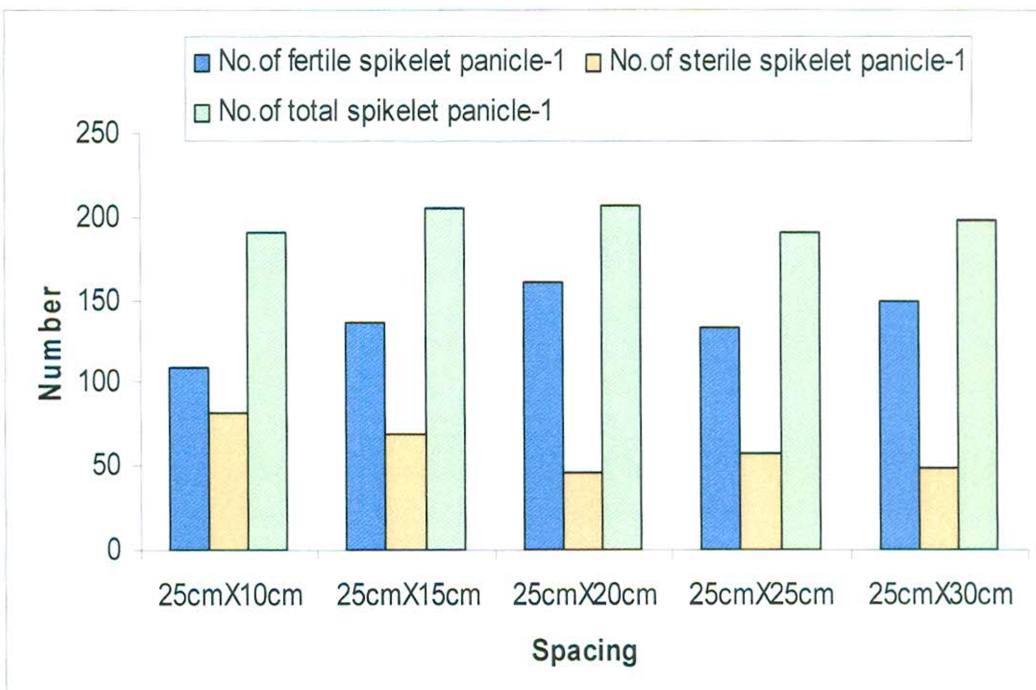

Fig. 8: Effect of spacing on number of fertile, sterile and total spikelet per panicle of BRRI dhan29

4.1.2.5. 1000 grain weight

The effect of different plant spacing on 1000 grain weight was not found significant (Appendix 4). However results observed that the highest 1000 grain weight was obtained at 25 cm x 30 cm (20.00 g) spacing and lowest (19.00 g) was found at the spacing 25 cm x 25 cm (Appendix 5).

4.1.2.6. Grain yield

The spacing had significant effect on Grain yield (Appendix 4). The highest grain yield (7.32 t ha^{-1}) was obtained from 25 cm x 20 cm spacing followed by 25 cm x 25 cm and the lowest grain yield (5.21 t ha^{-1}) was found from 25 cm x 10 cm spacing (Fig. 9 and Appendix 5).

4.1.2.7. Straw yield

Plant spacing was significant effect in respect of straw yield (Appendix 4). The highest straw yield (7.06 t ha^{-1}) was observed in 25cm x 30cm spacing which was identical to 25cm x 20cm and the lowest straw yield (5.77 t ha^{-1}) was found from 25 cm x 25 cm spacing (Fig. 9 and Appendix 5).

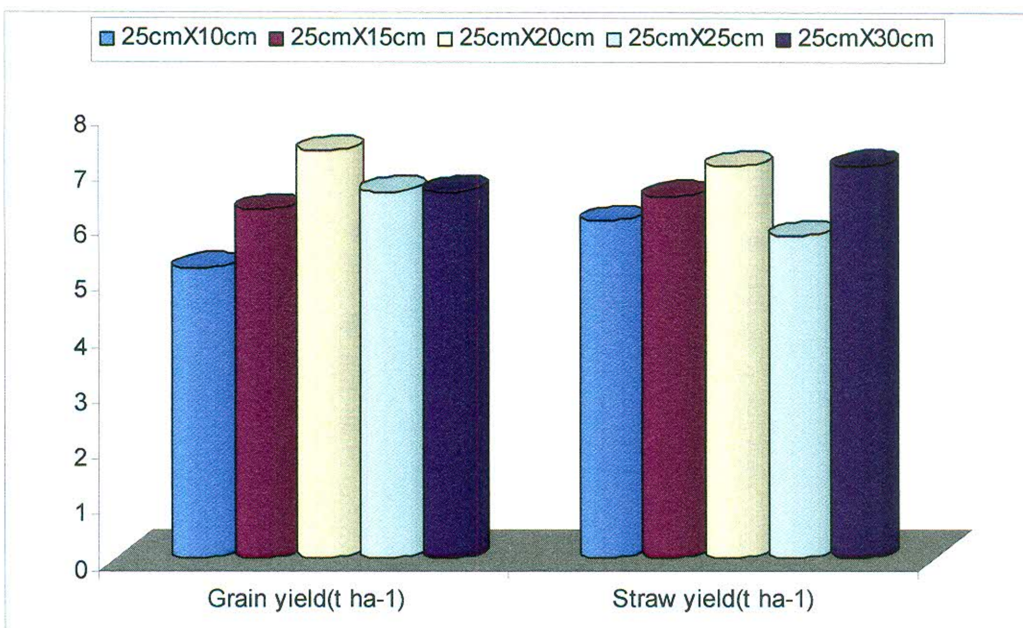

Fig. 9: Effect of spacing on grain yield and straw yield of BRRI dhan29

4.1.2.8. Biological yield

Biological yield was significantly affected by different plant spacing (Appendix 4). The highest biological yield (14.36 t ha^{-1}) was observed from 25cm x 20cm spacing followed by 25cm x 30cm spacing (13.64 t ha^{-1}) and the lowest biological yield (11.26 t ha^{-1}) was found from 25cm x 10cm spacing (Fig. 10 and Appendix 5).

4.1.2.9. Harvest index (%)

There was significant effect on harvest index due to the plant spacing (Appendix 4). The results noticed that spacing 25cm x 25cm produced the highest harvest index (53.32%) followed by 25cm x 20cm spacing (50.95%) and the lowest harvest index (46.27%) was observed from the spacing of 25cm x 10cm (Fig. 10 and Appendix 5).

Based on the present study, it could be suggested that the BRRI dhan29 grown in boro season under 25cm x 20cm spacing emerged out as a promising practice in order to get the desired plant growth and grain yield.

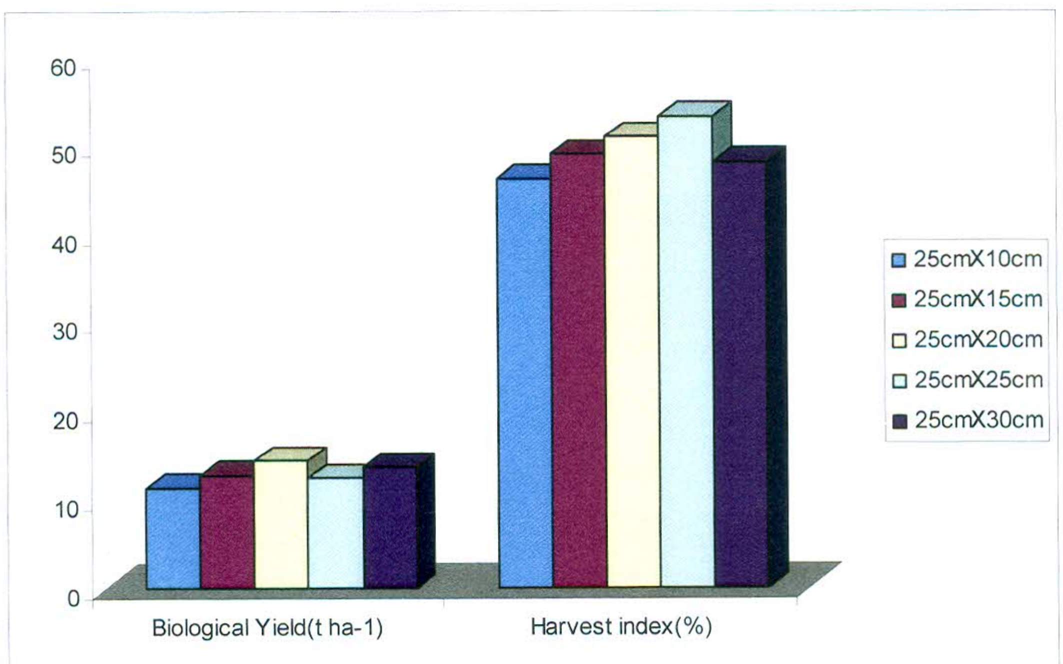

Fig. 10: Effect of spacing on biological yield and harvest index of BRRI dhan29

Fig : 25cm x 10cm spacing

Fig : 25cm x 15cm spacing

Fig : 25cm x 20cm spacing

Fig : 25cm x 25cm spacing

Fig : 25cm x 30cm spacing

Plate 2: Different treatment plot of experiment 1

Table 1: Effect of spacing on plant height, total tillers hill^{-1} before harvest of Boro rice (cv.BRRI dhan29)

Spacing	Plant height (cm)				No. of tiller plant^{-1}			
	35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
SP_1	38.13	54.04	60.97	70.23	09.07	10.07b	13.73c	10.53c
SP_2	37.82	53.80	58.51	67.85	10.07	13.27ab	20.00b	14.93bc
SP_3	40.05	56.70	60.32	68.07	11.47	16.13a	23.73b	17.80b
SP_4	39.12	56.73	61.05	68.23	10.60	15.47a	24.73b	17.73b
SP_5	38.63	55.59	59.39	68.08	09.87	16.20a	29.73a	23.00a
S(X)	00.82	00.89	00.72	01.25	00.92	00.69	00.98	00.98
level of sig.	NS	NS	NS	NS	NS	**	**	**
cv(%)	03.67	02.77	02.09	03.16	15.55	08.38	07.57	10.06

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SP_1=25 cm x 10 cm
SP_2=25 cm x 15 cm
SP_3=25 cm x 20 cm
SP_4=25 cm x 25 cm
SP_5=25 cm x 30 cm

4.2. Effect of time of transplanting on yield and yield component of rice (cv. BRRI dhan 29)

Results of different planting time effect on the yield and yield components of BRRI dhan29 in Boro season has been presented below.

4.2.1. Plant height

Plant height was significantly affected by planting time at 1% level of probability (Appendix 6). The tallest plant (104.9 cm) was observed from 25th January planting which was statistically similar to 10th February planting and the shortest plant (83.07 cm) was obtained from 25th December planting (Appendix 7).

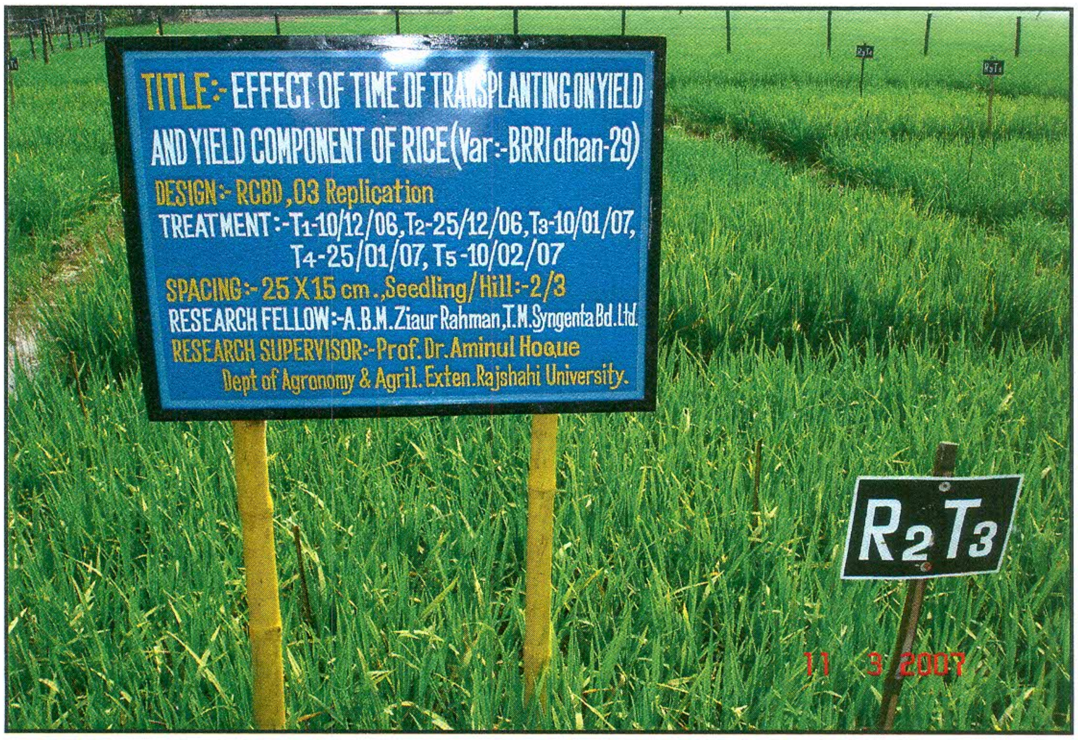

Plate 3: A General view of the experimental plot at tillering stage

4.2.2. Number of effective and total tiller hill^{-1}

There was significant effect on number of effective tiller hill^{-1} for different date of planting (Appendix 6). It was found that the highest number of effective tiller hill^{-1} (13.20) was produced on 10th January planting which was statistically similar to 25th

December and 25th January planting. The lowest number of effective tiller $hill^{-1}$ (9.00) was obtained on 10th February planting which was statistically similar to 10th December planting. But from the analysis of variance it was observed that the number of total tillers $hill^{-1}$ was not significantly affected by the date of planting. The highest number of total tiller $hill^{-1}$ (13.27) was obtained from 10 January planting. The lowest number of total tiller $hill^{-1}$(9.00) was found in 10 February planting (Fig. 11 and Appendix 7).

Fig. 11: Effect of planting time on no. of effective and total tiller per hill of BRRI dhan29

4.2.3. Number of fertile, sterile and total spikelet $panicle^{-1}$

Number of fertile spikelet $panicle^{-1}$ was significantly influenced by different dates of planting (Appendix 6). The highest number of fertile spikelet $panicle^{-1}$ (139.0) was observed in 25th January planting which was statistically similar to all of the planting dates. The lowest number of fertile spikelet $panicle^{-1}$ (103.5) was obtained in 10th February planting. It was observed that the number of sterile spikelet $panicle^{-1}$ was also significantly affected by planting time. The highest number of unfilled grains $panicle^{-1}$ (77.93) was found at 10th February planting which was statistically similar to

10th December and 25th January planting. The lowest Number of unfilled grains panicle^{-1} (44.13) was observed on 10th January panting which was statistically similar to 25th December planting. On the other hand, number of total spikelet panicle^{-1} was not significantly influenced by planting date. Highest number of total spikelet panicle^{-1} (193.17) was observed from 10th December planting and lowest number of total spikelet panicle^{-1}(173.00) was observed from 25th December planting (Fig. 12 and Appendix 7).

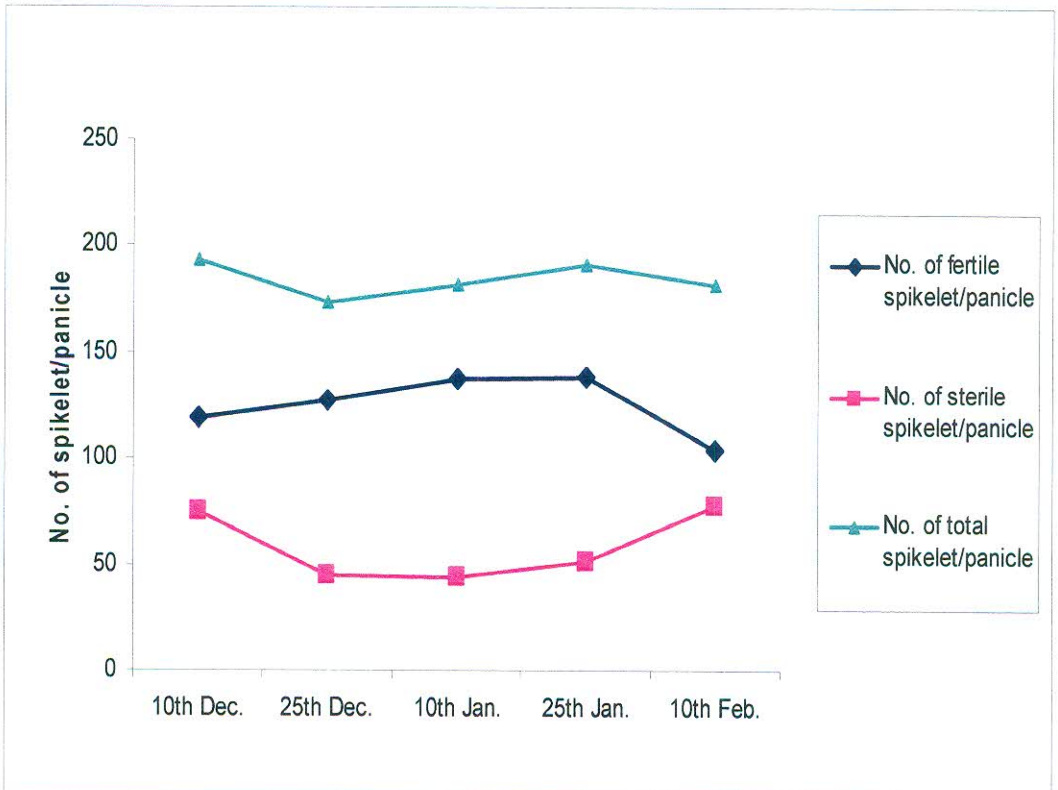

Fig. 12: Effect of planting time on no. of fertile, sterile and total spikelet per panicle of BRRI dhan29

4.2.5. 1000 grain weight

1000 grain weight was not significantly affected by planting date (Appendix 6). Though it was not statistically significant but numerically the highest 1000 grain wt. (20.33 g) was observed from 25th January and 10th February planting and the lowest (19.00 g) was obtained from 25th December planting (Appendix 7).

4.2.6. Grain yield, Straw yield and Biological yield

Both Grain yield, Straw yield and Biological yield was significantly influenced due to different dates of planting at 1% level of significance (Appendix 6). The highest grain yield (7.18 t ha^{-1}) was reported from 10^{th} January planting which was statistically similar to 25^{th} December and 25^{th} January planting. The lowest grain yield (5.07 t ha^{-1}) was noticed from 10^{th} February planting which was statistically similar to 10^{th} December planting. The straw yield followed the similar pattern of as that of grain yield. The highest straw yield (7.05 t ha^{-1}) was obtained from 25^{th} January planting which was statistically similar to 25^{th} December, 10^{th} January and 10^{th} February planting. The lowest straw yield (5.39 t ha^{-1}) was reported from 10^{th} December planting which was statistically similar to 25^{th} December and 10^{th} February planting. In case of biological yield, the highest (14.10 t ha^{-1}) was observed from 10^{th} January planting which was statistically similar to 25^{th} December and 25^{th} January planting. The lowest biological yield found in 10^{th} December planting which was statistically similar to 10^{th} February planting (Fig. 13 and Appendix 7).

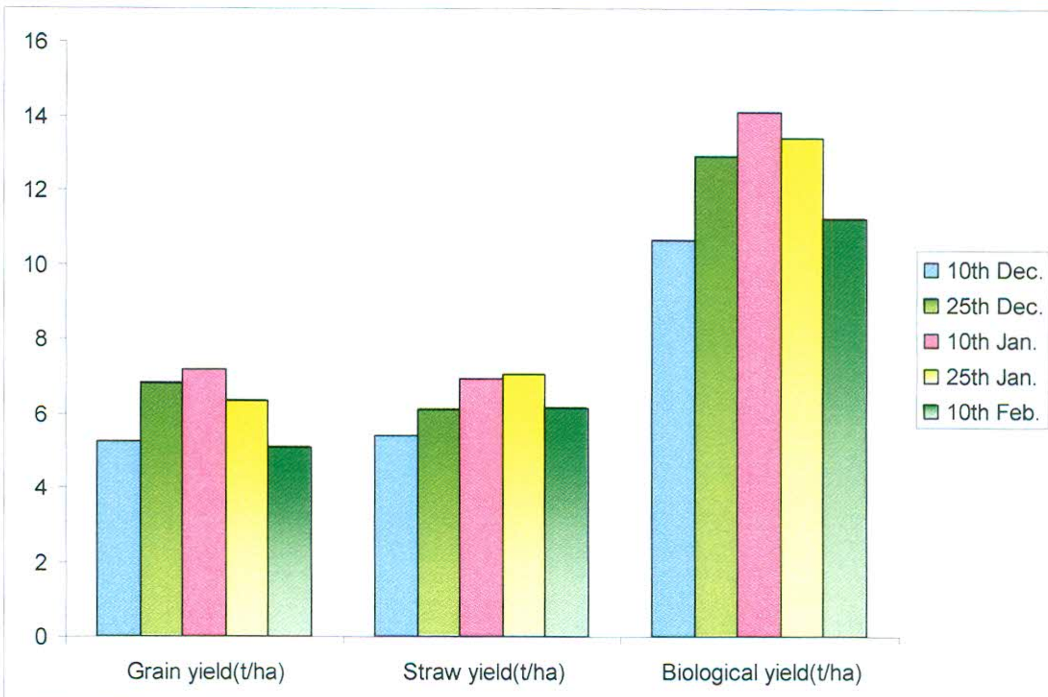

Fig. 13: Effect of planting time on grain, straw and biological yield of BRRI dhan29

4.2.7. Harvest Index

There was significant effect on harvest index due to different date of planting (Appendix 6). The highest harvest index (52.76%) was observed from 25th December planting which was statistically similar to 10th December and 10th January planting. The lowest harvest index (45.24%) was found from 10th February planting (Appendix 7).

From the above results the following conclusion may be drawn. All of the yield contributing character along with grain yield, straw yield, biological yield and harvest index was significantly affected by different planting dates and the highest values of those were observed on 10 January planting and the lowest on 10 December and 10 February planting and BRRI dhan29 should preferably be transplanted between 25 December to 25 January to have appreciable good yield.

Fig : 10th December planting

Fig : 25th December planting

Fig : 10th January planting

Fig : 25th January planting

Fig : 10th February planting

Plate 4: Different treatment plot

4.3. Effect of Nitrogen on yield and yield component of BRRI dhan29

Results of the present study regarding the effect of level of nitrogen fertilizer on the growth, yield and yield component of boro rice (cv.BRRI dhan29) have been presented and discussed in this chapter.

Plate 5: A General view of the experimental plot at tillering stage

4.3.1 Plant height and number of tiller hill^{-1} at vegetative phase

Nitrogen level influenced plant height significantly at all the sampling dates except at 50 DAT (Appendix 8). At 35 days after transplanting (DAT) the tallest Plant (37.35 cm) was produced with 130 kg N ha^{-1}. The shortest plant was produced from control (35.31 cm) which was statistically similar to 90 kg N ha^{-1} (35.37 cm), 110 kg N ha^{-1} (35.79 cm) and 150 kg N ha^{-1} (35.68 cm). At 65 DAT, the tallest plant (58.33 cm) was produced with 150 kg N ha^{-1} which was statistically similar to 130 kg N ha^{-1} (57.67 cm), 110 kg N ha^{-1}(57.00 cm) and 90 kg N ha^{-1} (56.51cm). The shortest plant height (51.62 cm) was obtained from control (0 kg N ha-1). The similar result was obtained from 80 DAT data. The shortest plant height was obtained from control (0 kg N ha^{-1}) at all stages of crop growth (Table 2).

Table 2: Effect of levels of nitrogen on plant height and total tiller hill^{-1} before harvest of boro rice (cv. BRRI dhan29)

Level of nitrogen (kg/ha)	Plant height (cm)				No of tiller plant^{-1}			
	35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
N_1	35.31b	49.11	51.62b	54.49b	9.07	10.20b	10.40c	9.13b
N_2	35.37b	52.61	56.51a	63.71a	9.53	14.40a	17.93b	13.13a
N_3	35.79b	50.69	57.00a	63.10a	10.80	14.80a	17.80b	14.53a
N_4	37.35a	53.57	57.67a	64.30a	9.93	15.20a	20.40a	15.00a
N_5	35.68b	53.75	58.33a	66.36a	9.87	13.73a	20.20a	14.73a
s(x)	0.41	2.26	0.69	0.94	0.39	0.45	0.46	0.38
Level of sig.	*	Ns	**	**	Ns	**	**	**
cv(%)	1.99	7.53	2.14	2.63	6.81	5.76	4.62	5.04

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
*   Significant at 5% level
**   Significant at 1% level

N1=0 Kg ha^{-1} (control)
N2=90 Kg ha^{-1}
N3=110 Kg ha^{-1}
N4=130 Kg ha^{-1}
N5=150 Kg ha^{-1}

Total number of tiller hill^{-1} was significantly influenced by different levels of nitrogen except at 35 DAT(Appendix 8).The highest number of tiller hill^{-1} (15.20) was obtained from 130 Kg N ha^{-1} which is statistically similar to 110 Kg N ha^{-1} (14.80), 90 kg N ha^{-1} (14.40) and 150 Kg N ha^{-1} (13.73).The lowest number of tiller hill^{-1} (10.20) was found from control (0 Kg N ha^{-1}).Similar Result was obtained at 80 DAT. The minimum number of total tiller hill^{-1} was produced from control (0 Kg N ha^{-1}) at all stages of crop growth (Table 2).

4.3.2 Yield and Yield contributing characters at harvest

4.3.2.1 Plant height

Application of different rates of nitrogen showed significant effect on plant height at 1% level of probability (Appendix 9). The tallest plant (89.19 cm) was observed when applied 150 Kg N ha^{-1} which is statistically similar to90 Kg N ha^{-1}, 110 Kg N ha^{-1} and 130 Kg N ha^{-1}. The shortest plant (74.13 cm) was observed in control treatment (0 kg N ha^{-1}) (Appendix 10).

4.3.2.2 Number of effective, non effective and total tiller hill^{-1}

Nitrogen level had significant effect on the production at effective tiller hill^{-1} (Appendix 9). The highest number of effective tiller hill^{-1}(13.00)was obtained from 110 Kg N ha^{-1} which was statistically similar to 90 Kg N ha^{-1} , 130 Kg N ha^{-1} and 150 Kg N ha^{-1} .The lowest number of effective tiller hill^{-1} (8.03)found from 0 Kg N ha^{-1}. The Number of non effective tiller hill^{-1}was not significantly influenced by nitrogen level. Results from Table 2 observed that the highest number of non effective tiller hill^{-1} (0.53) was produced by 130 Kg N ha^{-1} and the lowest one (0.33) was produced by 90 Kg N ha^{-1}. Number of total tiller hill^{-1}was significantly influenced due to effect of nitrogen rates. The highest number of total tiller hill^{-1} (13.40) was observed at 110 Kg N ha^{-1} which was identical to 90 Kg N ha^{-1} , 130 Kg N ha^{-1}, 150 Kg N ha^{-1} and the lowest number of total tiller hill^{-1} (8.43)was recorded at control (Appendix 10) .

4.3.2.3 Panicle length

Nitrogen level had no significant effect on panicle length (Appendix 9). However, the longest panicle (21.80 cm) was recorded from 90 kg N ha^{-1} which was similar to 11o kg N ha^{-1} followed by 150 kg N ha^{-1} and the shortest(20.73) was observed from control (0 kg N ha^{-1}) (Appendix 10)

4.3.2.4 Number of fertile, sterile and total spikelet panicel^{-1}

There was a significant differences in the effect of different nitrogen rates in respect of filled grains panicle^{-1} at 1% level of significance (Appendix 9). The highest number of grains panicle^{-1} (125.80) was obtained from110 kg N ha^{1}. The lowest number of grains panicle^{-1} (105.10) was found from the control (0 kg N ha^{-1}) and other rates of nitrogen differed significantly. Number of unfilled grains panicle^{-1} was significantly affected by nitrogen level at 1% level of significance. The maximum number of unfilled grains was found at 150 kg N ha^{-1} which was statistically similar to 130 kg N ha^{-1} and 110 kg N ha^{-1}. The minimum number was obtained at control (0kg Nha^{-1}) which was statistically identical to 90 kg N ha^{-1}. Number of total spikelet panicle^{-1} was significantly influenced by nitrogen rate at 1% lever of probability. The highest number of total grains panicle^{-1} was produced by 110 kg N ha^{-1} which was statistically identical to 130 & 150 kg Nha^{-1} and the lowest number of total grains panicel^{-1} was produced by 0 kg N ha^{-1} (Fig. 14 and Appendix 10).

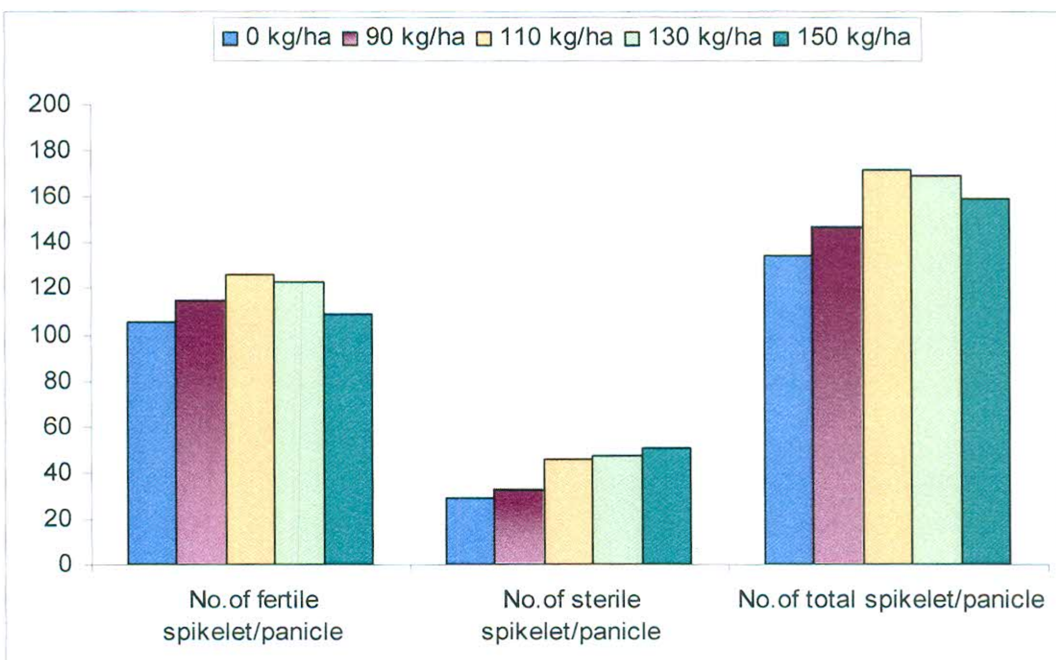

Fig. 14: Effect of nitrogen on number of fertile, sterile and total spikelet panicle^{-1} of BRRI dhan29

4.3.2.5 1000 grain weight (g)

The weight of 1000 grain was not significantly affected by the nitrogen level (Appendix 9). Numerically the highest weight of 1000 grain (20.33 g) was obtained from 90 kg N ha^{-1}.The lowest weight (19.00 g) was obtained from 130kg N ha^{-1} (Appendix 10).

4.3.2.6 Grain yield

Level of nitrogen had significant effect on grain yield at 1% level of probability (Appendix 9). The highest grain yield (7.18 t ha^{-1}) was obtained from 110 kg N ha^{-1} which was statistically similar to 130 kg N ha^{-1} and 150 kg N ha^{-1}. The lowest grain yield (3.50 t ha^{-1}) was obtained from 0 kg N ha^{-1} (Fig. 15 and Appendix 10).

4.3.2.7 Straw yield

Straw yield was significantly influenced by nitrogen rate at 1% level of probability (Appendix 9). The highest straw yield (7.31 t ha^{-1}) was produced at 110 kg N ha^{-1} which was statistically identical at 90 kg N ha^{-1}, 130kg N ha^{-1} and 150 kg N ha^{-1}. The lowest straw yield was observed at control (3.46 t ha^{-1}) (Fig. 15 and Appendix 10).

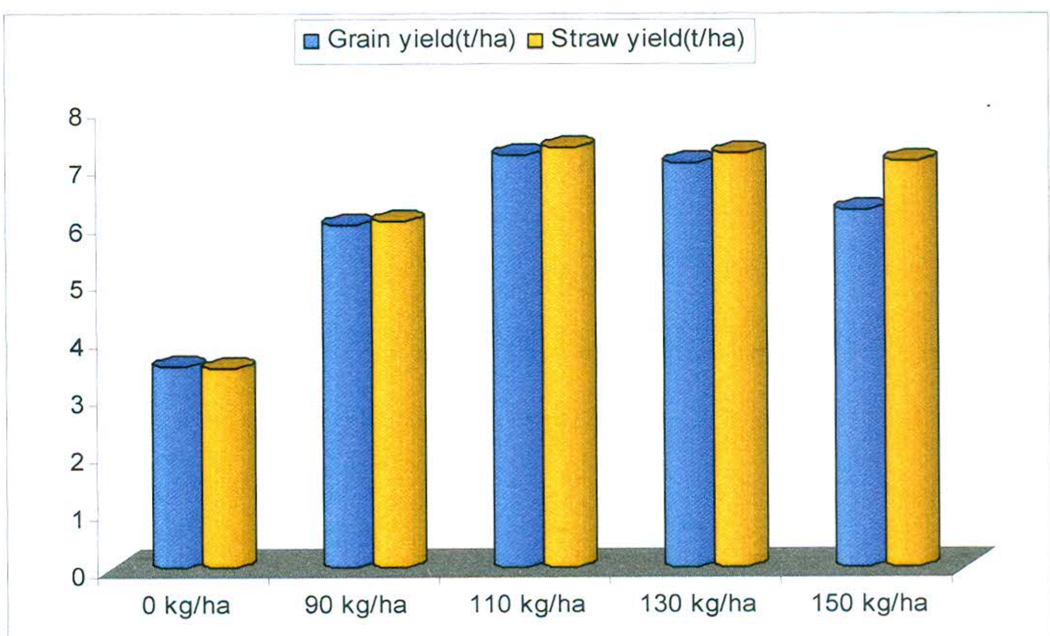

Fig. 15: Effect of nitrogen on grain yield and straw yield of BRRI dhan29

4.3.2.8 Correlation between grain yield and effective tiller hill^{-1}

The degree of relationship between grain yield and number of effective tiller hill^{-1} of BRRI dhan29 was studied. The result revealed that grain yield and number of effective tiller hill^{-1} have a significant positive relationship at 1% level of significance. The correlation coefficient r=0.836* and the regression line of X (grain yield) on effective tiller hill^{-1} have the equation y=1.2631x + 3.9235. The positive slope indicates positive relationship (Fig. 16).

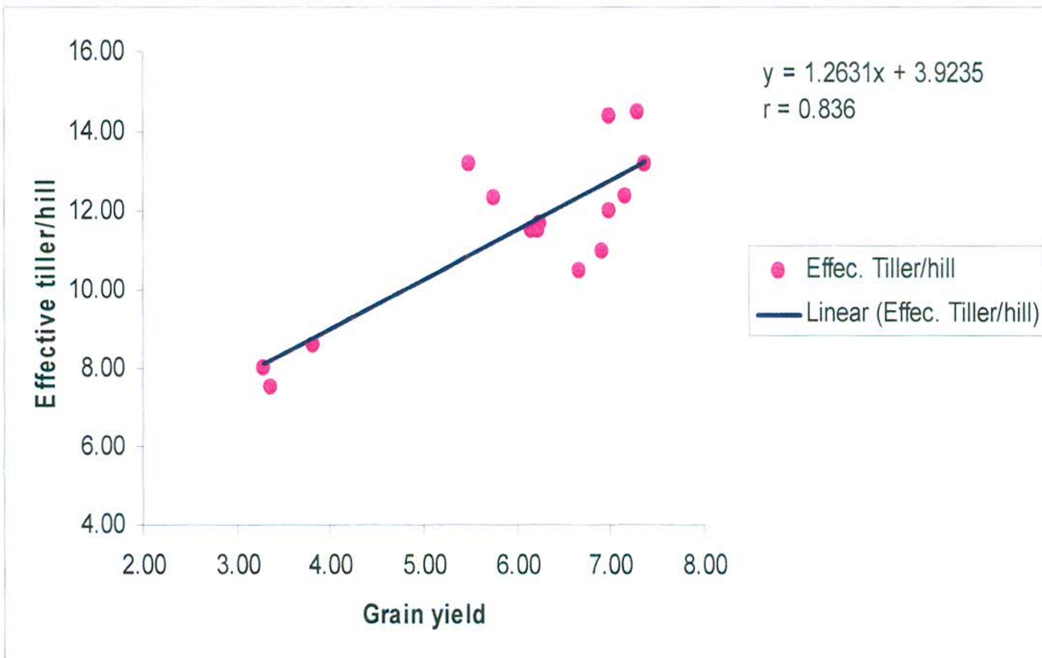

Fig. 16: Correlation between grain yield and effective tiller hill^{-1}

4.3.2.9 Correlation between grain yield and fertile spikelet panicle^{-1}

The degree of relationship between grain yield and number of fertile spikelet panicle^{-1} of BRRI dhan29 was studied. The result revealed that grain yield and number of fertile spikelet panicle^{-1} a significant relationship. The correlation coefficient r=0.658* and the regression line of X (grain yield) on number of fertile spikelet panicle^{-1} have the equation y=4.5939x + 87.852. The positive slope indicates positive relationship (Fig. 17).

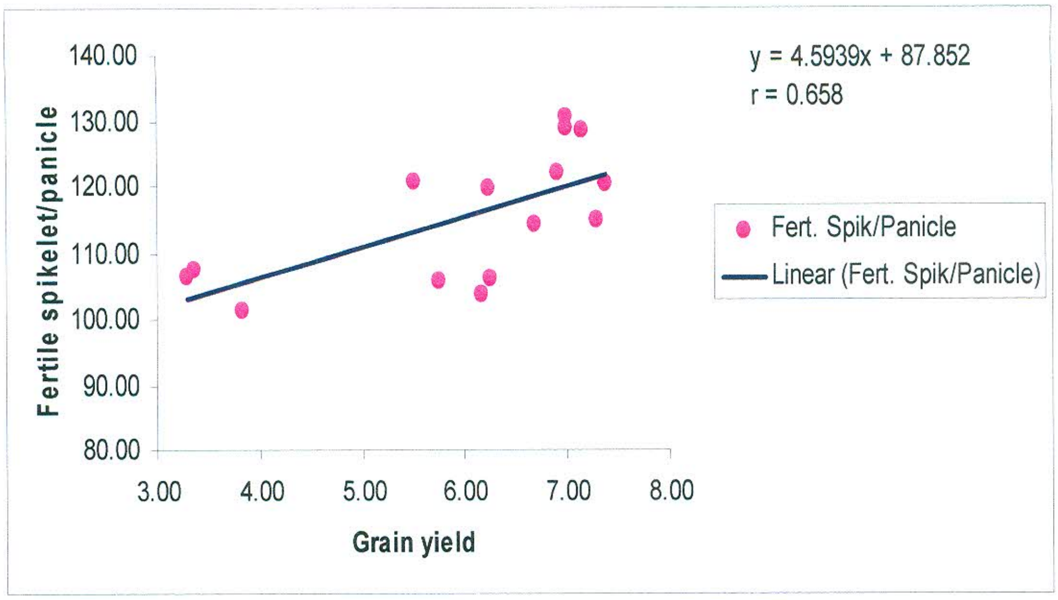

Fig. 17: Correlation between grain yield and fertile spikelet panicle^{-1}

4.3.2.10 Biological yield and Harvest index (%)

The rate of nitrogen had significant effect on the biological yield at 1% level of probability. The highest biological yield (14.49 t ha^{-1}) was obtained from 110 Kg N ha^{-1} , which was statistically similar to 90 kg N ha^{-1} ,130Kg Nha^{-1} and 150Kg N ha^{-1}. The lowest biological yield (6.96 t ha^{-1}) was obtained from 0 Kg N ha^{-1}. The effect of harvest index on nitrogen level was influenced at 1% level of significance (Appendix 9). Numerically, the highest harvest index (50.28%) was obtained from 0 Kg N ha^{-1} and the lowest (46.79%) obtained from 150Kg N ha^{-1} (Appendix 10).

4.3.2.11 Simple correlation between yield and yield components of boro rice (cv. BRRI dhan29)

Correlation co-efficient was done in order to determine the relationship between different crop characters, yield and yield component at harvest. The correlation matrix has been presented in table. Grain yield was positively correlated with plant height, total tiller hill^{-1}, bearing tiller hill^{-1}, total spikelet panicle^{-1}, fertile spikelet panicle^{-1} and sterile spikelet panicle^{-1}. Plant height was positively correlated with bearing tiller hill^{-1}, total spikelet panicle^{-1} and sterile spikelet panicle^{-1} and negatively correlated with non bearing tiller hill^{-1} and 1000 grain weight. Total tiller hill^{-1} was positively correlated with bearing tiller hill^{-1}, total spikelet panicle^{-1} and sterile spikelet panicle^{-1}. Bearing tiller hill^{-1} was positively correlated with total, fertile and sterile spikelet panicle^{-1}. Non bearing tiller hill^{-1} was negatively correlated with panicle length, total and fertile spikelet panicle^{-1}. Total spikelet panicle^{-1} was positively correlated with fertile and sterile spikelet panicle^{-1} (Table 3).

From the above result of the present experiment, it is revealed that BRRI dhan29 grown in 110 kg N ha^{-1} produced the highest grain yield.

Table 3: Simple correlation between yield and yield contributing character of boro rice(cv. BRRI dhan29)

	Grain yield	Plant height	Total tiller hill^{-1}	Bearing tiller hill^{-1}	Non bearing tiller hill^{-1}	Panicle length	Total spikelet panicle^{-1}	Fertile spikelet panicle^{-1}	Sterile spikelet panicle^{-1}	1000 grain weight
Grain yield	1									
Plant height	0.713**	1								
Total tiller hill^{-1}	0.799**	0.487	1							
Bearing tiller hill^{-1}	0.836**	0.569*	0.978**	1						
Non bearing tiller hill^{-1}	0.104	-0.103	0.478	0.411	1					
Panicle length	0.358	0.421	0.339	0.382	-0.055	1				
Total spikelet panicle^{-1}	0.810**	0.573*	0.583*	0.639*	-0.143	0.414	1			
Fertile spikelet panicle^{-1}	0.658**	0.318	0.503	0.570*	-0.240	0.240	0.843**	1		
Sterile spikelet panicle^{-1}	0.677**	0.589*	0.539*	0.550*	0.059	0.352	0.804**	0.497	1	
1000 grain weight	0.113	-0.083	0.417	0.417	0.491	0.180	-0.165	-0.106	-0.137	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Fig : 0 kg Nitrogen/hec.

Fig : 90 kg Nitrogen/hec.

Fig : 110 kg Nitrogen/hec.

Fig : 130 kg Nitrogen/hec.

Fig : 150 kg Nitrogen/hec.

Plate 6: Different treatment plots of experiment 3

4.4: Effect of seedling age and seedling number per hill on yield and yield component of rice (cv. BRRI dhan29)

Result obtained from the present study regarding the effect of seedling age and seedling number per hill on the performance of boro rice cv. BRRI dhan29 are presented in this chapter.

4.4.1 Growth parameters at 35, 50, 65 and 80 days after transplanting

4.4.1.1 Plant height

Effect of seedling age

There was significant effect of seedling age on plant height at all growth stages except at 65 days after transplanting (Appendix 11). At 35 DAT taller plant height (44.13 cm) was observed with 60 day old seedling and shorter plant (32.48 cm) was obtained at 30 day old seedling. At 50 DAT taller plant height (53.50 cm) was found with 50 day old seedling and shorter plant (46.18 cm) was found at 30 day old seedling. At 80 DAT the tallest plant (71.14 cm) was found with 60 days old seedling which was statistically similar to 30, 40 and 50 day old seedling (Fig. 18 and Appendix 13).

Effect of seedling number hill^{-1}

Plant height was not significantly affected (Appendix 11) by seedling hill^{-1} at all growth stages of BRRI than 29 (Fig. 19 and Appendix 14).

Effect of interaction between seedling age and seedling hill^{-1}

It was observed from the analysis of variance that plant height was statistically not significant (Appendix 11) due to interaction between seedling age and seedling hill^{-1}. A general view of the effect of seedling age and seedling hill^{-1} on plant height of rice is shown in Appendix 15. Though it was not statistically significant but numerically the tallest plant (45.23 cm) was found in the treatment combination 60 days old seedling x 6 seedling hill^{-1} and the shortest plant (32.22 cm) was observed in the treatment combination of 30 days old seedling x 6 seedling hill^{-1} at 35 days after transplanting. At 50 days after transplanting, the tallest plant (54.43 cm) was found in the treatment combination of 40 days old seedling x 2 seedling hill^{-1} and the shortest plant (45.70 cm) was found in the treatment combination of 30 days old seedling x 2 seedling hill^{-1}. At 65 days after transplanting, the tallest plant (62.28 cm) was found in the treatment combination of 60 days old seedling x 6 seedling hill^{-1} and the shortest plant (50.60 cm) was found in the treatment combination of 50 days old seedling x 6 seedling hill^{-1}. At 80 days after transplanting the tallest (75.08 cm) plant was found in the treatment combination of 60 days old seedling x 6 seedling hill^{-1} and the shortest plant (62.75 cm) was obtained in the treatment combination of 30 days old seedling x 2 seedling hill^{-1}.

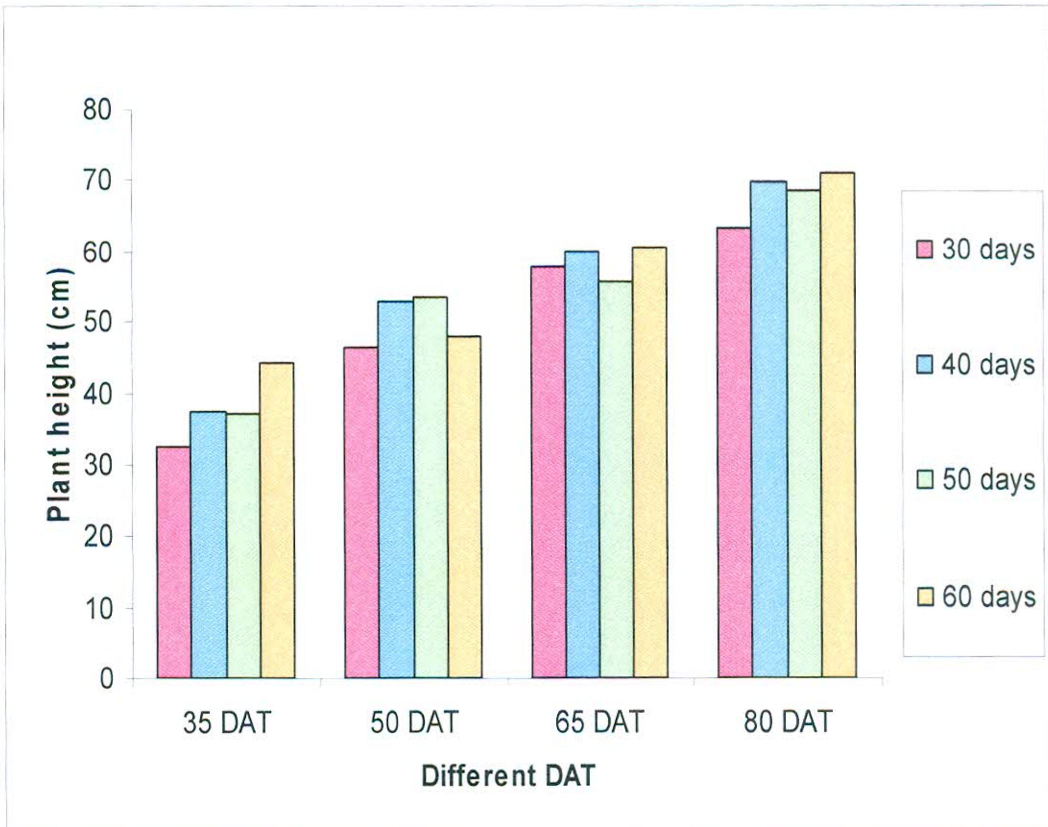

Fig. 18: Effect of seedling age on Plant height at diff. DAT of BRRI dhan 29

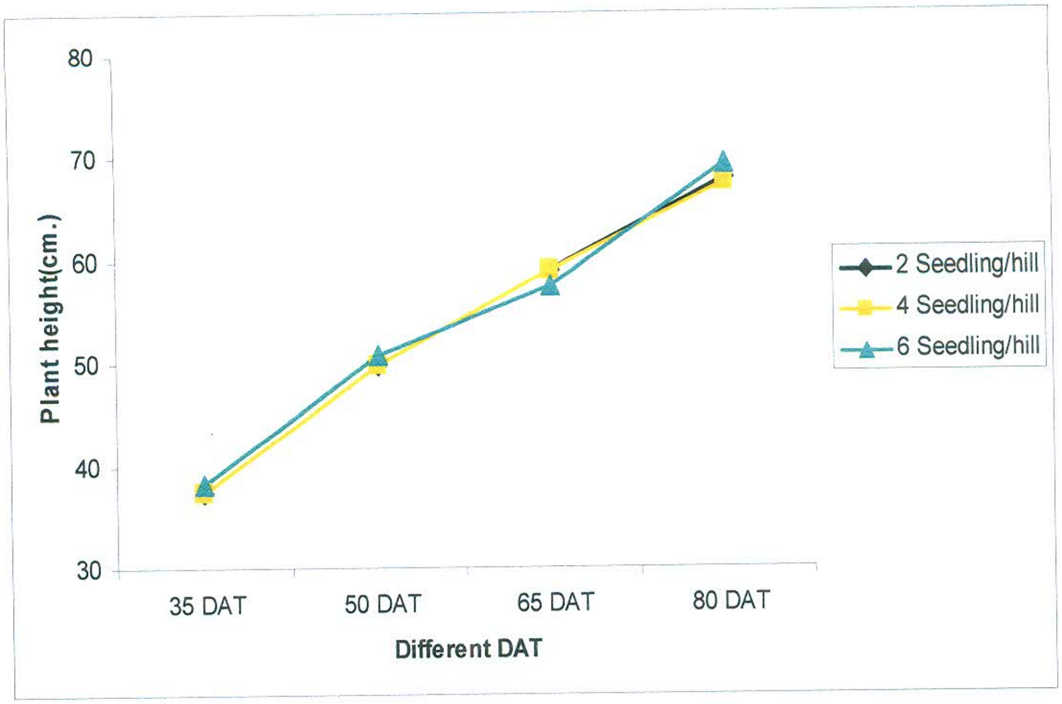

Fig. 19: **Effect of seedling number per hill on plant height at diff. DAT of BRRI dhan 29**

Plate 7: A General view of the experimental plot at tillering stage

4.4.1.2 Number of tiller plant^{-1}

Effect of seedling age

Number of tiller plant^{-1} was significantly influenced by seedling age at different days after transplanting (35, 50, 65, 80 DAT) (Appendix 11). For all the cases higher number of tiller hill^{-1} was recorded from 30 or 40 days old seedling and lower was recorded from 50 or 60 days old seedling (Fig. 20).

Effect of seedling hill^{-1}

Number of tiller hill^{-1} was significantly influenced by the number of seedling hill^{-1} at 35 and 50 days after transplanting but statistically non- significant at 65 and 80 days after transplanting (Appendix 11). The highest number of tiller hill^{-1}(18-72) was produced when 6 seedlings were transplanted hill^{-1} which was statistically similar to 4 seedling hill^{-1} and the lowest one (12.80) was produced when 2 seedling was transplanted hill^{-1} at 50 DAT. Similarly in all case the highest number of tiller hill^{-1} was obtained from seedling hill^{-1} and the lowest from 2 seedling hill^{-1} (Fig. 21).

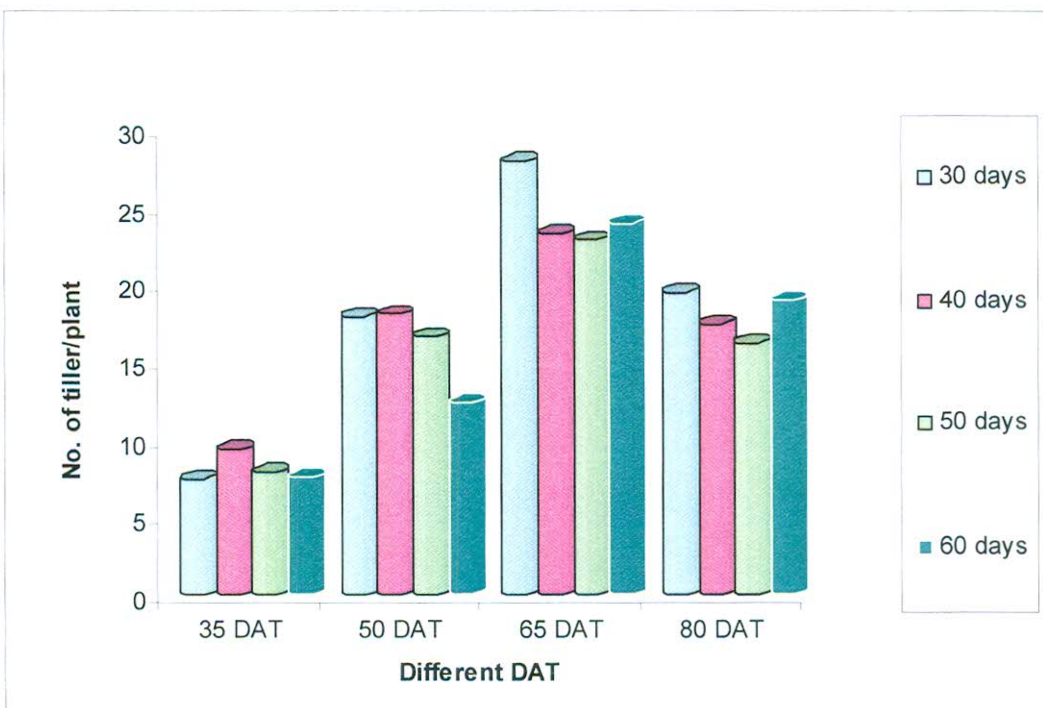

Fig. 20: Effect of Seedling age on tiller per hill at diff. DAT of BRRI dhan 29

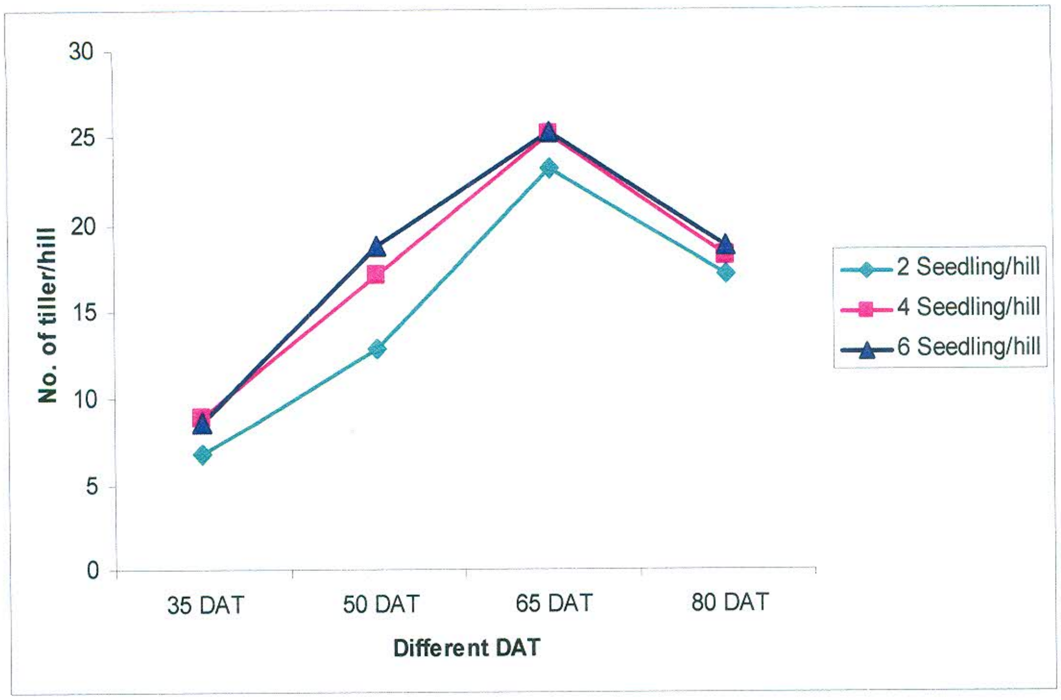

Fig. 21: Effect of seedling number hill^{-1} on tiller per plant at diff. DAT of BRRI dhan 29

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non significant in all cases of growth period (Appendix 11). A general view of the effect of seedling age and seedling number hill^{-1} on number of tiller hill^{-1} of rice is shown in Appendix 15. Though it was not significant statistically, numerically the highest number of tiller hill^{-1} (10.67) was found in the treatment combination of 40 days old seedling x 4 seedling hill^{-1} and the lowest (5.40) was found in the treatment combination 30 day old seedling x 2 seedling hill^{-1} at 35 DAT. At 50 DAT, the highest number of tiller hill^{-1} (20.13) was found in the treatment combination of 30 day old seedling x 6 seedling hill^{-1} and the lowest (8.80) was found in the treatment combination of 60 day old seedling x 2 seedling hill^{-1}. At 65 DAT, the highest number of tiller hill^{-1}(29.33) was found in the treatment combination of 30 day old seedling x 4 seedling hill^{-1} and the lowest (20.80) was found in the treatment combination of 40 day old seedling x 2 seedling hill^{-1}. At 80 Days after transplanting the highest number of tiller hill^{-1} (19.73) was found in the treatment combination of 60 day old seedling x

6 seedling hill^{-1} and the lowest (14.00) was found in the treatment combination of 50 day old seedling x 2 seedling hill^{-1}.

4.4.2.1 Yield and yield components at harvest

4.4.2.1 Plant height

Effect of seedling age

Plant height was significantly influenced by seedling age at 1% level of significance (Appendix 12). The tallest plant (97.23 cm) was a found from 30 day old seedling which was statistically similar to 40, 50 and 60 day old seedling (Appendix 16).

Effect of seedling hill^{-1}

The plant height was significantly influenced by seedling hill^{-1} at 1% level of significance (Appendix 12). The tallest plant (96.64 cm) was found in 2 seedling hill^{-1} which was statistically similar to 4 and 6 seedling hill^{-1} (Appendix 17).

Effect of interaction between seedling age and seedling hill^{-1}

Analysis of variance reveals that the plant height was statistically non significant due to interaction between seedling age and seedling hill^{-1} (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on plant height of rice is shown in Appendix 18. Though it was not significant statistically, numerically the tallest plant (98 .43 cm) was found in the treatment combination 30 days old seedling x 2 seedling hill^{-1} and the shortest plant (90.16 cm) was found in the treatment combination of 50 days old seedling x 6 seedling hill^{-1}

4.4.2.2 Number of effective tiller hill^{-1}

Effect of seedling age

Number of effective tiller hill^{-1} was significant at 1% level of probability due to age of seedling (Appendix 12). Higher number of effective tiller hill^{-1}(13.20) was produced by 40 days old seedling and lower number of effective tiller hill^{-1} (10.56) was produced by 60 days old seedling (Fig. 22).

Effect of seedling hill^{-1}

Number of effective tiller hill^{-1} was significant at 5% level of probability due to seedling hill^{-1} (Appendix 12). The highest number of effective tiller hill^{-1} (13.02) was found in 4 seedling hill^{-1} which was statistically similar to 2 and 6 seedling hill^{-1} (Fig. 23).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on number of effective tiller hill^{-1} of rice is shown in Appendix 18. Numerically the highest number of effective tiller hill^{-1}(13.47) was found in the treatment combination of 40 days old seedling x 4 seedling hill^{-1} and the lowest (9.80) was found in the treatment combination of 60 days old seedling x 2 seedling hill^{-1}.

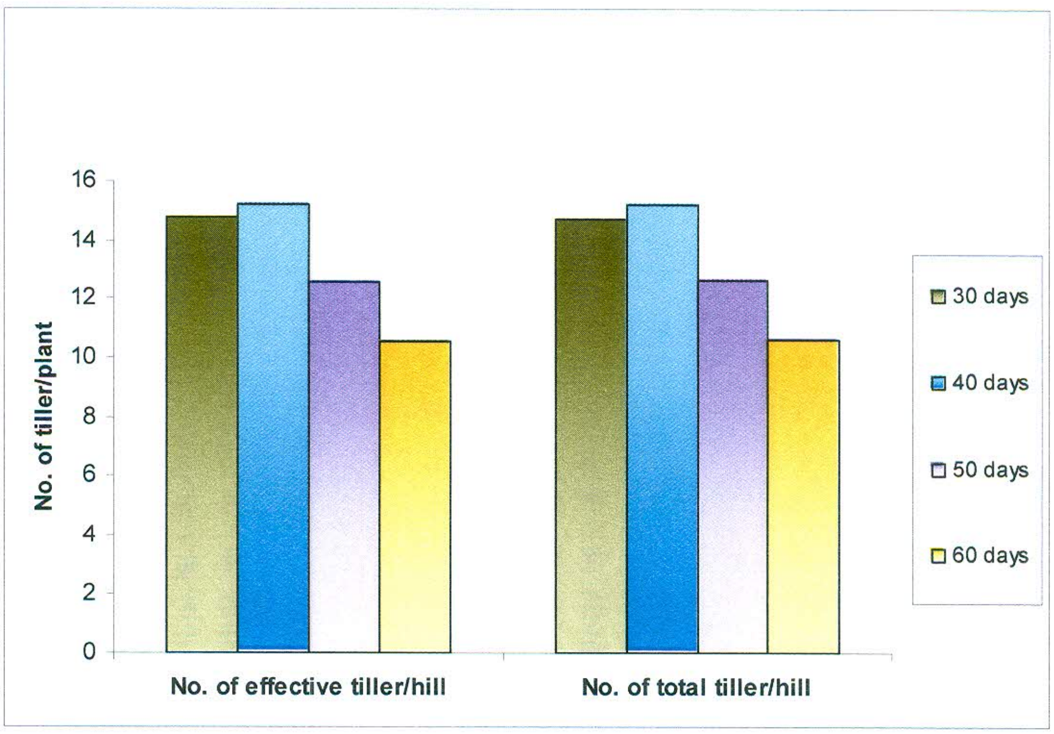

Fig. 22: Effect of Seedling age on effective and total tiller per hill of BRRI dhan 29

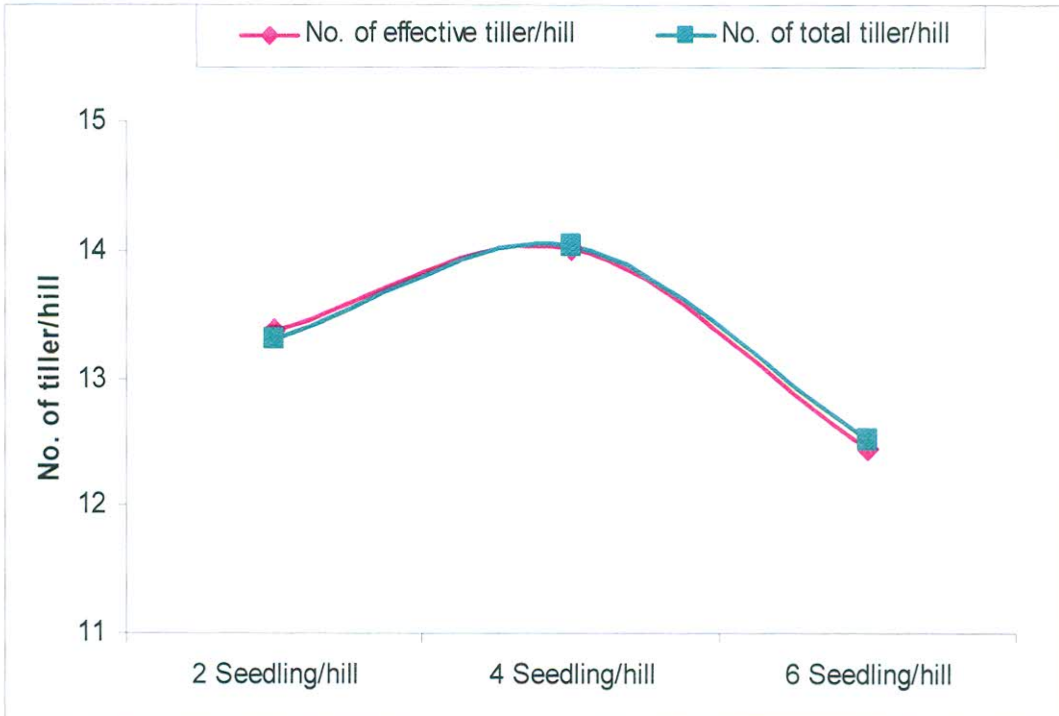

Fig. 23: Effect of Seedling age on effective and total tiller per hill of BRRI dhan 29

Fig : 40 days seedling & 06 seedling/hill

Fig : 30 days seedling & 06 seedling/hill

Fig : 40 days seedling & 04 seedling/hill

Fig : 30 days seedling & 04 seedling/hill

Fig : 40 days seedling & 02 seedling/hill

Fig : 30 days seedling & 02 seedling/hill

Plate 8: Different treatments plot

Fig : 60 days seedling & 06 seedling/hill

Fig : 50 days seedling & 06 seedling/hill

Fig : 60 days seedling & 04 seedling/hill

Fig : 50 days seedling & 04 seedling/hill

Fig : 60 days seedling & 02 seedling/hill

Fig : 50 days seedling & 02 seedling/hill

Plate 9: Different treatments Plot

4.4.2.3 Number of total tiller hill^{-1}

Effect of seedling age

Total number of tiller hill^{-1} was significantly influenced by seedling age at 1% level of significance (Appendix 12). Higher total tiller hill^{-1} (13.20) was recorded from 40 day seedling and lower (10.62) was recorded from 60 day old seedling (Fig. 22).

Effect of seedling hill^{-1}

Number of total tiller hill^{-1} was significant at 5% level of probability due to seedling hill^{-1} (Appendix 12). The highest number of total tiller hill^{-1}(13.04) was found in 4 seedling hill^{-1} which was statistically similar to two and six seedling hill^{-1} (Fig. 23).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on number of total tiller hill^{-1} of rice is shown in Appendix 18. Numerically the highest number of total tiller hill^{-1}(13.47) was found in the treatment combination of 40 days old seedling x 4 seedling hill^{-1} and the lowest (9.47) was found in the treatment combination of 50 days old seedling x 6 seedling hill^{-1}.

4.4.2.4 Panicle length

Effect of seedling age

Panicle length was significantly influenced by seedling age at 1% level of significance (Appendix 12). It was observed that longer panicle (24.17 cm) was found in 30 day seedling and shorter one (21.97 cm) was found in 40 day old seedling which was statistically similar to 50 and 60 day old seedling (Appendix 16).

Effect of seedling hill^{-1}

The length of panicle was significantly influenced by the seedling hill^{-1} (Appendix 12). The highest length of panicle (23.46 cm) was found in 2 seedling hill^{-1} which was statistically identical to 4 and 6 seedling hill^{-1} (Appendix 17).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on panicle length of rice is shown in Appendix 18. Numerically the tallest panicle (25.18 cm) was found in the treatment combination of 30 days old seedling x 2 seedling hill^{-1} and the smallest (21.40 cm) was found in the treatment combination of 40 days old seedling x 6 seedling hill^{-1}.

4.4.2.5 Number of fertile spikelet panicle^{-1}

Effect of seedling age

There was significant difference in the effect of different seedling age in respect of number of fertile spikelets panicle^{-1} at 1% level of significance (Appendix 12). Higher number of filled spikelet panicle^{-1}(125.23) was recorded from 50 day old seedling which was statistically similar to 30, 40 and 60 day old seedling (Fig. 24).

Effect of seedling hill^{-1}

There was no significant difference in the effect of seedling hill^{-1} in respect of number of fertile spikelet panicle^{-1} (Appendix 12). Numerically higher number of filled spikelet panicle^{-1}(116.97) was recorded from 2 seedling hill^{-1} and lower one (100.93) was in 6 seedling hill^{-1} (Fig. 25).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on number of fertile spikelet panicle^{-1} of rice is shown in Appendix 18. Numerically the highest number of fertile spikelet panicle^{-1} (133.67) was found in the treatment combination of 50 days old seedling x 2 seedling hill^{-1} and the lowest (82.67) was found in the treatment combination of 60 days old seedling x 6 seedling hill^{-1}.

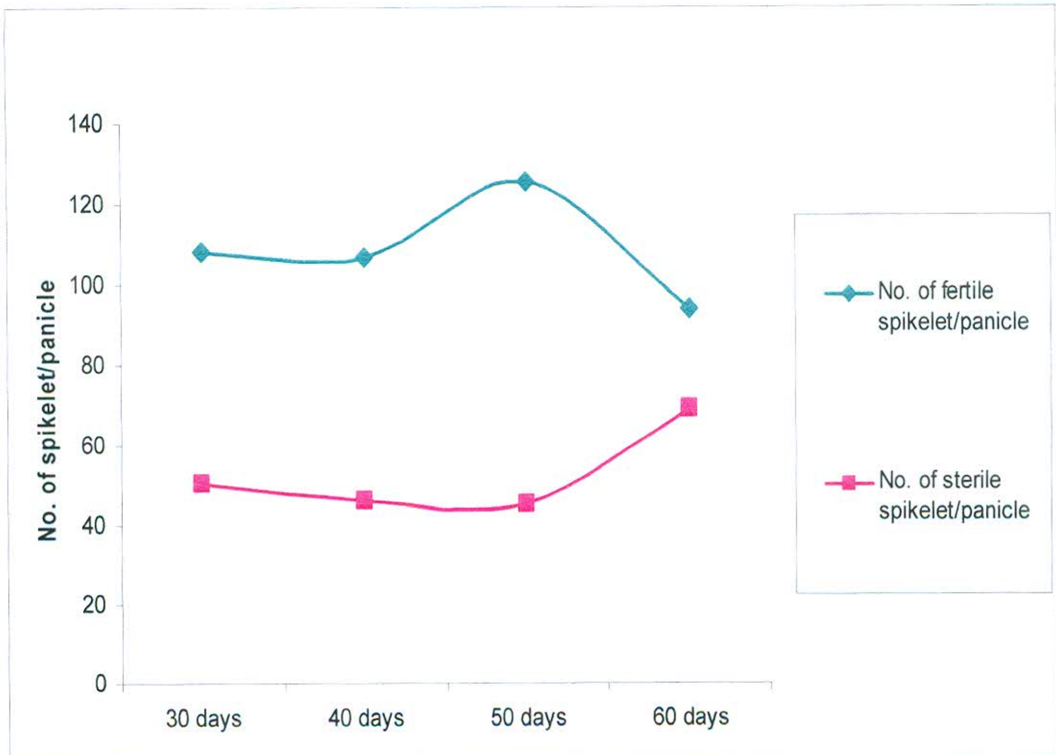

Fig. 24: Effect of Seedling age on fertile and sterile spikelet panicle^{-1} of BRRI dhan 29

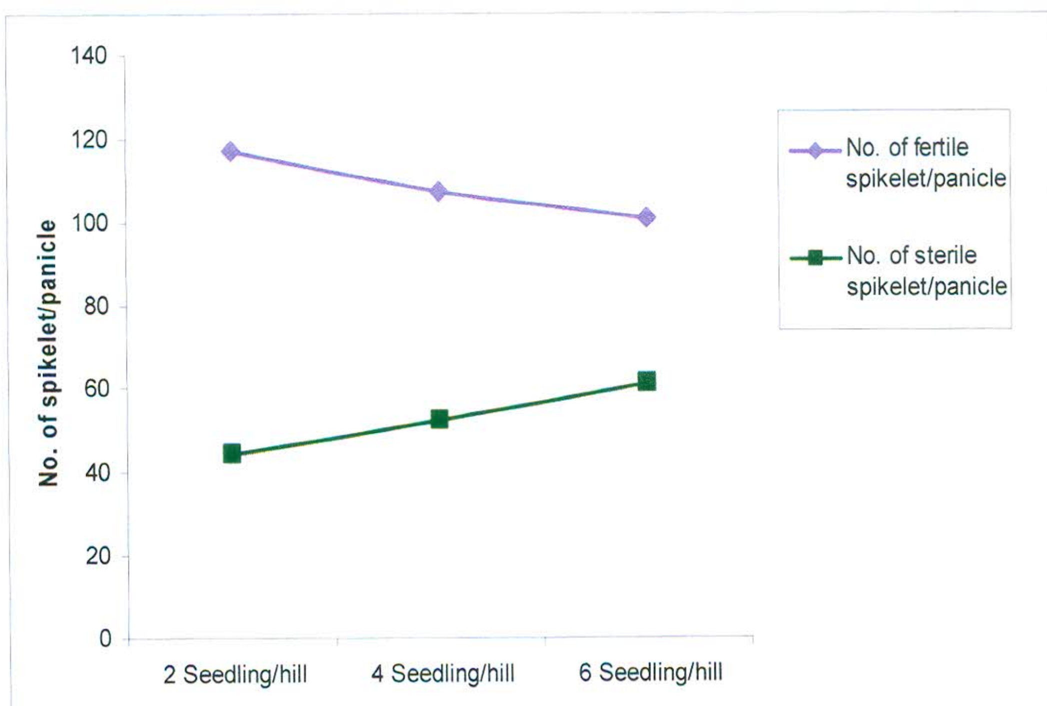

Fig. 25: Effect of Seedling number per hill on fertile and sterile spikelet panicle^{-1} of BRRI dhan 29

4.4.2.6 Number of Sterile spikelet panicle^{-1}

Effect of seedling age

Number of sterile spikelet panicle^{-1} was significantly influenced by seedling age at 1% level of significance (Appendix 12). Higher number of unfilled spikelets panicle^{-1} (68.87) was recorded from 60 day old seedling which was statistically similar to 30, 40 and 50 day seedling (Fig. 24).

Effect of seedling hill^{-1}

The number of sterile spikelet panicle^{-1} was significantly influenced by seedling hill^{-1} at 5% level of significance (Appendix 12). The highest number of sterile spike lets panicle^{-1} (61.27) was observed with 6 seedling hill^{-1} which was statistically similar to 2 and 4 seedling hill^{-1} (Fig. 25).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on number of sterile spikelet panicle^{-1} of rice is shown in Appendix 18. Numerically the highest number of sterile spikelet panicle^{-1} (71.87) was found in the treatment combination of 60 days old seedling x 6 seedling hill^{-1} and the lowest (35.33) was found in the treatment combination of 40 days old seedling x 2 seedling hill^{-1}.

4.4.2.7 1000 grain weight

Effect of seedling age

1000 grain weight was not significantly influenced due to the effect of seedling age (Appendix 12). Numerically, the highest 1000 grain weight (20.44 gm) was found in 50 day seedling and the lowest (19.56 gm) was found in 60 day old seedling (Appendix 16).

Effect of seedling hill^{-1}

The effect of seedling hill^{-1} on weight of 1000 grain was not significant (Appendix 12). The result reveals that numerically the highest weight of 1000 grain (20.17gm) was obtained from 2 seedling hill^{-1}. The lowest weight of 1000 grain (19.42gm) was obtained from 6 seedling hill^{-1} (Appendix 17).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically non-significant (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on 1000 grain weight of rice is shown in Appendix 18. Numerically the highest 1000 grain weight (20.67gm) was found in the treatment combination of 50 days old seedling x 4 seedling hill^{-1} and the lowest (18.67gm) was found in the treatment combination of 60 days old seedling x 6 seedling hill^{-1}.

4.4.2.8 Grain yield

Effect of seedling age

Grain yield was significantly influenced by seedling age at 1% level of significance (Appendix 12). It is observed that higher grain yield (6.77 t ha^{-1}) was found from 40 days old seedling which was statistically similar to 30 day seedling. The lower one (5.28 t ha^{-1}) was recorded from 60 day old seedling (Fig. 26 and Appendix 16).

Effect of seedling hill^{-1}

Different number of seedling hill^{-1} under this study exerted significant effect on grain yield at 1% level of significance (Appendix 12). The highest grain yield (6.28 t ha^{-1}) was achieved from 2 seedling hill^{-1} which was statistically similar to 4 and 6 seedling hill^{-1} (Fig. 27 and Appendix 17).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically significant at 5% level of probability (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on grain yield of rice is shown in Appendix 18. The highest grain yield (7.39 t ha^{-1}) was found in the treatment combination of 40 day old seedling x 2 seedling $hill^{-1}$ and the lowest (4.99 tha^{-1}) was found in the treatment combination of 60 day old seedling x 2 seedling $hill^{-1}$ (Fig. 28).

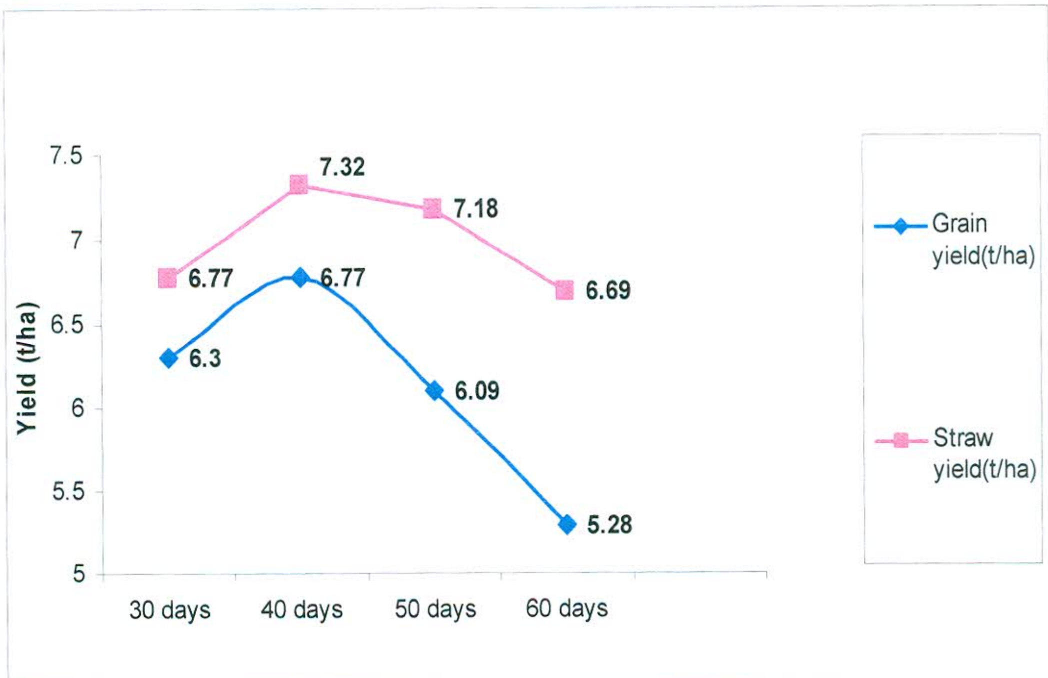

Fig. 26: Effect of Seedling age on grain yield & straw yield of BRRI dhan 29

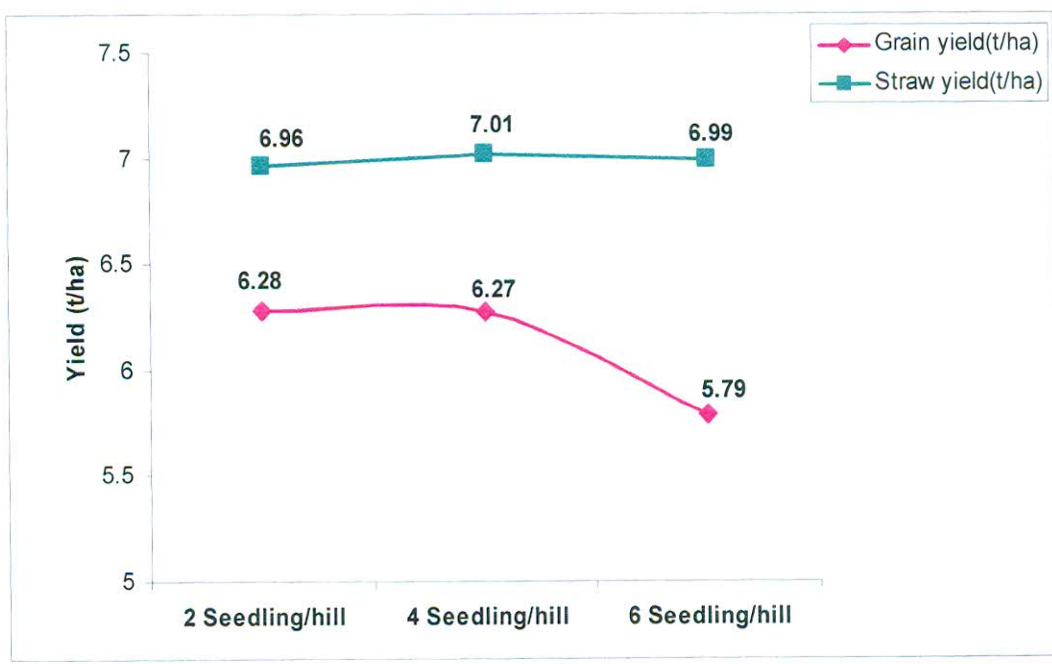

Fig. 27: Effect of seedling number $hill^{-1}$ on grain yield & straw yield of BRRI dhan 29

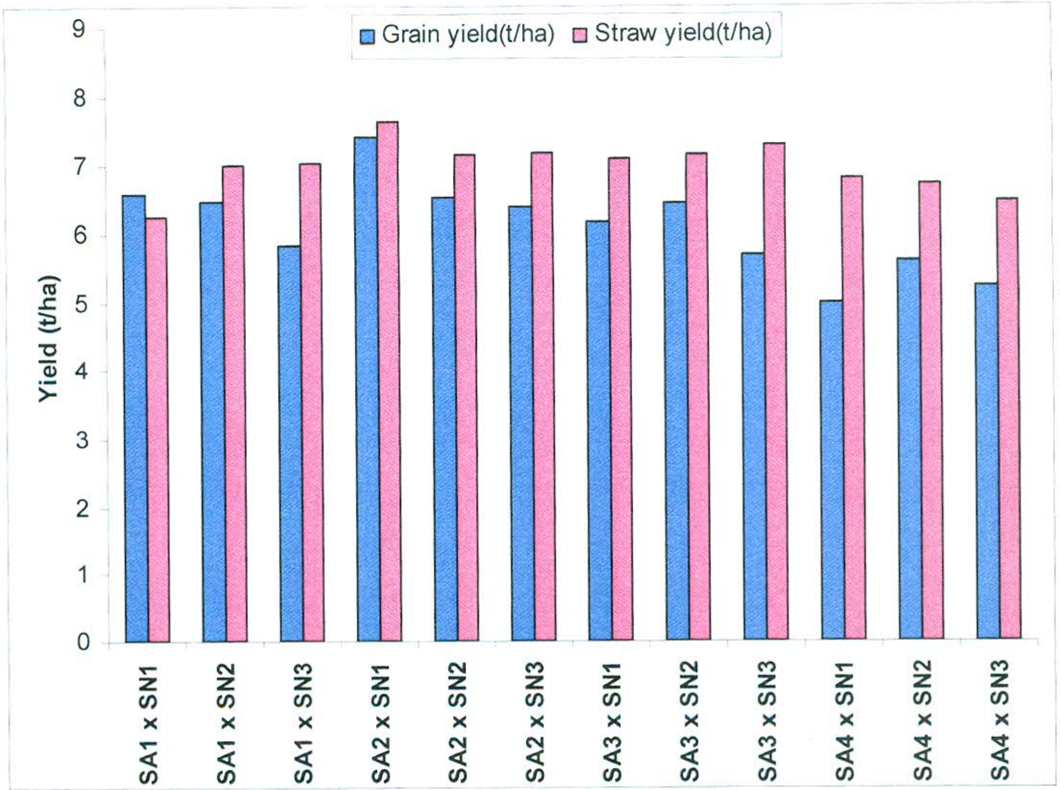

Fig. 28: Effect of interaction of Seedling age and Seedling number hill^{-1} on grain yield & straw yield of BRRI dhan 29

4.4.2.9 Straw yield

Effect of seedling age

The effect of seedling age on straw yield was significantly influenced at 1% level of significance (Appendix 12). It is observed that statistically straw yield in 30, 40, 50 and 60 day seedling is similar but numerically the highest straw yield (7. 32 tha^{-1}) was found in 40 day old seedling and lowest (6.69 t ha^{-1}) was found in 60 day old seedling (Fig. 26 and Appendix 16).

Effect of seedling hill^{-1}

Straw yield was not significantly influenced by seedling hill^{-1} (Appendix 12). The highest straw yield (7.01 t ha^{-1}) was found from 4 seedling hill^{-1} and the lowest (6.69 t ha^{-1}) was found from 2 seedling hill^{-1} (Fig. 27 and Appendix 17).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically significant at 5% level of probability (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on straw yield of rice is shown in Appendix 18. The highest straw yield (7.64 t ha^{-1}) was found in the treatment combination of 50 day old seedling x 2 seedling hill^{-1} and the lowest (6.26 t ha^{-1}) was found in the treatment combination of 30 day old seedling x 2 seedling hill^{-1} (Fig. 28).

4.4.2.10 Biological yield

Effect of seedling age

The effect of seedling age on Biological yield was significantly influenced at 1% level of significance (Appendix 12). Higher biological yield (14.09 t ha^{-1}) was obtained from 40 day old seedling which was statistically similar to 30 and 50 day old seedling. The lower (11.99 t ha^{-1}) was obtained from 60 day seedling (Fig. 29).

Effect of seedling hill^{-1}

Effect of the number of seedlings hill^{-1} was found to be significant with respect to biological yield (Appendix 12). The highest biological yield (13.29 t ha^{-1}) was obtained from 4 seedling hill^{-1} which was statistically similar to 2 and 6 seedling hill^{-1} (Fig. 30).

Effect of interaction between seedling age and seedling hill^{-1}.

Interaction effect between seedling age and seedling hill^{-1} was found statistically significant at 5% level of probability (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on biological yield of rice is shown in Appendix 18. The highest biological yield (15.03 t ha^{-1}) was found in the treatment combination of 50 day old seedling x 2 seedling hill^{-1} and the lowest (11.81 tha^{-1}) was found in the treatment combination of 60 day old seedling x 2 seedling hill^{-1} (Fig. 31).

4.4.2.11 Harvest Index

Effect of seedling age

Harvest index was significantly influenced by seedling age at 1% level of significance (Appendix 12). It is observed that highest harvest index (48.18%) was found from 30 day old seedling which was statistically similar to 40, 50 and 60 day old seedling (Fig. 29).

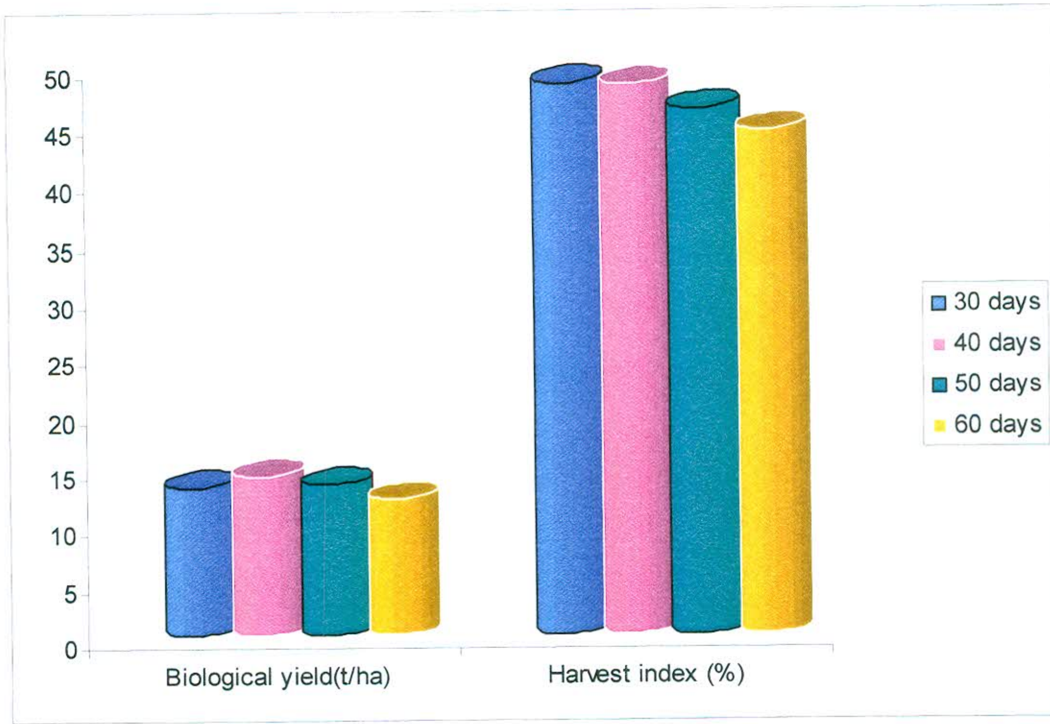

Fig. 29: Effect of Seedling age on biological yield and harvest index of BRRI dhan 29

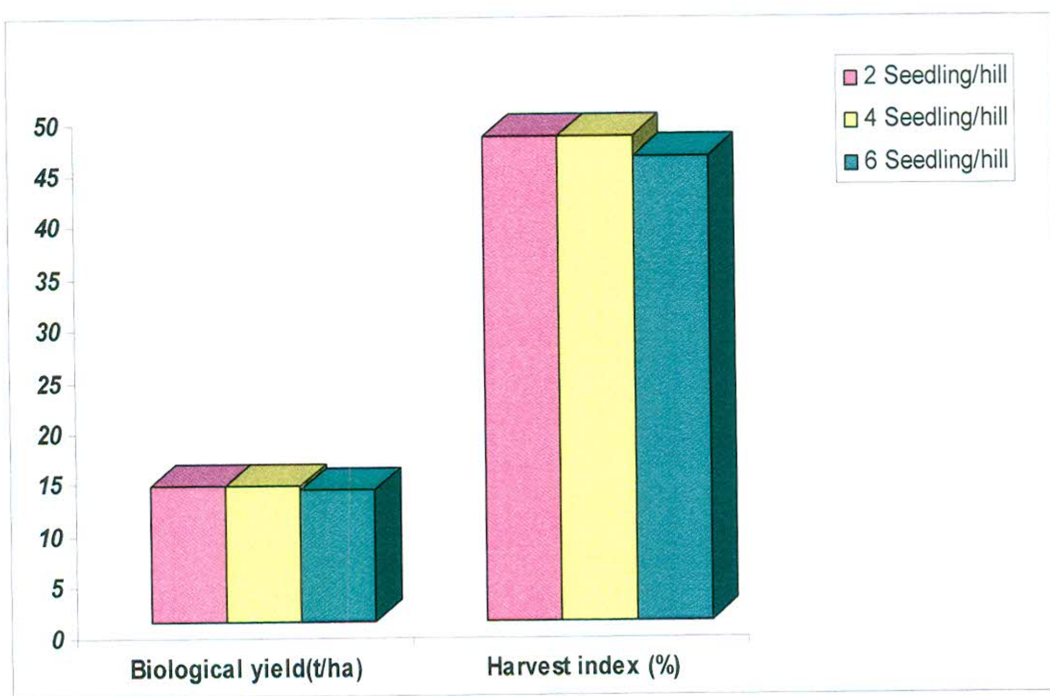

Fig. 30: Effect of seedling number $hill^{-1}$ on biological yield and harvest index of BRRI dhan 29

Effect of seedling hill^{-1}

Harvest index was significantly influenced by seedling hill^{-1} at 1% level of significance (Appendix 12). It is observed that highest harvest index (47.25%) was found from 2 seedling hill^{-1} which was statistically similar to 4 and 6 seedling hill^{-1} (Fig. 30).

Effect of interaction between seedling age and seedling hill^{-1}

Interaction effect between seedling age and seedling hill^{-1} was found statistically significant at 5% level of probability (Appendix 12). A general view of the effect of seedling age and seedling hill^{-1} on harvest index of rice is shown in Appendix 18. The highest harvest index (51.14 %) was found in the treatment combination of 30 day old seedling x 2 seedling hill^{-1} and the lowest (42.25 %) was found in the treatment combination of 60 day old seedling x 2 seedling hill^{-1} (Fig. 31).

From the result of the present experiment it is revealed that BRRI dhan29 with 40 days old seedling and 2 seedling hill^{-1} produced the highest grain yield.

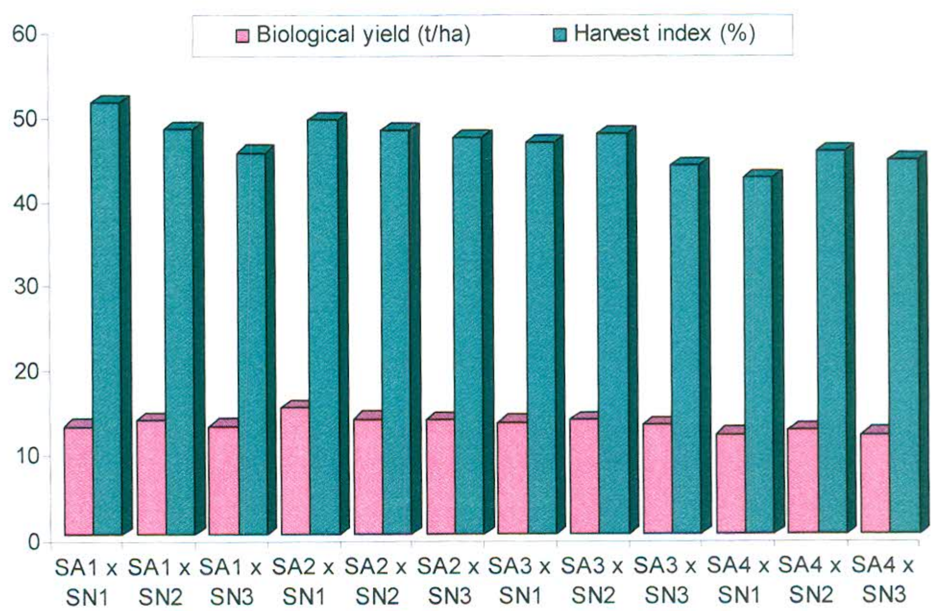

Fig. 31: Effect of interaction of seedling age and seedling hill^{-1} on biological yield and harvest index of BRRI dhan 29

4.5: Effect of method of weeding on the yield and yield component of rice (cv. BRRI dhan29)

Result obtained from the present study regarding the effect of method of weeding on plant height, tillering pattern, yield and yield components of rice (cv. BRRI dhan29) are presented in this chapter. The analysis of variance of method of weeding on different yield components have been presented in Appendix 19 and 20.

Plate 10: A General view of the experimental plot at tillering stage

4.5.1. Plant height at different days after planting

Different weed control method was significantly influenced on plant height at all the sampling dates except at 50 days after transplanting (Appendix 19). At 35 days after transplanting the longest plant (28.00 cm) was observed from two hand weeding method which was statistically similar to all the method except no weeding control. At 50 days after transplanting the tallest plant (42.23 cm) was found from two hand weeding method and the shortest from application of Rifit @ 1.5 L ha^{-1}. At 65 days after transplanting the highest plant height (71.93 cm) was obtained from application of Rifit @ 1.0 L ha^{-1} which was statistically similar to all the methods except no weeding control. At 80 days after transplanting, the tallest plant (84.87 cm) was observed from two hand weeding method which was statistically similar to all the methods except no weeding Control. At maturity, the tallest plant (106.4cm) was observed from two hand weeding method which was statistically similar to all the weeding method applied and the shortest plant (102.7cm) was found from no weeding control (Fig. 32 and Appendix 21).

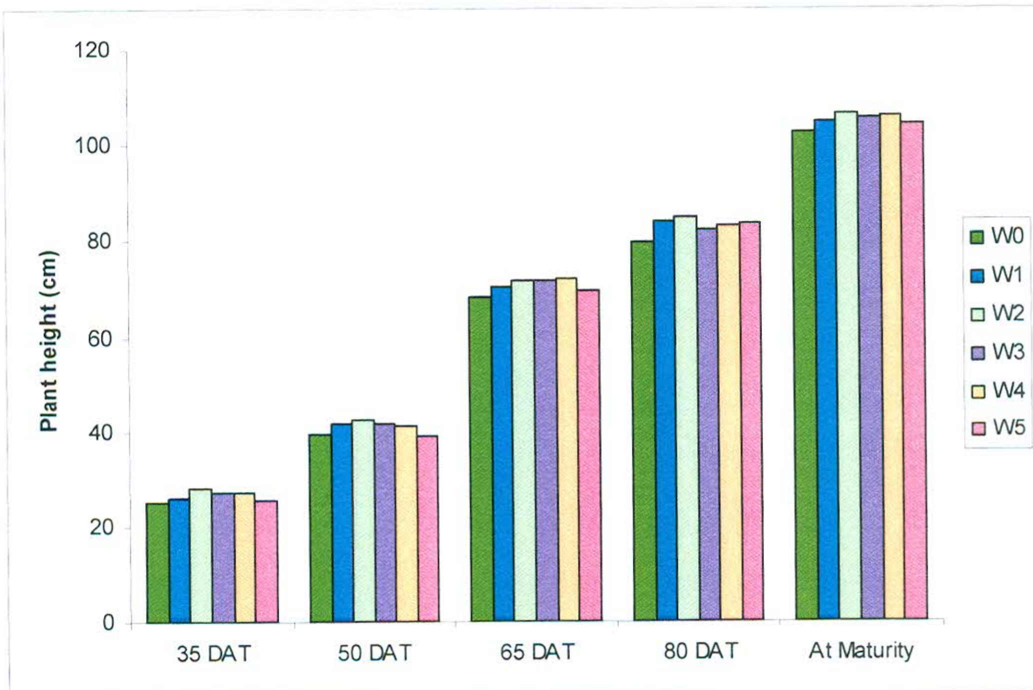

Fig. 32: Effect of methods of weeding on plant height at different DAT

4.5.2. Tillering pattern

Number of tiller hill^{-1} was significantly affected by different weed control methods at all sampling dates (Appendix 19). At 35 days after transplanting, the highest number of tiller hill^{-1} (4.57) was observed from application of Rifit @ 1.0 L ha^{-1} which was statistically similar to all the weeding methods applied except application of Rifit @ 1.5 L ha^{-1} and lowest (3.37) was observed from no weeding control. At 50 days after transplanting, the highest (14.67) number of tiller hill^{-1} was found from application of

Rifit @ 1.0 L ha^{-1} which was statistically similar to all the weeding method applied except one hand weeding and the lowest (11.87) was observed from no weeding control. At 65 days after transplanting , the highest tiller $plant^{-1}$ (25.20) was observed from two hand weeding method which was statistically similar to all the method applied and the lowest (18.87) was found from no weeding control. At 80 days after transplanting, the highest tiller $plant^{-1}$ (16.53) was found from two hand weeding method which was statistically similar to all the weeding method applied except one hand weeding and the lowest tiller $plant^{-1}$ (13.53) was observed from no weeding control. At maturity, the highest number of total tiller $hill^{-1}$ (14.66) found from the treatment of application of Rifit @ 0.5 L ha^{-1} which was statistically similar all of the treatment except one hand weeding. The lowest number (9.80) of total tiller $hill^{-1}$ was observed from no weeding control treatment (Fig. 33 and Appendix 22).

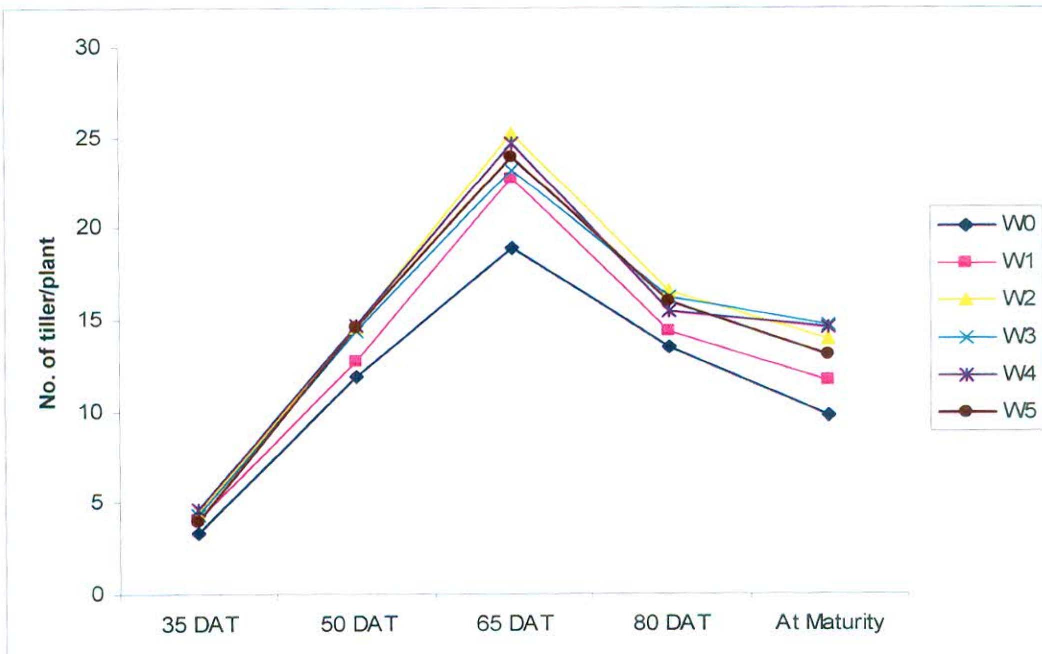

Fig. 33: Effect of methods of weeding on tillering at different DAT

4.5.3. No. of effective & non effective tiller $hill^{-1}$

There was significant effect on number of effective and non effective tiller $hill^{-1}$ by different weeding method (Appendix 20). The highest number of effective tiller $hill^{-1}$ (14.33) was observed from application of Rifit @ 0.5 L ha^{-1} which was statistically similar to all the weed control method applied and the lowest (9.33) was obtained from no weeding control treatment. On the other hand, the highest number of non–effective tiller hill^{-1} (0.53) was observed from application of Rifit @ 1.0 L ha^{-1} which was statistically similar to application of Rifit @ 0.5 Lha^{-1} and no weeding control treatment. The lowest number of non-effective tiller hill^{-1} (0.20) was obtained from application of Rifit @ 1.5 L ha^{-1} which was statistically similar to one hand weeding, two hand weeding method and application of Rifit @ 0.5 L ha^{-1} (Appendix 23).

4.5.4. No. of fertile and sterile and total spikelet panicle^{-1}

There was significant effect on number of fertile and sterile and total spikelet panicle-^{1} by different weed control treatment (Appendix 20). The highest number of fertile spikelet panicle^{-1} (154.2) was observed from the two hand weeding treatment which was statistically similar to application of Rifit @ 1.0 Lha^{-1} and one hand weeding treatment. The lowest number of fertile spikelet panicle^{-1} (131.1) was obtained from no weeding control treatment which was statistically similar to one hand weeding treatment, application of Rifit @ 0.5 L ha^{-1} and 1.5 L ha^{-1} treatment. The highest number (59.67) of sterile spikelet panicle^{-1} was observed in application of Rifit @ 0.5 L ha^{-1} treatment. The lowest number (40.47) of sterile spikelet panicle^{-1} was recorded from application of Rifit @ 1.0 L ha^{-1} treatment which was statistically identical to all the weed control treatment applied and also no weeding control treatment. The highest number of total spikelet panicle^{-1} (198.37) was observed from application of Rifit @ 0.5 L ha^{-1} and the lowest (173.97) was obtained from no weeding control treatment (Fig. 34 and Appendix 23).

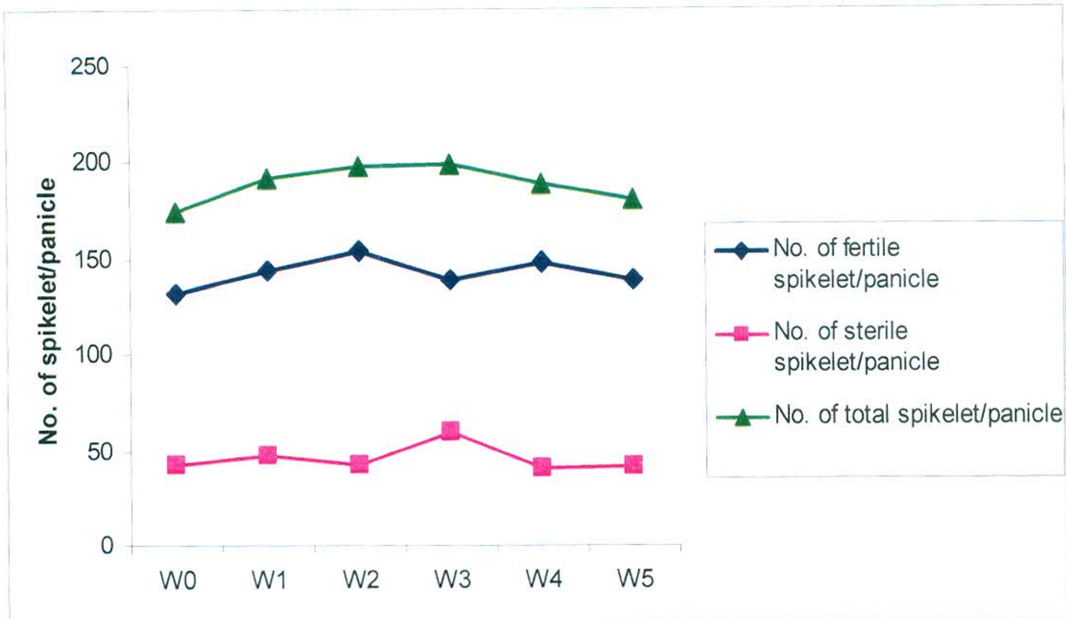

Fig. 34: Effect of methods of weeding on fertile, sterile and total spikelet panicle^{-1} of BRRI dhan29

4.5.5. Grain yield

Significant variation was observed in grain yield due to the effect of different weed control treatments at 1% level of significance (Appendix 20). Among the different weed control treatments, the highest grain yield (7.22 t ha^{-1}) was recorded from application of Rifit @ 1.0 L ha^{-1} treatment which was statistically identical to all the weed control treatment. The lowest grain yield (5.30 t ha^{-1}) was observed from no weeding control treatment (Fig. 35 and Appendix 23).

4.5.6. Straw yield

Straw yield of rice significantly influenced by different weed control method at 1% level of significance (Appendix 20). The highest straw yield (7.08 t ha^{-1}) was obtained from application of Rifit @ 1.0 L ha^{-1} treatment which was statistically identical to all the weed control method applied except one hand weeding treatment. The lowest (5.15 t ha^{-1}) straw yield was found from no weeding control treatment (Fig. 35 and Appendix 23).

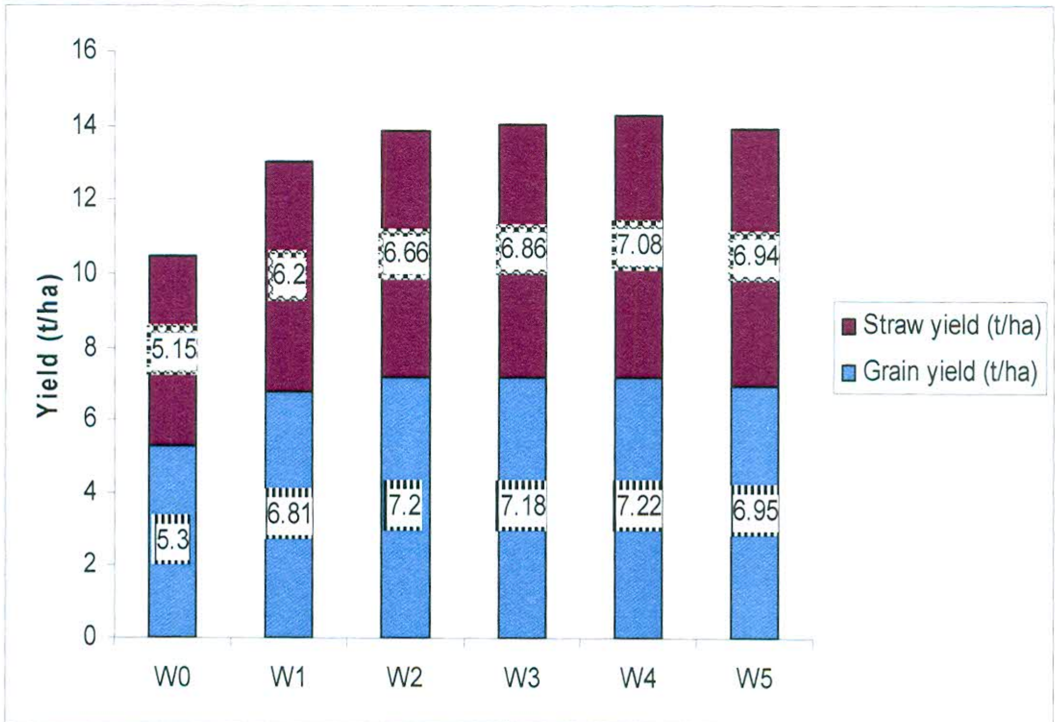

Fig. 35: Effect of methods of weeding on grain yield and straw yield of BRRI dhan29

Fig: No weeding control plot at 20 DAT

Fig : One hand weeding plot at 20 DAT

Fig : Two hand weeding plot at 20 DAT

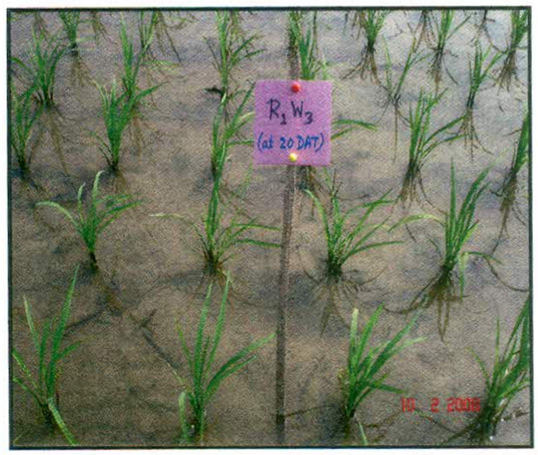

Fig: Rifit @ .5 L/ha apply plot at 20 DAT

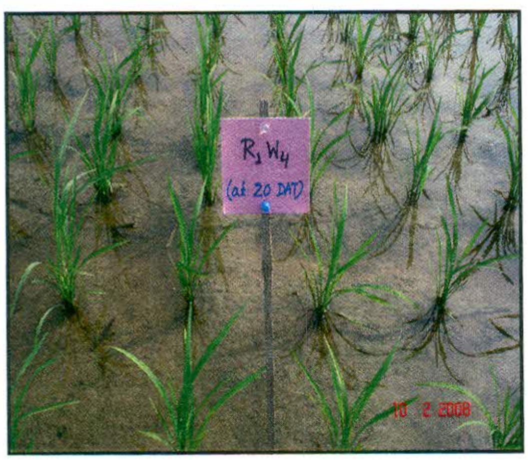

Fig: Rifit @ 1 L/ha apply plot at 20 DAT

Fig: Rifit @ 1.5 L/ha apply plot at 20 DAT

Plate 11: Different treatment plot of the experiment at 20 DAT

Fig : No weeding control plot at 40 DAT

Fig : One hand weeding plot at 40 DAT

Fig : Two hand weeding plot at 40 DAT

Fig: Rifit @ .5 L/ha apply plot at 40 DAT

Fig: Rifit @ 1 L/ha apply plot at 40 DAT

Fig: Rifit @ 1.5 L/ha apply plot at 40 DAT

Plate 12: Different treatment plot of the experiment at 40 DAT

Fig : No weeding control plot at harvesting

Fig : One hand weeding plot at harvesting

Fig : Two hand weeding plot at harvesting

Fig: Rifit @ .5 L/ha apply plot at harvesting

Fig: Rifit @ 1 L/ha apply plot at harvesting

Fig: Rifit @1.5 L/ha apply plot at harvesting

Plate 13: Different treatment plot of the experiment at harvesting

4.5.7. Biological yield and harvest index

Biological yield was significantly affected by different weed control treatment at 1% level of significance (Appendix 20). The highest (14.30 t ha^{-1}) biological yield observed from application of Rifit @ 1.0 L ha^{-1} treatment which was statistically identical to all the weed control treatment applied except one hand weeding method. The lowest (10.45 t ha^{-1}) biological yield was obtained in the no weeding control plot. It was observed that weed control treatment had no significant influenced on the harvest index. However, numerically, the highest (52.25) harvest index was found from one hand weeding method and the lowest (50.05) harvest Index was observed from application of Rifit @ 1.5 L ha^{-1} treatment (Fig. 36 and Appendix 23).

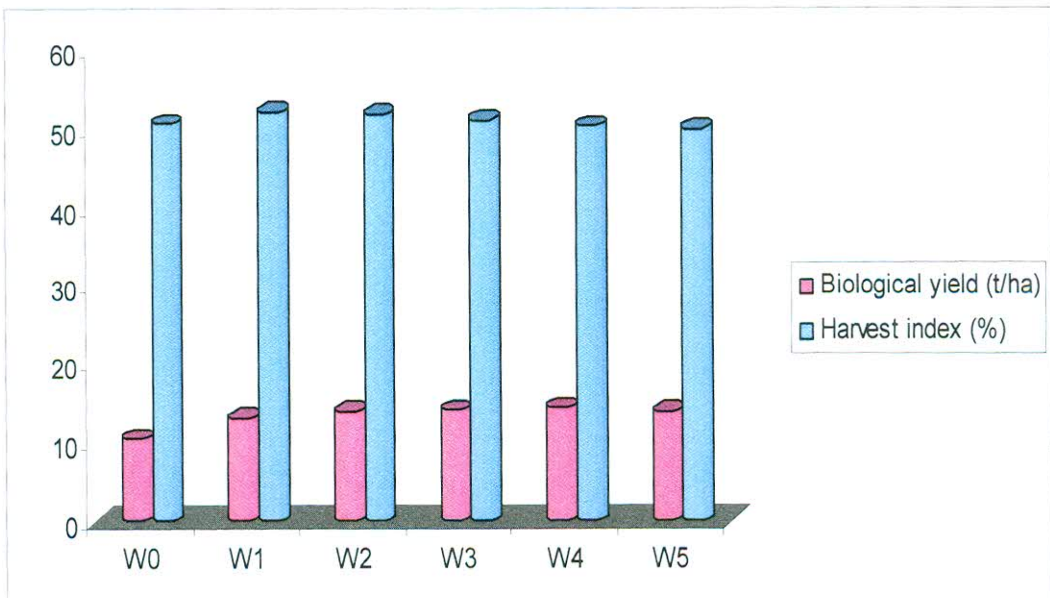

Fig. 36: Effect of methods of weeding on biological yield and harvest index of BRRI dhan29

From the above results, it is evident that weed infestation also reduced the rice yield significantly. Weed free treatment showed higher yield and the no weeding treatment provided significantly lower yield.

Chapter 5

DISCUSSION

DISCUSSION

5.1. Effect of spacing on yield and yield component of BRRI dhan29

The effect of spacing in boro rice plays an important role on growth and yield. Optimum plant spacing produce optimum number of plants per unit area which enhance better growth and yield and ultimately higher grain yield at harvest. In all sampling at vegetative stage, the shortest plant was observed with 25cm X 15cm spacing and this is due to closer spacing. The results shows that wider spacing 25cm x 30cm contained the highest number of total tillers hill^{-1} due to more efficient use of nitrogen fertilizer and closer spacing (25cm x 10cm) produced the lowest number of total tillers hill^{-1} due to more competition among the plant population for fertilizer, space, sunlight etc. Haque and Nasiruddin (1988) also noticed that wider spacing produced higher tillers hill^{-1}. The results also indicate that wider spacing had a tendency to produce more effective tiller hill^{-1} than closer spacing. Shah (1998) noticed that number of productive tillers per hill was higher at wider spacing than closer spacing. The similar results was observeded by Verma *et al.* (2002). The results further indicated that the number of non effective tiller hill^{-1} decreased at closes spacing (25cm x 10cm) which might de helped to increase effective tillers hill^{-1}. It was also reported that closer spacing produce more effective tiller hill^{-1} (Verma *et al.* ,2002). Mobasser *et al.* (2007) observed similar result that planting spaces had significant effect on total tiller number and the highest tiller number (23.5) were obtained at 30 X 30 cm planting spaces. This might be due to the fact that from wider spacing plant got more nutrients and moisture which eventually led to develop of more grain comparing to closes spacing. The results are consistent with that of karim *et al.* (1992). Shah (1998) also reported that number of filled grains per panicle decreased with the decreased of spacing indicating planting density had a pronounced effect on it. Mobasser *et al* (2007) noticed similar result that total spikelet per panicle (178.6) was produced at 25 X 25 cm planting spaces. Mobasser *et al* (2007) found that planting spaces had no significant effect on 1000 grains weight. The result exhibited a gradual reduction in grain yield with the increase in plant spacing or in other words with the decrease in plant population per unit area. Ramakrishna *et al.*

(1992) also noticed similar views regarding the effects of plant spacing on grain yield of rice. The highest harvest index in 25 cm x 25 cm spacing was contributed by its highest grain yield . The closest spacing produced the highest straw yield compared to that of grain yield resulting the lowest harvest index. Partially similar results are noticed by Verma *et al* (2002). Results indicated that wider spacing had linearly increasing effect on the performance of individual plants. The plants grown with wider spacing have more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed better as individual plants. The reason for deviation of this linearity in case of grain yield per plot is that the yield does not entirely depend upon the performance of individual plant but also on the total number of plants per plot and yield contributing parameters within plant.

5.2. Effect of time of transplanting on yield and yield component of rice (cv. BRRI dhan29)

Among the crop production tools, proper time planting is one of the major prerequisites that allow the crop to complete its life phase timely and successfully under a specific agro-ecology. Plant height differ significantly due to the different planting dates and early planting in boro season shows shortest plant and gradually it increases and the delay planting was the longest plant. This is due to in early planting in late December fall in cold temperature and the vegetative growth hampered and it takes more time to recovery the transplanting shock. In late January the temperature goes up and plant can express the highest vegetative growth. Among yield components, effective tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers per unit area and the data presented in table- indicated that the effective tiller differed significantly due to the transplanting dates. In early planting less number of effective tiller due to cold effect and late planting produces less effective tiller due to high temperature reduces vegetative phase of rice plant. Mid January produces highest effective tiller due to optimum temperature, humidity and sun shine hours. Total tiller is the sum of effective and non effective tiller and can not play significant effect on yield. Similar result was reported by Anonymous (2002). Mid and late January planting produces highest fertile and lowest sterile spikelet due to obtain optimum temperature, sunlight and humidity during heading period but early and late season planting produces lowest fertile and highest sterile spikelet due to low temperature at PI stage and high temperature and humidity at heading stage increases sterility percentage. Similar result was noticed by Anonymous (2002). 1000 grain weight was not significantly affected by planting date and Ashraf *et al.* (1999) reported that 1000 grain weight is an important yield determining component and a genetic character least influenced by environment. The highest grain yield on 10 January planting might be due to prevailing higher temperature that enhance the vegetative growth of rice plant. Grain yield is a function of interplay of various yield components such as number of productive tillers, filled spikelets per panicle and 1000 grain weight (Hassan *et al.* 2003). Similar result was obtained in case of grain yield in this study.

5.3.Effect of nitrogen on yield and yield component of BRRI dhan29

It could be the observation from the result that the use of increasing level of nitrogen was found to produce taller plants. This significant variation in respect of plant height might be due to higher N nutrient uptake of plants from different levels of nitrogen. Similar trend of plant height due to different levels of nitrogen was obtained by Awan *et al.* (1984) and Bhuiyan and Shah (1990) who reported a positive influence of nitrogen on plant height. However, a general trend was observed that the number of total tiller hill^{-1} increased with increased level of nitrogen . The Results were in close conformity with those of Reddy *et al.* (1986) and Hussain *et al.* (1989). The results explicitly confirm similar results obtained by Reddy *et al.* (1988) who recorded a positive effect of nitrogen level on plant height and the increasing in plant height due to application of increased level of nitrogen might be associated with stimulating effect of nitrogen of various physiological processes including cell division and cell elongation of the plant. Sikder *et al.*(2006) also stated that plant height increased significantly with the increasing rate of N. Different nitrogen level had significant effect on number of effective and total tiller hill^{-1} and the effective and total tiller increased up to application of N 130 kg/ha then decreased gradually. Similar result was observed by Dubey *et al.* (1991), Pandey *et al.*(1991), Thakur (1993) and Ni-Zhihua (1997).

Number of fertile and total spikelet panicle^{-1} increase with the increase of nitrogen level up to 110 kg N/ha and then decrease gradually. The results are compliance with Behera (1998). The increase in grain yield and straw yield due application of N level was mainly due to improvement in yield component i.e. longest panicle length and highest number of effective tiller hill^{-1}, highest fertile spikelet panicle^{-1}. These results are in agreement with those obtained by Hussain and sharma (1991), Dwivedi (1997) who reported that the grain yield increased significantly up to the application of 120 kg N ha^{-1}. Present study indicates that the increasing nitrogen level increased grain yield up to 110 kg N ha^{-1}. Usha *et at*, (2001) also reported straw yield increase with the increase of N level.

5.4:Effect of seedling age and seedling number hill^{-1} on yield and yield component of Rice(cv. BRRI dhan29)

Transplanting of seedlings of optimum age and optimum seedling hill^{-1} ensures better rice yield. At the vegetative stage, due to the age effect the highest plant was obtained from older seedling than younger seedling but, seedling hill^{-1} was not significant effect on plant height due to the same seedling age. The result indicates that tillering capacity of young seedling was higher than older seedlings. These results were partially in agreement with those of Roy and Satter (1992). They reported that younger seedlings produced more tillers. Mozumder (1997) also reported that 35 days old seedling showed better performance for production of total tillers/hill. In all cases, the highest number of tiller hill^{-1} was obtained from 6 seedling hill^{-1} and the lowest from 2 seedling hill^{-1}.These results are in agreement with the findings of Pataniswary and Gomez (1976) who reported that number of tiller hill^{-1} increased with increasing number of seedling hill^{-1}. Fertile spikelet panicle^{-1} was higher in younger seedling then decrease gradually in older seedling due to loss of potentiality of the older seedling at nursery and to recovery of transplanting shock. Number of grains panicle^{-1} decreased with the increasing seedling number hill^{-1} due to reducing in vegetative growth due to decrease number of seedling hill^{-1} was perhaps, the reason for this reduction in the number of grains panicle^{-1} . This result was in agreement with Islam (1989) who stated that 3 seedlings hill^{-1} well as 4 seedlings hill^{-1}.The number of grains per panicle decreased with increasing seedling density was reported by Inaba and Kitano (2005). Higher grain yield was obtained by 40 day old seedling might be the reasons of higher panicle length, 1000 grain weight , no. of effective tiller hill^{-1} and filled grains /panicle. Mondal and Ray (1984) and Banik *et al.* (1997) also reported that the highest grain yield was obtained from 35 day old seedling. Rashid *et al* (1990) observed a similar result that 35 day old seedling gave higher grain and straw yield than that of 50 day old seedling. There was no significant difference of yield between 2,4, and 6 seedling hill^{-1} due to no statistical difference of effective tiller hill^{-1}, panicle length, fertile spikelet and sterile spikelet panicle^{-1} but, 40 days old seedling along with 2 seedling hill^{-1} produced the highest yield.

5.5: Effect of method of weeding on the yield and yield component of rice (cv. BRRI dhan29)

The lowest plant height produced in no weeding treatment (W_0) was significantly inferior to rest of the weed control treatments. Result indicated that heavy weed infestation in the no weeding treatment might have hampered the normal growth and development of rice plants and ultimately plants became shorter. Similar results were also reported by Patil *et al.* (1986) and Ahmed *et al.* (2008) that plant height significantly reduced by heavy weed infestation. Results of this study showed that weed free condition was best for tiller production. The cause of the highest number of total tiller hill^{-1} might due to the least competition for nutrient, air space, light and water between crop plants and weeds. Attalla and Kholosy (2002) also reported that the highest number of tiller hill^{-1} emerged in crop which was kept weed free. Similar results were reported by Ahmed *et al* (2008).The weed control treatment exhibited almost the same trend of effect on bearing tillers hill^{-1} and the highest number of effective tiller hill^{-1} was observed from weed control method applied and the lowest was obtained from no weeding control treatment. This might be due to the fact that the higher competition of weeds did not allow the rice plant to produce more number of bearing tiller hill^{-1} in the no weeding treatment. Similar findings were also reported by Hasanuzzaman *et al.* (2007). In the treatment where weeds were controlled effectively, higher number of fertile and total spikelet panicle^{-1} and lower number of sterile spikelet panicle^{-1}was recorded due to less competition between weeds and crops for nutrient, water, light etc. Similar findings were also reported by Ahmed *et. al.* (2008) where the number of filled grains panicle^{-1} were increased due to weed control over no weeding. In this study, the highest grain yield was recorded from the weed control treatment and the lowest grain yield was observed from no weeding control treatment. The increased yield in treatment plot might be contributed by higher number of effective tiller hill^{-1}, higher number of fertile spikelet panicle^{-1}, lower number of sterile spikelet panicle^{-1} over no weeding treatment. Again weeding kept the land clean and soil was aerated which facilitated the crop for absorption of greater amount of plant nutrient, moisture and greater reception of solar radiation for better growth. The lowest grain yield in the no weeding treatment plot might be due to resultant effects of the poor performance of yield contributing characters. Similar findings were also reported by Polthanee *et al.*, (1996), Sanjoy *et al.* (1999), Gogoi *et al.* (2001), Attalla and Kholosy (2002), Ahmed *et al.*, (2008) where different weed control practices significantly increased the rice yield over the un weeded control. The highest straw yield was obtained from application of weed control treatment and the lowest straw yield was found from no weeding control treatment because of severe weed infestation that hampered the normal growth and development of rice plant and also its tillering capacity and finally reduced the straw yield. Due to sufficient growth, the highest straw yield was found in weed free treatment. Alam *et. al.* (1995) also reported the similar result. Variation of biological yield among the treatments was dependent upon the severity of weed infestation. Higher weed infestation not only reduced the grain yield but also hampered the plant growth and tillering capacity and ultimately reduced straw yield and also biological yield.

Chapter 6

SUMMARY

SUMMARY

The research work was carried out at the Research and Development Farm of Syngenta Bangladesh Limited (Multinational Plant Science Company, former Ciba-Geigy) located at Birgram, Bogra, Bangladesh during two consecutive Boro season from November'2006 to May'2007 and November'2007 to May'2008 in order to optimizing the yield of rice (cv. BRRI dhan29) through appropriate agronomic practices like Spacing, time of transplanting, nitrogen rate, seedling age, seedling number hill^{-1} and method of weed control. Five experiment consisting a set of treatment for each experiment was included and experiment 1, 2, 3 and 5 was laid out in a randomized complete block design with three replication and exp. 4 was laid out in a randomized complete block design (factorial) with three replication. Each replication was represent a block in the experiment. Each block was divided into unit plots where the treatment were allocated at random. The size of unit plot was 4.0 m x 2.5 m. Seedlings were transplanted in the well-puddle experimental plots as per experimental treatments in the schedule. Intercultural operations such as fertilization, weeding, water and pest management was done as and when necessary. Data on growth parameters were recorded at 15 days interval starting from 35 DAT to 80 DAT. Harvesting was done when 90% of the grains became golden in color. Ten hills were randomly selected from each unit plot prior to harvest for recording yield component data. Grain and straw yields were recorded from 5.0 m^2 area of each unit plot excluding border area. The collected and calculated data were analyzed statistically and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

Spacing had no significant effect on plant height at all sampling but it had significant effect on yield and yield contributing character in respect of effective tiller hill^{-1}, total tiller hill^{-1}, fertile spikelet panicle^{-1}, sterile spikelet panicle^{-1}, Grain yield, straw yield, biological yield and harvest index. BRRI dhan29 produced higher number of effective tiller per m^2, highest fertile spikelet panicle^{-1}(160.7)and lowest sterile spikelet panicle^{-1}(45.80), as a result the highest grain yield (7.32 t ha^{-1}) and biological yield (14.36 t

ha^{-1}) was obtained from 25cm x 20cm spacing. The highest straw yield (7.06 t ha^{-1}) was obtained from 25cm x 30cm spacing due to highest non effective tiller $hill^{-1}$(0.67). The lowest grain yield (5.21 t ha^{-1}) and biological yield (11.26 t ha^{-1}) was found in 25cm x 10cm spacing due to lowest effective tiller $hill^{-1}$(9.53), lowest fertile spikelet $panicle^{-1}$(109.3) and highest sterile spikelet $panicle^{-1}$ (81.47).

Results revealed that transplanting time had significant effect on yield and yield contributing characters of rice (cv. BRRI dhan29). The highest number of effective tiller $hill^{-1}$(13.20), total tiller $hill^{-1}$(13.27), grain yield (7.18 t ha^{-1}) and biological yield (14.10 t ha^{-1}) was obtained from 10^{th} January planting. The highest plant height (104.9 cm), fertile spikelet $panicle^{-1}$(139.0) total spikelet $panicle^{-1}$(190.80), 1000 grain wt. (20.33 gm), straw yield (7.05 t ha^{-1}) were obtained from 25^{th} January planting. The highest sterile spikelet $panicle^{-1}$(77.93) was found in 10^{th} February planting which was statistically similar to 10^{th} December planting.

Different levels of nitrogen had significant effect on most of the parameters. Plant height increased with the increase level of nitrogen but number of total tiller $hill^{-1}$ increase with the increase level of nitrogen up to 130.0 kg/ha. The highest plant height (89.19 cm) was observed when applied 150 kg N/ha and highest number of total tiller $hill^{-1}$(13.40) was obtained from 110 kg N/ha. The highest number of effective tiller $hill^{-1}$(13.00), panicle length (21.80 cm), fertile spikelet $panicle^{-1}$(125.80) total spikelet $panicle^{-1}$(171.67), Grain yield (7.18 t ha^{-1}), Straw yield (7.31 t ha^{-1}) and Biological yield (14.49 t ha^{-1}) were obtained from 110 kg N ha^{-1}. The highest non-effective tiller was observed from 130 kg N ha^{-1} and highest sterile spikelet $panicle^{-1}$was obtained from 150 kg N ha^{-1}.

At vegetative stage, plant height was not significantly influenced due to seedling number $hill^{-1}$ and the interaction effect of seedling age and seedling number $hill^{-1}$ but there was significant effect due to seedling age of all sampling except at 65 DAT. Number of tiller $hill^{-1}$ was significantly influenced due to seedling age and seedling number $hill^{-1}$ but there was no significant effect on tiller $hill^{-1}$ due to interaction of seedling age and seedling number $hill^{-1}$.Yield and yield contributing character of BRRI dhan29 was significantly affected due to seedling age and seedling number $hill^{-1}$ but grain yield, straw yield, biological yield and harvest index was significantly affected due to interaction of seedling age and seedling number $hill^{-1}$. Highest grain yield (6.77 t ha^{-1}) was found in 40 days old seedling which was statistically similar to 30 days old seedling. Highest grain yield (6.28 t ha^{-1}) was obtained in 2 seedling $hill^{-1}$ which was statistically similar to 4 and 6 seedling $hill^{-1}$. However, highest grain yield (7.64 t ha^{-1}) was obtained due to interaction of 40 days old seedling age and 2 seedling $hill^{-1}$.

Plant height, total number of tiller $hill^{-1}$, number of effective tiller $hill^{-1}$, number of non-effective tiller $hill^{-1}$, number of fertile sterile and total spikelet $panicle^{-1}$, grain yield, straw yield and biological yield were significantly affected by weeding method except 1000 grain weight and harvest index. Significant variation was observed between weeding and no-weeding treatment plot. Highest grain yield (7.22 t ha^{-1}), straw yield(7.08 t ha^{-1}) and biological yield (14.30 t ha^{-1}) was found in application of rifit @ 1.0 L Ha^{-1}) which was statistically similar to all the weed control method applied in the experiment.

Based on the findings of the present study, it may be concluded that the spacing of 25cm x 20cm coupled with 40 days old seedling and 2 seedling $hill^{-1}$ transplanting at 10^{th} January, application of nitrogen @ 110 kg/ha and controlling of weeds by applying Rifit @ 1.0 L/ha showed better performance in respect of growth, yield and yield component of rice (cv. BRRI dhan29) that will increase the rice production and contribute to the food security in Bangladesh.

Chapter 7
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REFERENCES

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APPENDICES

Appendix 1a: Monthly temperature, relative humidity, sunshine hour and rainfall of experimental site during the growth period (Boro'2006-2007)

Year	Month	*Air temperature($^{\theta}$C)			** Rainfall (mm)	* Relative humidity	** Sunshine (hrs)
		Max.	Min.	Avg.			
2006	November	29.6	18.5	24.1	001	77.33	169.3
	December	26.9	14.0	20.5	000	74.33	147.5
2007	January	24.3	10.7	17.5	000	76.03	76.6
	February	26.2	15.5	20.9	018	76.25	141.4
	March	33.2	20.4	26.8	027	66.37	234.4
	April	32.9	23.3	28.1	028	73.33	182.8
	May	35.5	25.2	30.4	092	71.67	240.5

* Monthly average
**Monthly total

Source : Regional Inspection Centre, Bangladesh Metrological Department, Bogra

Appendix 1b: Monthly temperature, relative humidity, sunshine hour and rainfall of experimental site during the growth period (Boro'2007-2008)

Year	Month	*Air temperature(^{0}C)			** Rainfall (mm)	* Relative humidity	** Sunshine (hrs)
		Max.	Min.	Avg.			
2007	November	30.6	19.1	24.9	015	76.33	225.8
	December	26.0	13.0	19.5	000	77.00	147.0
2008	January	24.1	12.5	18.3	027	80.33	102.8
	February	25.9	13.1	19.5	000	72.33	163.1
	March	30.5	19.9	25.2	022	74.33	154.2
	April	34.0	23.2	28.6	019	72.00	218.7
	May	34.5	24.4	29.5	221	74.66	223.1

* Monthly average
**Monthly total

Source : Regional Inspection Centre, Bangladesh Metrological Department, Bogra

Appendix 2: Morphological and chemical characteristics of the experimental soil

A. Morphological characterizes of the soil.

Location:	R & D Farm, Syngenta Bangladesh Limited,Birgram Bogra
Soil tract:	Barind Tract
General soil type:	Grey terrace soil
Soil series:	Amnura
Land type:	High land
Parent material:	Modhupur clay
Agro-ecological zone:	25
Topography:	Level
Drainage:	Imperfectly drained

B. Chemical characteristics of the initial soil (0-15 cm depth)

Constituents	Results
P^H	5.7
Organic Matter (%)	1.3
Total N (%)	0.11
Available Phosphorus (ppm)	15
Available Sulphur (ppm)	14
Exchangeable Potassium (me %)	0.14

Source: Fertilizer recommendation guide

Appendix 3: Summary of the analysis of variance (mean square values) for the growth characters of Boro rice (cv. BRRI dhan 29) as affected by different spacing

Source of variation	Degree of freedom	Mean square values							
		Plant height (cm)				No of tiller $plant^{-1}$			
		35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
Replication	2	0.23	4.73	6.06	12.79	0.24	1.17	0.10	2.81
Spacing	4	2.31^{NS}	5.91^{NS}	3.54^{NS}	2.90^{NS}	2.38^{NS}	20.47**	106.40**	62.30**
Errer	8	2.02	2.36	1.57	4.68	2.52	1.42	2.87	2.86
cv(%)		3.67	2.77	2.09	3.16	15.55	8.38	7.57	10.06

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SP_1=25 cm x 10 cm
SP_2=25 cm x 15 cm
SP_3=25 cm x 20 cm
SP_4=25 cm x 25 cm
SP_5=25 cm x 30 cm

Appendix 4: Summary of the analysis of variance (mean square values) for the yield and yield component of BRRI dhan 29 as application of spacing

Source of variation	Degree of freedom	Mean square values												
		Plant height (cm)	No. of effective tiller $hill^{-1}$	No. of non effective tiller $hill^{-1}$	No. of total tiller $hill^{-1}$	Panicle length (cm)	No. of fertile spikelet $panicle^{-1}$	No. of sterile spikelet $panicle^{-1}$	No. of total spikelet $panicle^{-1}$	1000 grain wt . (gm)	Grain yield $t\ ha^{-1}$	Straw yield $t\ ha^{-1}$	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	33.64	0.16	0.14	0.36	0.29	255.60	321.68	8.29	1.67	0.08	0.56	0.99	4.76
Spacing	4	21.02^{NS}	39.44 **	0.13^{NS}	43.18^{**}	0.24^{NS}	1113.95**	648.06**	160.65^{NS}	0.43^{NS}	1.77 **	1.00 **	4.26**	21.67**
Error	8	30.86	2.42	0.26	21.66	0.55	87.47	85.85	271.17	0.33	0.13	0.04	0.11	3.36
cv(%)		6.29	10.63	108.98	10.90	3.26	6.78	15.30	8.30	2.96	5.63	2.98	2.53	3.70

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SP_1=25 cm x 10 cm
SP_2=25 cm x 15 cm
SP_3=25 cm x 20 cm
SP_4=25 cm x 25 cm
SP_5=25 cm x 30 cm

Appendix 5: Effect of spacing on the yield and yield contributing characters of Boro rice (cv.BRRI dhan29)

Spacing	Plant height (cm)	No. of effective tiller $hill^{-1}$	No. of non effective tiller $hill^{-1}$	No. of total tiller $hill^{-1}$	Panicle length (cm)	No. of fertile spikelet $panicle^{-1}$	No. of sterile spikelet $panicle^{-1}$	No. of total spikelet $panicle^{-1}$	1000 grain wt. (gm)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Bio logical yield ($t\ ha^{-1}$)	Harvest index (%)
SP_1	87.39	09.53c	0.20	09.73c	22.73	109.3b	81.47a	190.93	19.67	5.21c	6.06bc	11.26d	46.27b
SP_2	87.71	12.73bc	0.47	13.20bc	22.93	136.3a	68.87ab	205.13	19.67	6.26b	6.51ab	12.77bc	49.04ab
SP_3	91.99	16.13ab	0.67	16.80ab	22.83	160.7a	45.80b	206.47	19.33	7.32a	7.05a	14.36a	50.95ab
SP_4	89.61	15.67ab	0.33	16.00ab	22.27	134.0ab	57.47ab	191.47	19.00	6.59ab	5.77c	12.36c	53.32a
SP_5	84.91	19.07a	0.67	19.73a	22.43	149.3a	49.13b	198.40	20.00	6.59ab	7.06a	13.64ab	48.27ab
S(X)	03.21	00.89	0.29	0.95	0.43	5.40	5.35	9.51	00.33	0.20	0.11	0.18	1.05
level of sig.	NS	**	NS	**	NS	**	**	NS	NS	**	**	**	**
cv(%)	6.29	10.63	108.98	10.90	3.26	6.78	15.30	8.30	2.96	5.63	2.98	2.53	3.70

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SP_1=25 cm x 10 cm
SP_2=25 cm x 15 cm
SP_3=25 cm x 20 cm
SP_4=25 cm x 25 cm
SP_5=25 cm x 30 cm

Appendix 6: Summary of the analysis of variance (mean square values) for the yield and yield component of BRRI dhan 29 as affected by different planting time

Source of variation	Degree of freedom	Mean square values										
		Plant height (cm)	No. of effective tiller $hill^{-1}$	No. of total tillers $hill^{-1}$	No. of fertile spikelet $panicle^{-1}$	No. of sterile spikelet $panicle^{-1}$	No. of total spekelet $panicle^{-1}$	1000 grain wt . (gm)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	8.25	0.87	1.04	16.39	42.68	24.89	0.27	0.38	0.12	0.88	2.09
Planting Time	4	510.84**	9.42*	9.02^{NS}	647.45*	796.13**	197.59^{NS}	2.73^{NS}	2.63**	1.36**	6.47**	25.64**
Error	8	2.75	2.63	2.55	127.35	91.95	277.29	0.93	0.12	0.24	0.55	2.93
cv(%)		1.80	15.00	14.59	9.01	16.31	9.05	4.85	5.69	7.81	5.93	3.48

NS= Not significant
* Significant at 5% level
** Significant at 1% level

T_1=10th December Planting
T_2=25th December Planting
T_3=10th January Planting
T_4=25th January planting
T_5=10th February Planting

Appendix 7: Effect of planting time on the yield and yield contributing characters of Boro rice, BRRI dhan29

Time of Planting	Plant Height (cm)	No. Of Effective Tiller $hill^{-1}$	No. of total tiller $hill^{-1}$	No. of fertile spikelet $panicle^{-1}$	No. Of Sterile spikelet $panicle^{-1}$	No. of total spikelet $panicle^{-1}$	1000 grain wt.(g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
T_1	75.26d	9.20b	9.53	118.5ab	74.67a	193.17	19.33	5.25b	5.39b	10.64c	49.34abc
T_2	83.07c	11.80ab	11.87	127.6a	45.40b	173.00	19.00	6.80a	6.09ab	12.89ab	52.76a
T_3	92.49b	13.20a	13.27	137.5a	44.13b	181.63	19.33	7.18a	6.91a	14.10a	50.91ab
T_4	104.9a	10.80ab	11.07	139.0a	51.80ab	190.80	20.33	6.37a	7.05a	13.42a	47.49bc
T_5	104.5a	9.00b	9.00	103.5b	77.93a	181.43	20.33	5.07b	6.15ab	11.22bc	45.24c
S(X)	0.96	0.94	0.92	6.52	5.54	9.61	0.56	0.20	0.29	0.43	0.99
level of sig.	**	*	NS	*	**	NS	NS	**	**	**	**
cv(%)	1.80	15.00	14.59	9.01	16.31	9.05	4.85	5.69	7.81	5.93	3.48

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
*   Significant at 5% level
**   Significant at 1% level

T_1=10th December Planting
T_2=25th December Planting
T_3=10th January Planting

T_4=25th January planting
T_5=10th February Planting

Appendix 8: Summary of the analysis of variance (mean square values) for the growth characters of Boro rice (cv. BRRI dhan 29) as affected by different level of Nitrogen

Source of variation	Degree of freedom	Mean square values							
		Plant height (cm)				No of tillers plant^{-1}			
		35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
Replication	2	0.85	3.35	0.64	4.11	2.70	2.86	1.44	0.65
Nitrogen level	4	2.10*	11.94^{NS}	21.29**	63.10**	1.22^{NS}	12.15**	49.70**	17.89**
Error	8	0.51	15.32	1.44	2.69	0.45	0.62	0.64	0.45
cv(%)		1.99	7.53	2.14	2.63	6.81	5.76	4.62	5.04

NS= Not significant
* Significant at 5% level
** Significant at 1% level

N1=0 Kg/ha(control)
N2=90 Kg/ha
N3=110 Kg/ha
N4=130 Kg/ha
N5=150 Kg/ha

Appendix-9: Summary of the analysis of variance (mean square values) for the yield and yield component of BRRI dhan29 as affected by different rate of nitrogen

Source of variation	Degree of freedom	Mean square values												
		Plant height (cm)	No. of effective tiller hill-1	No. of non effective tiller hill-1	No. of total tillers hill-1	Panicle length (cm)	No. of fertile spikelet panicle-1	No. of sterdle spikelet panicle-1	No. of total spekelet panicle-1	1000 grain wt . (gm)	Grain yield (t ha-1)	Straw yield (t ha-1)	Biologica l yield (t ha-1)	Harvest index (%)
Replication	2	26.86	1.45	0.01	1.22	0.69	70.62	90.44	173.07	0.47	0.03	0.14	0.05	5.18
Nitrogen level	4	** 101.84	** 9.21	Ns 0.02	** 9.42	Ns 0.62	** 1044.98	** 270.03	** 2029.33	Ns 0.83	** 6.62	** 7.95	** 28.75	** 5.62
Error	8	7.88	1.14	0.13	0.87	1.35	88.85	8.87	101.58	1.38	0.13	0.27	0.72	.87
cv(%)		3.34	8.91	88.56	7.52	5.38	6.91	7.27	5.68	5.98	5.95	8.32	6.96	1.90

NS= Not significant
* Significant at 5% level
** Significant at 1% level

N1=0 Kg/ha(control)
N2=90 Kg/ha
N3=110 Kg/ha
N4=130 Kg/ha
N5=150 Kg/ha

Appendix 10: Effect of levels of nitrogen on the yield and yield contributing characters of Boro rice (cv.BRRI dhan29)

Level of Nitrogen kg/ha	Plant height (cm)	No. of effective tiller hill^{-1}	No. of non effective tiller hill^{-1}	No. of total tiller hill^{-1}	Panicle length (cm)	No. of fertile spikelet panicle^{-1}	No. of sterile spikelet panicle^{-1}	No. of total spikelet panicle^{-1}	1000 grain wt.(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biologic al yield (t ha^{-1})	Harvest index (%)
N1	74.13b	8.03b	0.40	8.43b	20.73	105.10c	29.40b	134.50c	19.33	3.50c	3.46b	6.96b	50.28a
N2	85.85a	12.07a	0.33	12.40ab	21.80	114.70ab c	32.20b	146.90bc	20.33	5.97b	6.04a	12.01a	49.73a
N3	84..37a	13.00a	0.40	13.40a	21.80	125.80a	45.87a	171.67a	20.00	7.18a	7.31a	14.49a	49.61a
N4	86.80a	12.50a	0.53	13.03a	21.66	122.50ab	47.00a	169.50ab	19.00	7.06a	7.23a	14.29a	49.43a
N5	89.19a	11.50a	0.40	11.90ab	21.70	108.70bc	50.40a	159.10ab	19.66	6.23ab	7.09a	13.32a	46.79b
S(X)	1.62	0.71	0.21	0.84	0.66	3.38	1.72	4.79	0.67	0.20	0.29	0.49	0.53
level of sig.	**	*	Ns	**	Ns	**	**	**	NS	**	**	**	**
cv(%)	3.34	10.66	88..56	12.33	5.38	5.07	7.27	5.31	5.98	5.95	8.32	6.96	1.90

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
* Significant at 5% level
** Significant at 1% level

N1=0 Kg/ha(control)
N2=90 Kg/ha
N3=110 Kg/ha
N4=130 Kg/ha
N5=150 Kg/ha

Appendix 11: Summary of the analysis of variance (mean square values) for the growth characters of Boro rice (cv. BRRI dhan 29) as affected by seedling age and seedling no. hill^{-1}

Source of variation	Degree of freedom	Mean square values							
		Plant height (cm)				No of tillers plant^{-1}			
		35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
Replication	2	22.36	28.51	57.89	168.47	5.07	14.92	10.82	2.34
Seedling Age	3	207.61**	120.45**	47.90^{NS}	108.54**	7.35*	64.83**	48.82**	20.23**
Seedling Number/hill	2	2.12^{NS}	3.50^{NS}	9.82^{NS}	11.07^{NS}	16.97**	112.49**	16.55^{NS}	9.18^{NS}
SA x SN	6	1.84^{NS}	7.63^{NS}	33.69^{NS}	11.95^{NS}	1.24^{NS}	1.39^{NS}	9.07^{NS}	2.38^{NS}
Error	22	1.75	4.19	36.54	10.84	2.33	3.25	6.42	2.70
cv(%)		3.51	4.08	10.33	4.82	18.89	11.12	10.34	9.12

NS= Not significant
* Significant at 5% level
** Significant at 1% level

Appendix 12: Summary of the analysis of variance (mean square values) for the yield and yield component of BRRI dhan 29 as affected by seedling age and seedling no. hill^{-1}

Source of variation	Degree of freedom	Mean square values												
		Plant height (cm)	No. of effective tiller hill-1	No. of non effective tiller hill-1	No. of total tillers hill-1	Panicle length (cm)	No. of fertile spikelet panicle-1	No. of sterdle spikelet panicle-1	No. of total spekelet panicle-1	1000 grain wt . (gm)	Grain yield (t ha-1)	Straw yield (t ha-1)	Biological yield (t ha-1)	Harvest index (%)
Replication	2	36.44	2.00	.03	2.00	.56	918.79	214.11	290.19	1.44	.28	.11	.26	7.94
Seedling Age	3	37.46**	41.74**	.01^{NS}	39.75**	9.42**	1499.21*	1105.23**	495.08^{NS}	1.41^{NS}	3.47**	.86**	.71**	34.83**
Seedling No./hill	2	51.66**	7.45*	.01^{NS}	6.89*	5.87**	782.88^{NS}	842.79*	25.83^{NS}	2.03^{NS}	.95**	.01^{NS}	.86*	16.93**
SA x SN	6	1.50^{NS}	.51^{NS}	.01^{NS}	.76^{NS}	.59^{NS}	273.73^{NS}	124.58^{NS}	283.21^{NS}	.66^{NS}	.39*	.31*	.73*	10.13*
Error	22	7.75	1.49	.01	1.46	.78	230.71	155.24	428.50	1.02	.13	.10	.25	2.95
cv(%)		2.95	9.19	374.26	9.09	3.89	14.01	23.68	12.86	5.08	5.86	4.61	3.80	3.69

NS= Not significant
* Significant at 5% level
** Significant at 1% level

Appendix 13: Effect of seedling age on plant height and total tiller hill^{-1} before harvest of Boro rice, BRRI dhan29

Seedling Age	Plant height (cm)				No of tiller plant^{-1}			
	35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
SA_1	32.48c	46.18b	57.91	63.27a	7.44a	17.89a	27.93a	19.49a
SA_2	37.24b	52.96a	60.06	69.94a	9.40a	18.07a	23.27a	17.42a
SA_3	37.09b	53.50a	55.49	68.63a	7.91a	16.59a	22.87a	16.20a
SA_4	44.13a	47.85b	60.53	71.14a	7.56a	12.31b	23.96a	18.98a
s(x)	.44	.68	2.01	1.10	.51	.60	.84	.55
level of sig.	**	**	NS	**	*	**	**	**
cv(%)	3.51	4.08	10.33	4.82	18.89	11.12	10.34	9.12

In a column, the means having same letter (s) do not differ significantly whereas, dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SA_1 = 30 days old seedling
SA_2 = 40 days old seedling
SA_3 = 50 days old seedling
SA_4 = 60 days old seedling

Appendix 14: Effect of seedling number $hill^{-1}$ on plant height and total tiller $hill^{-1}$ before harvest of Boro rice, BRRI dhan29

Seedling Number/ hill	Plant height (cm)				No of tiller $plant^{-1}$			
	35 DAT	50 DAT	65 DAT	80 DAT	35 DAT	50 DAT	65 DAT	80 DAT
SN_1	37.42	49.75	58.98	67.96	6.72a	12.80b	23.15	17.07
SN_2	37.58	49.88	59.06	67.46	8.92a	17.13a	25.15	18.22
SN_3	38.21	50.74	57.45	69.31	8.60a	18.72a	25.22	18.78
s(x)	.38	.59	1.74	.95	.44	.52	.73	.47
level of sig.	NS	NS	NS	NS	**	**	NS	**
cv(%)	3.51	4.08	10.33	4.82	18.89	11.12	10.34	9.12

In a column, the means having same letter (s) do not differ significantly whereas, dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SN_1 = 02 seedling $hill^{-1}$
SN_2 = 04 seedling $hill^{-1}$
SN_3 = 06 seedling $hill^{-1}$

Appendix 15: Effect of interaction of seedling age x seedling number $hill^{-1}$ on plant height and total tiller $hill^{-1}$ before harvest of Boro rice, BRRI dhan 29

SA x SN	Plant height (cm)				No of tiller $plant^{-1}$			
	35 DAT	**50 DAT**	**65 DAT**	**80 DAT**	**35 DAT**	**50 DAT**	**65 DAT**	**80 DAT**
SA_1 x SN_1	32.67	45.70	56.70	62.75	5.40	14.67	28.60	19.60
SA_1 x SN_2	32.54	46.50	60.97	63.47	8.00	18.87	29.33	19.60
SA_1 x SN_3	32.22	46.35	56.05	63.59	8.93	20.13	25.87	19.27
SA_2 x SN_1	37.67	54.43	58.18	70.85	8.33	14.67	20.80	16.33
SA_2 x SN_2	36.39	50.42	61.12	69.93	10.67	19.73	23.53	17.47
SA_2 x SN_3	37.66	54.03	60.89	69.03	9.20	19.80	25.47	18.47
SA_3 x SN_1	36.57	53.05	60.36	67.63	6.87	13.07	20.93	14.00
SA_3 x SN_2	36.96	54.22	55.51	68.69	8.73	16.70	22.93	16.93
SA_3 x SN_3	37.73	53.25	50.60	69.56	8.13	20.00	24.73	17.67
SA_4 x SN_1	42.75	45.81	60.66	70.60	6.27	8.80	22.27	18.33
SA_4 x SN_2	44.41	48.39	58.65	67.74	8.27	13.20	24.80	18.87
SA_4 x SN_3	45.23	49.35	62.28	75.08	8.13	14.93	24.80	19.73
s(x)	.76	1.18	3.49	1.90	.88	1.04	1.46	.95
level of sig.	NS	NS	NS	NS	NS	NS	NS	NS
cv(%)	3.51	4.08	10.33	4.82	18.89	11.12	10.34	9.12

In a column, the means having same letter (s) do not differ significantly whereas, dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SA_1 = 30 days old seedling
SA_2 = 40 days old seedling
SA_3 = 50 days old seedling
SA_4 = 60 days old seedling

SN_1 = 02 seedling $hill^{-1}$
SN_2 = 04 seedling $hill^{-1}$
SN_3 = 06 seedling $hill^{-1}$

Appendix 16: Effect of seedling age on the yield and yield contributing characters of Boro rice cv. BRRI dhan29

Seedling Age	Plant height(cm)	No. of effective tiller $hill^{-1}$	No. of non effective tiller $hill^{-1}$	No. of total tiller $hill^{-1}$	Panicle length (cm)	No. of fertile spikelet $panicle^{-1}$	No. of sterile spikelet $panicle^{-1}$	No. of total spikelet $panicle^{-1}$	1000 grain wt.(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
SA_1	97.23a	12.80a	.02	12.82a	24.17a	107.9a	5049a	158.40	19.67	6.30a	6.77a	13.07ab	48.18a
SA_2	93.55a	13.20a	.00	13.20a	21.97b	106.7a	46.02a	152.71	20.44	6.77a	7.32a	14.09a	48.03a
SA_3	92.46a	11.58ab	.02	11.60ab	22.04b	125.2a	45.11a	170.31	19.89	6.09b	7.18a	13.28a	45.90a
SA_4	94.52a	10.56b	.07	10.62b	22.83ab	93.76a	68.87a	162.69	19.56	5.28b	6.69a	11.99b	44.03a
S(X)	.93	.40	.03	.40	.30	5.06	4.15	6.90	.34	.12	.11	.17	.57
level of sig.	**	**	NS	**	**	**	**		NS	**	**	**	**
cv(%)	2.95	9.19	374.26	9.09	3.89	14.01	23.68	12.86	5.08	5.86	4.61	3.80	3.69

In a column, the means having same letter (s) do not differ significantly whereas, dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SA_1 = 30 days old seedling
SA_2 = 40 days old seedling
SA_3 = 50 days old seedling
SA_4 = 60 days old seedling

Appendix 17: Effect of seedling number hill^{-1} on the yield and yield contributing characters of boro rice cv. BRRI dhan29

Seedling Number/hill	Plant height(cm)	No. of effective tiller hill^{-1}	No. of non effective tiller hill^{-1}	No. of total tiller hill^{-1}	Panicle length (cm)	No. of fertile spikelet panicle^{-1}	No. of sterile spikelet panicle^{-1}	No. of total spikelet panicle^{-1}	1000 grain wt.(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
SN_1	96.64a	12.38a	.00	12.38a	23.46a	116.97	44.53a	161.50	20.17	6.28a	6.96	13.23a	47.25a
SN_2	94.17a	13.02a	.02	13.04a	22.74a	107.27	52.07a	159.38	20.08	6.27a	7.01	13.29a	47.19a
SN_3	92.52a	11.45a	.07	11.52a	22.06a	100.93	61.27a	162.20	19.42	5.79a	6.99	12.80a	45.16a
S(X)	.80	.35	.03	.35	.26	4.38	3.60	5.98	.29	.10	.09	.14	.50
level of sig.	**	*	NS	*	**	NS	*	NS	NS	**	NS	*	**
cv(%)	2.95	9.19	374.26	9.09	3.89	14.01	23.68	12.86	5.08	5.86	4.61	3.80	3.69

In a column, the means having same letter (s) do not differ significantly whereas, dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

NS= Not significant
* Significant at 5% level
** Significant at 1% level

SN_1 = 02 seedling hill^{-1}
SN_2 = 04 seedling hill^{-1}
SN_3 = 06 seedling hill^{-1}

Appendix 18: Effect of interaction of seedling age x seedling number hill^{-1} on the yield and yield contributing characters of boro rice cv. BRRI dhan29

SA x SN	Plant height (cm)	No. of effective tiller hill^{-1}	No. of non effective tiller hill^{-1}	No. of total tiller hill^{-1}	Panicle length (cm)	No. of fertile spikelet panicle^{-1}	No. of sterile spikelet panicle^{-1}	No. of total spikelet panicle^{-1}	1000 grain wt.(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
SA_1 x SN_1	98.43	12.40	0.00	12.40	25.18	112.60	36.87	149.47	20.00	6.58b	6.26d	12.84bc	51.14a
SA_1 x SN_2	97.78	12.93	0.00	12.93	23.99	111.20	49.60	160.80	19.33	6.49bc	7.02bc	13.51b	48.08bc
SA_1 x SN_3	95.48	12.07	0.07	12.14	23.33	99.93	65.00	164.93	19.67	5.83cde	7.03abc	12.85bc	45.30cdef
SA_2 x SN_1	95.73	12.67	0.00	12.67	22.63	126.73	35.33	162.07	20.33	7.39a	7.64a	15.03a	49.15ab
SA_2 x SN_2	92.80	13.47	0.00	13.47	21.87	92.33	45.27	137.60	20.67	6.54b	7.14ab	13.68b	47.81bc
SA_2 x SN_3	92.13	12.47	0.00	12.47	21.40	101.00	57.47	158.47	20.33	6.39bc	7.17ab	13.55b	47.13bcd
SA_3 x SN_1	95.27	11.67	0.00	11.67	22.11	133.67	35.60	169.27	20.33	6.16bcd	7.10abc	13.25bc	46.45bcde
SA_3 x SN_2	91.97	11.60	0.07	11.67	22.17	121.80	49.00	170.80	20.33	6.46bc	7.15ab	13.61b	47.45bcd
SA_3 x SN_3	90.16	9.47	0.00	9.47	21.83	120.13	50.73	170.87	19.00	5.68de	7.29ab	12.97bc	43.79ef
SA_4 x SN_1	97.13	9.80	0.00	9.80	23.90	94.88	70.33	165.21	20.00	4.99f	6.82bcd	11.81d	42.25f
SA_4 x SN_2	94.15	10.07	0.00	10.07	22.93	103.73	64.40	168.33	20.00	5.61def	6.74bcd	12.35cd	45.41cdef
SA_4 x SN_3	92.30	10.80	0.20	11.00	21.67	82.67	71.87	154.53	18.67	5.25ef	6.49cd	11.82d	44.42def
s(x)	1.61	0.70	0.06	0.70	0.51	8.77	7.19	11.95	0.58	0.21	0.19	0.29	0.99
level of sig.	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	*
cv(%)	2.95	9.19	374.26	9.09	3.89	14.01	23.68	12.86	5.08	5.86	4.61	3.80	3.69

Appendix 19: **Summary of the analysis of variance (mean square values) for the growth characters of rice (cv. BRRI dhan29) as affected by different methods of weeding**

Source of variation	Degree of freedom	Mean square values									
		Plant height (cm)					No of tillers $plant^{-1}$				
		35 DAT	50 DAT	65 DAT	80 DAT	At Maturity	35 DAT	50 DAT	65 DAT	80 DAT	At Maturity
Replication	2	3.620	0.377	2.471	0.616	0.896	0.051	0.620	1.282	0.180	2.212
Methods of Weeding	5	4.485**	4.755^{NS}	7.006*	9.853**	5.545**	0.541^{**}	4.155**	15.336**	4.000**	16.242**
Error	10	0.953	1.656	1.620	1.565	0.872	0.031	0.439	1.312	0.516	1.385
cv(%)		3.69	3.15	1.80	1.51	0.89	4.26	4.80	4.96	4.68	8.18

NS= Not significant
* Significant at 5% level
** Significant at 1% level

W_0= No weeding
W_1= One hand weeding
W_2= Two hand weeding

W_3= Rifit 500 EC @ 0.5 L ha^{-1}
W_4= Rifit 500 EC @ 1.0 L ha^{-1}
W_5= Rifit 500 EC @ 1.5 L ha^{-1}

Appendix 20: Summary of the analysis of variance (mean square values) for the yield and yield component of rice (cv. BRRI dhan29) as affected by different methods of weeding

Source of variation	Degree Of freedom	Mean square values									
		No. Of effective tiller hill-1	No. of non effective tiller $hill^{-1}$	No. Of Fertile Spikelet $panicle^{-1}$	No. Of Sterile Spikelet $panicle^{-1}$	No. Of Total Spekelet $panicle^{-1}$	1000 grain wt. (gm)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	2.220	0.002	126.187	41.829	169.802	1.056	0.040	1.022	0.687	20.644
Methods of Weeding	5	** 16.975	* 0.048	* 370.619	** 155.198	NS 220.958	NS 1.156	** 1.652	** 1.555	** 6.242	NS 2.177
Error	10	1.471	0.012	100.197	8.288	98.453	0.456	0.091	0.052	0.114	2.280
cv(%)		8.64	31.73	6.51	6.29	4.97	3.30	4.46	3.53	2.54	2.95

NS= Not significant
* Significant at 5% level
** Significant at 1% level

W_0= No weeding
W_1= One hand weeding
W_2= Two hand weeding

W_3= Rifit 500 EC @ 0.5 L ha^{-1}
W_4= Rifit 500 EC @ 1.0 L ha^{-1}
W_5= Rifit 500 EC @ 1.5 L ha^{-1}

Appendix 21: Effect of methods of weeding on plant height at different days after transplanting of rice (cv. BRRI dhan29)

Methods of Weeding	Plant height (cm)				
	35 DAT	50 DAT	65 DAT	80 DAT	At Maturity
W_0	25.00b	39.60	68.20b	79.67b	102.7b
W_1	25.80ab	41.47	70.40ab	84.13a	104.7ab
W_2	28.00a	42.23	71.70a	84.87a	106.4a
W_3	27.33ab	41.67	71.87a	82.40ab	105.7a
W_4	27.27ab	41.33	71.93a	83.20a	106.0a
W_5	25.40ab	39.07	69.47ab	83.40a	104.5ab
s(x)	0.56	0.74	0.73	0.72	0.54
level of sig.	**	NS	*	**	**
cv(%)	3.69	3.15	1.80	1.51	0.89

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
* Significant at 5% level
** Significant at 1% level

W_0= No weeding
W_1= One hand weeding
W_2= Two hand weeding

W_3= Rifit 500 EC @ 0.5 L ha^{-1}
W_4= Rifit 500 EC @ 1.0 L ha^{-1}
W_5= Rifit 500 EC @ 1.5 L ha^{-1}

Appendix 22: Effect of methods of weeding on total tiller hill^{-1} at different days after transplanting of rice (cv. BRRI dhan29)

Methods of Weeding	No of tiller plant^{-1}				
	35 DAT	**50 DAT**	**65 DAT**	**80 DAT**	**At maturity**
W_0	3.37c	11.87c	18.87b	13.53c	9.80c
W_1	4.10ab	12.80bc	22.73a	14.40bc	11.67bc
W_2	4.40ab	14.53ab	25.20a	16.53a	13.97ab
W_3	4.27ab	14.40ab	23.13a	16.20ab	14.66a
W_4	4.57a	14.67a	24.67a	15.40abc	14.53a
W_5	3.93b	14.53ab	23.90a	15.93ab	13.07ab
s(x)	0.10	0.38	0.66	0.41	0.55
level of sig.	**	**	**	**	**
cv(%)	4.26	4.80	4.96	4.68	7.34

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
* Significant at 5% level
** Significant at 1% level

W_0= No weeding
W_1= One hand weeding
W_2= Two hand weeding

W_3= Rifit 500 EC @ 0.5 L ha^{-1}
W_4= Rifit 500 EC @ 1.0 L ha^{-1}
W_5= Rifit 500 EC @ 1.5 L ha^{-1}

Appendix 23: Effect of methods of weeding on the yield and yield contributing characters of rice (cv. BRRI dhan29)

Methods of weeding	No. of effective tiller $hill^{-1}$	No. of non effective tiller $hill^{-1}$	No. of fertile spikelet $panicle^{-1}$	No. of sterile spikelet $panicle^{-1}$	No. of total spikelet $panicle^{-1}$	1000 grain wt.(g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
W_0	9.33c	0.47ab	131.1c	42.87b	173.97c	19.33	5.30b	5.15c	10.45c	50.73
W_1	11.40bc	0.27bc	143.9abc	47.20b	191.1ab	20.33	6.81a	6.20b	13.01b	52.25
W_2	13.67ab	0.30bc	154.2a	42.87b	197.07a	20.67	7.20a	6.66ab	13.87ab	51.96
W_3	14.33a	0.33abc	138.7bc	59.67a	198.37a	21.00	7.18a	6.86a	14.04a	51.19
W_4	14.00ab	0.53a	147.9ab	40.47b	188.37abc	20.33	7.22a	7.08a	14.30a	50.53
W_5	12.87ab	0.20c	139.0bc	41.47b	180.47bc	21.00	6.95a	6.94a	13.89ab	50.05
S(X)	0.55	0.06	3.16	1.66	3.15	0.39	0.17	0.13	0.19	0.87
level of sig.	**	*	**	**	**	NS	**	**	**	NS
Cv(%)	7.51	31.73	3.84	6.29	2.90	3.30	4.46	3.53	2.54	2.95

In a column, the means having same letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS= Not significant
* Significant at 5% level
** Significant at 1% level

W_0= No weeding
W_1= One hand weeding
W_2= Two hand weeding

W_3= Rifit 500 EC @ 0.5 L ha^{-1}
W_4= Rifit 500 EC @ 1.0 L ha^{-1}
W_5= Rifit 500 EC @ 1.5 L ha^{-1}