INFLUENCE OF POPULATION DENSITY ON GROWTH AND YIELD OF INBRED AND HYBRID BORO RICE

BY

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CERTIFICATE

This is to certify that the thesis entitled, "**INFLUENCE OF POPULATION DENSITY ON GROWTH AND YIELD OF INBRED AND HYBRID BORO RICE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **NOWALIN REZA,** Registration No. **04-01413** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Dr. Md. Hazrat Ali)
Research Supervisor
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Dated: 11-05-2011
Place: Dhaka, Bangladesh

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to April 2009 to study the influence of four levels of population density viz. 1, 2, 3 and 4 seedlings hill^{-1} on growth and yield of inbred (BRRI dhan28 and BRRI dhan29) and hybrid (BRRI hybrid dhan2 and ACI hybrid dhan2) *boro* rice. The experiment was laid out in two factors Randomized Complete Block Design with three replications. Results showed that *boro* rice varieties differed significantly in all growth and yield characters and hybrid dhan gave superior return in case of yield. Among the varieties ACI hybrid dhan2 produced the highest grain yield (7.66 t ha^{-1}). Two seedlings hill^{-1} gave the maximum tillers hill^{-1} (18.15), highest dry matter hill^{-1} (5.23 g), maximum effective tiller hill^{-1} (13.19), longest panicle (29.43 cm) and highest grain yield (6.63 t ha^{-1}) while one seedling hill^{-1} had the highest numbers of filled grains panicle^{-1} (85.90), maximum 1000 grain weight (23.50 g) and highest harvest index (47.46%). Interaction result showed that ACI hybrid dhan2 coupled with transplanting 2 seedling' hill^{-1} gave the highest grain yield (8.58 t ha^{-1}) while ACI hybrid dhan2 in combination with 1 seedling hill^{-1} gave the highest harvest index (50.14%).

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ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0}C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local variety
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MPCU	=	Mussorie phos-coated urea
MV	=	Modern variety
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
SCU	=	Sulphur coated urea
t ha^{-1}	=	Tons per hectare
UNDP	=	United Nations Development Program
Zn	=	Zinc

Chapter 1
Introduction

INTRODUCTION

Rice (*Oryza sativa*) is the most important food grain and life for more than half of the population in the world. More than 90 percent of the world's rice is grown and consumed in Asia. It is the grain that has shaped the cultures, diets, and economies of billions of people in Asia. For them, life without rice is simply unthinkable. Between now and 2020, about 1.2 billion new rice consumers will be added in Asia (IRRI, 2006). Feeding these people will require the greatest effort in the history of agriculture, especially rice production. Rice production systems make a vital contribution to the reduction of hunger and poverty in Bangladesh. Total rice production in Bangladesh was 10.32 million tons in the year 1975-76 when the country's population was only 79.90 millions and cultivated rice area was 10.32 million ha (BBS and DAE, 2007). However, the country is producing 34.28 million tons rice in the year of 2008-09, where *Boro* rice contributed more than 55% (18.5 million tons). From the analysis of the last few years data we found that its contribution in total rice production follows a increasing trend. Recently, the rate is increasing rapidly due to adoption of high yielding rice varieties, including modern rice cultivation technologies, improvement of irrigation facilities and applications of fertilizer and pesticides. But for continuing this production trend there should be proper management practices. HYV Boro rice production depends on a considerable part on it.

The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. As it is not possible to have horizontal expansion of rice area, rice yield unit^{-1} area should be increased to meet this ever-increasing demand of food in the country. The population of Bangladesh will increase to 173 million in 2020 which is 31 percent higher than the present level (FAO, 1998). The current level of annual rice production of around 545 million tons could be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 using less land indeed the great challenge in Asia (Dawe, 2003). A study showed that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management input (Beinroth *et al.*, 2001).

Bangladesh is one of the poor country of the world due to its dense population and threatened by floods and storms. In Bangladesh rice occupies 10.58 million hectares of land which is about 77 percent of the cultivated area (BBS, 2009). About 75% of the total cropped area and more than 80% of the total irrigated area of Bangladesh is planted to rice (Hossain and Deb, 2003) and there are three diverse growing seasons of rice namely aus, aman and boro. In Bangladesh boro rice occupies around 4.61 million hectares of land which is around 43.57 percent of the total rice cultivation area (BBS, 2008). Boro season give higher grain yield as the climatic conditions in the boro season are favorable for higher grain yield (Haque, 2004). So boro season is very important for our rice production. Our food security also largely depends on boro season production. So we have to give more emphasis in this season for increasing rice production.

Rice yield can be increased in many ways of them developing new high yielding variety and by adopting proper agronomic management practices to the existing varieties to achieve their potential yield is important. For developing the high yielding varieties. Japan initiated first breeding program in 1981 (Wang, 2001). IRRI also started super rice breeding program to give rise to 30% more rice yield (13-15 t ha^{-1}) than the current modern high yielding plant types (IRRI, 1993). Generally the yield of hybrid rice varieties is 10%-15% more than the improved inbred varieties. It has great potentiality for food security of poor countries where arable land is scarces population is expanding and labour is cheap. In our country BRRI has started breeding program for the development of super high yielding varieties with large panicles and high yield potentialities. Growth and yield of rice are strongly influenced by genotype as well as environmental factors (BRRI, 2003). The genetic potentiality of a rice variety is almost fixed, but grain yield can be increased by the manipulation of management practices and by growing rice in recommended season (BRRI, 1999).

Number of seedling(s) $hill^{-1}$ is an important factor for the growth and yield of rice. Optimal population density and leaf area influence the availability of sunlight and nutrients for growth and development. Competition within the hill is an integral part of the physical environment and the competition by neighbors often accentuate the complexity. Both the factors contribute to the determination of yield. Plasticity of the plant and the influence of competition by neighboring plants effects on yield (Donald, 1963). As growth proceeds, intra plant competition becomes progressively operative, until when flowering and seed setting occur. The load of panicles is as great as to lead to competition among the panicles themselves and thereby to reduce the efficiency of seed production in the individual inflorescence. Most of the farmers have the tendency to use access seedling $hill^{-1}$ but increasing number of seedling $hill^{-1}$ did not influence the grain yield up to a constant level, but decreased there after (Ghosh *et al.*, 1988). Grain yield was negatively correlated with increasing seedling hill^{-1} (Nakano and Mizushima, 1994). Seedlings hill^{-1} had no effect on panicles hill^{-1}, grains panicle^{-1} and grain yield (Shah *et al.*, 1991). Wen and Yang (1991) found that effective panicles, the number of grains panicle^{-1} and the 1000-grain weight were also higher with only one (1) seedling hill^{-1}. Obulamma *et al.* (2002) recorded the highest grain yield, crop growth rate and net assimilation rate from one seedling hill^{-1}. Panda *et al.* (1991) found that grain yield was highest with four (4) seedlings hill^{-1}. Biswas and Salokhe (2001) revealed similar yield of rice by planting 2-4 vegetative tillers hill^{-1}. Excess or less number of seedling hill^{-1} may badly affect the normal physiological activities (Miah *et al.*, 2004).

So the proposed study is designed to find out the variety under which population as well as which interaction is optimum for rice cultivation in inbred varieties BRRI dhan28 & BRRI dhan29 and hybrid varieties BRRI hybrid dhan2 & ACI hybrid dhan2 with the following objectives-

1. Identify the suitable *boro* rice varieties (Inbred/hybrid) that gives higher yield.
2. Identify the optimum plant population for higher yield.
3. Identify the optimum combination of variety& population density for higher yield.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Management practices have considerable effects on the growth and development of any crop particularly *boro* rice. Among these population density is the important factor in considering inbred and hybrid rice. Numerous studies have been performed evaluating the influence of population density on the performance of inbred and hybrid rice. Population density for higher yield in case of inbred and hybrid rice had been proved to be assessed. Under above circumstances the influences of population density on the growth and yield of inbred and hybrid rice have been reviewed in this chapter under the following headings-

2.1 Influence of population density on growth and yield of rice

2.1.1 Effect on growth character

2.1.1.1 Plant height

Hushine (2004) reported that number of seedling hill^{-1} significantly influenced all the growth parameters except plant height. Miah *et al.* (2004) carried out an experiment to determine the effects of planting rate of 1, 2, 3 or 4 seedlings hill^{-1} on the yield and yield components of transplanted rice cv. BINA dhan 4. Plant height was highest with planting of 1 and 2 seedlings hill^{-1}, respectively.

Faruque (1996) reported that plant height increased with the increased number of seedling(s) hill^{-1}.

Shah *et al.* (1991) reported that plant height increased with decrease in seedling number hill^{-1}.

2.1.1.2 Tillering pattern

Inaba and Kitano (2005) reported on tiller production of rice plants (cv. Kinuhikari) transplanted at different seedling numbers $hill^{-1}$ (1, 3, 5, 7 and 9 seedlings $hill^{-1}$) in Japan. Tillering duration decreased with increasing number of seedlings $hill^{-1}$ (density), and that in the 9-seedling hills was two weeks shorter than that in the 1-seedling hills. The higher the seedling density, the earlier was the time of tillering. In 1 to 5-seedling hills, the tiller production rate increased with increasing seedling density, but the rate decreased in the hills with higher seedling densities.

Shrirame *et al.* (2000) carried out a field experiment during the kharif 1996 in Nagpur, Maharashtra, India on rice cv. TNRH10, TNRH13 and TNRH18 grown at 1, 2 or 3 seedlings $hill^{-1}$ and found that two seedlings $hill^{-1}$ gave significantly higher number of tillers $hill^{-1}$ than three seedlings $hill^{-1}$.

Hossain and Haque (1990) reported that the number of basal tillers $plot^{-1}$ increased with increasing seedling number.

Hussain *et al.* (1989) carried out an experiment with rice cv. Baspati and observed that the number of tillers increased upto 16.4 $hill^{-1}$ with increasing number of seedlings $hill^{-1}$.

Patniswamy and Gomez (1976) reported that number of total tillers $hill^{-1}$ increased with increasing number of seedlings $hill^{-1}$.

2.1.1.3 Leaf area index and total dry matter production

Masum *et al.* (2008) found that four seedlings $hill^{-1}$ had the highest numbers of leaf area index and total dry matter.

Miah *et al.* (2004) reported that leaf area index and total dry matter were highest with the planting of 4 seedlings hill^{-1}.

Obulamma *et al.* (2002) carried out an experiment with hybrid rice DPRH-1 and APHR-2. The treatments were 4 spacings (15 x 10, 20 x 20, 15 x 15 and 20 x 15 cm^2) and 3 seedlings hill^{-1} (1, 2 and 3 seedlings hill^{-1}). One seedling hill^{-1} recorded the highest grain yield, while 3 seedlings hill^{-1} had the highest leaf area index and dry matter production.

2.1.2 Effect on yield contributing character

2.1.2.1 Effective tillers hill^{-1}

Baloch *et al.* (2006) initiated studies for two consecutive years to find out the effect of time of transplanting and seedlings hill^{-1} (1, 2, 3 or 4) on the productivity of rice in Dera Ismail Khan district of North West Frontier Province (NWFP), Pakistan. They reported that the maximum productive tillers (548.3 m^{-2}) were recorded with 4 seedlings hill^{-1} followed by 533.3 productive tillers m^{-2} with 3 seedlings hill^{-1} on the same date.

Park *et al.* (1998) stated that increasing plant density hill^{-1} increased total tiller numbers but decreased the proportion of effective tillers.

BINA conducted an experimenton the number of seedlings hill^{-1} of four rice varieties of aus rice viz.: Iratom24, Iratom38, BR3 and Pajam with, use the number of seedling hill^{-1} as 1, 2, 3 and 4. It was found that the number of effective tillers hill^{-1} increased progressively from 1 seedling hill^{-1}, seedlings number 2, 3 and 4 seedlings gave statistically same effective tillers hill^{-1} (BINA, 1987).

Islam (1980) conducted an experiment to determine the suitable number of seedling $hill^{-1}$ for transplanting aman rice cv. Nizershail, Tilackchari and Badshabog. The results revealed that 2-3 seedlings $hill^{-1}$ were as good as 3-4 seedlings $hill^{-1}$ with respect to effective tillers $hill^{-1}$ production.

2.1.2.2 Panicle length, filled grains panicle $^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage, 1000-grain weight

Hasanuzzaman *et al.* (2009) reported that 4 seedlings $hill^{-1}$ produced the highest number of panicles $hill^{-1}$ whereas single seedling produced maximum values of panicle length, no of spikelets $hill^{-1}$ and 1000-grain weight.

Wang *et al.* (2006) reported that planting of one seedling $hill^{-1}$ was suitable for hybrids, whereas planting of 3 seedlings $hill^{-1}$ was suitable for conventional cultivars.

Pariyani and Naik (2004) reported that planting one or two seedlings $hill^{-1}$ did not show significant variations in yield attributes like panicle length, filled grains, sterile spikelets, 1000-grains weight of rice.

Karmakar *et al.* (2002) showed that number of effective tillers $hill^{-1}$ and straw yield were the highest with 6 seedlings $hill^{-1}$ while panicle length, grains $panicle^{-1}$ were the highest with 2 seedlings $hill^{-1}$ in case of late transplant *aman* rice.

Bisht *et al.* (1999) conducted a field experiment on hybrid variety PRH1 transplanting with 1, 2 and 3 seedlings $hill^{-1}$ and reported that number of panicles and total spikelets increased with 2 or 3 seedlings $hill^{-1}$. Rajarathinam and Balasubramaniyan (1999) found that the planting one seedling $hill^{-1}$ gave similar results to planting 2 seedlings $hill^{-1}$ in respects of yield parameters viz. panicles m^{-2}, panicle weight and length, grains $panicle^{-1}$, filled grains $panicle^{-1}$, filled grain percentage and 1000-grain weight of hybrid rice cv. CORH-2.

Ghosh *et al.* (1998) observed that panicles m^{-2} increased but grains $panicle^{-1}$ and panicle weights were decreased with increasing seedlings $hill^{-1}$.

Nakano and Mizushima (1994) elucidated the effect of the number of seedling $hill^{-1}$ on yield components and yield, rice plants cv. Nipponbare and Hourei, which were transplanted at three levels (1, 4, and 7) and two levels (4 and 7) of the seedling number $hill^{-1}$ in 1984 and 1985, respectively. In the higher seedling number $hill^{-1}$ the number of filled grains $panicle^{-1}$ and the percentage of filled grain were smaller. The 1000-grains-weight was not affected by the seedling number $hill^{-1}$.

Wen and Yang (1991) reported that late rice yields in a double cropping system were higher with 1 seedling $hill^{-1}$ than with 4 seedlings $hill^{-1}$. The proportion of effective panicle, the number of grains $panicle^{-1}$ and 1000 grain weight were also higher with only 1 seedlings $hill^{-1}$.

Singh (1990) observed that panicle $hill^{-1}$ and grain $panicle^{-1}$ increased with increase seedlings $hill^{-1}$, but panicle length, filled spikelets $panicle^{-1}$ and seed size decreased.

Rameswamy *et al.* (1987) reported that increasing number of seedlings $hill^{-1}$ had an adverse effect on yield parameters of rice. All yield parameters were reduced with more than two seedlings $hill^{-1}$. Singh *et al.* (1987) conducted an experiment with seed rate in nursery and seedlings $hill^{-1}$ on yield of transplanted rice. They found that grains $panicle^{-1}$ and number of seedlings $hill^{-1}$ had no significant effect. Akita (1978) conducted an experiment with (a) 4, (b) 16, (c) 25 or (d) 49 tillers m^{-2}. Results of number of panicles, glumous spikelets and grain and paddy weight $hill^{-1}$ decreased in the order of (a)> (b)> (c)> (d). Maximum values of this parameters m^{-2} were obtained in (c). Numbers of glumous spikelets $panicle^{-1}$ decreased in the order of (a)> (d)> (c)> (b). Percentage of ripened grains was 90, 92, 90 and 78 % in (a), (b), (c) and (d) respectively.

2.1.3 Effect on grain yield and Straw yield

Masum *et al.* (2008) conducted a field experiment at the experimental field of Sher-e-Bangla agricultural university during July to December 2007 to find out the effect of four levels of seedling $hill^{-1}$ *viz.*; 1, 2, 3 and 4 and two forms of nitrogen fertilizer-prilled urea (PU) and urea supergranules (USG) on growth, yield and yield components of modern (BRRI dhan44) and traditional (Nizershail) transplant *aman* rice. Results showed that two seedlings $hill^{-1}$ gave the highest grain yield (3.96 t ha^{-1}).

Baloch *et al.* (2006) also reported that among seedlings $hill^{-1}$ highest paddy yield and net return with 1 seedling $hill^{-1}$. It explains that the use of more seedlings $hill^{-1}$ not only adds to cost but is also a mere wastage of natural resources. Nayak *et al.* (2006) studied on the effect of planting varying number of seedlings $hill^{-1}$ (1, 2 and 3 seedlings $hill^{-1}$) on yield components as well as yield of 3 hybrid cultivars (Pro-Agro6201, CNHR-3 and PAC-801) and one high-yielding cultivar (Khitish) of rice. The hybrid cultivars exhibited better performance in terms of yield components and yield at 2 seedlings $hill^{-1}$ than at one seedling $hill^{-1}$ but there was no yield advantage by planting 3 seedlings $hill^{-1}$ over 2 seedlings $hill^{-1}$. Khitish performed better at 3 seedlings $hill^{-1}$ than at 1 or 2 seedlings $hill^{-1}$.

Zhang *et al.* (2004) conducted a field experiment with III You 98 (sown on 11 May 2002) in Hefei, Anhui, China. The effects were investigated of different transplanting densities and number of seedlings $hill^{-1}$ (1 and 2) on some agronomic traits and grain yield-related indices. Although differences in plant height, panicle length and 1000-grain weight were insignificant but extremely significant differences in grain yield were noted. Crop management including reasonably close planting and 2 seedlings $hill^{-1}$ resulted in relatively high grain yield. For yields of more than 10.0 t ha^{-1}, the transplanting density should be 281300 hills ha^{-1} at 2 seedlings $hill^{-1}$ or 365800 hills ha^{-1} at 1 seedling $hill^{-1}$.

Rajesh and Thanunathan (2003) conducted an experiment on traditional Kambanchamba rice variety in Tamil Nadu, India, during the 2000/01 samba season. The seedling age (30, 40 and 50 days), number of seedlings (2 and 4 seedlings $hill^{-1}$) and spacing (20x15, 20x10 and 15x15 cm) were tested. Planting of 2 seedlings $hill^{-1}$ recorded the maximum grain yield of 2.85 and 2.65 t ha^{-1} in experiments I and II, respectively.

Dongarwar *et al.* (2002) carried out an experiment with hybrid rice KJTRH-1 with 3 spacing (20 x 20, 20 x 15 and 20 x 20 cm^2) and 2 levels of seedlings (1 and 2 seedlings $hill^{-1}$) were tested. Irrespective of spacing treatments planting of one seedling $hill^{-1}$ was on at par with planting of two seedlings $hill^{-1}$ in respect of grain yield. Islam *et al.* (2002) conducted an experiment with fine rice cv. Kalizira including three hill densities viz.; 25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm and two levels of seedlings $hill^{-1}$ viz.; 2 seedlings $hill^{-1}$ and 4 seedlings $hill^{-1}$. The highest grain yield was recorded form 25 cm x 20 cm spacing and 2 seedlings $hill^{-1}$.

Kabir (2002) carried out an experiment to find out the effect of variety and number of seedlings $hill^{-1}$ on yield and yield contributing characters of *boro* rice. The experiment comprised of three varieties viz.; Sonar Bangla 1, BINA dhan 5 and BINA dhan 6 and four different numbers of seedlings $hill^{-1}$ viz.; 1, 2, 3 and 4 seedlings $hill^{-1}$. Number of seedlings differed significantly in respect of growth characters and yield attributes. The highest grain yield (5.37 t ha^{-1}) was obtained from 2 seedlings $hill^{-1}$ and lowest grain yield (4.58 t ha^{-1}) was obtained from single seedling $hill^{-1}$ which was statistically similar to 3 seedlings $hill^{-1}$ (4.77 t ha^{-1}) and 4 seedlings $hill^{-1}$ (4.35 t ha^{-1}). The highest straw yield (6.52 t ha^{-1}) was obtained from 2 seedlings $hill^{-1}$ and the lowest one (5.11 t ha^{-1}) was obtained from 4 seedlings $hill^{-1}$.

Molla (2001) reported that seedlings $hill^{-1}$ significantly influenced the number of tillers, mature panicles m^{-2} and rice yield. Two seedlings $hill^{-1}$ had significantly higher yield than one seedling, including other parameters, in hybrids. For HYV, no significant response was obtained by increasing the number of seedlings from 3 to 6.

Shrirame *et al.* (2000) reported that one seedling $hill^{-1}$ gave significantly higher harvest index (HI) but grain yield were not affected by seedlings number $hill^{-1}$. Srivastava and Tripathi (2000) carried out an experiment where rice cv. Hybrid

6201 and R 320-300 were grown at 20 cm x 15 cm or 15 cm x 10 cm spacing at 1, 2 and 3 seedlings hill^{-1} and observed that cv. R 320-300 grown at the 15 cm x 10 cm spacing at 2 seedlings hill^{-1} produced the highest grain yield of 7.59 t ha^{-1}.

Experiment was conducted at BRRI to find out the effect of seedling number on the panicle production and yields of a local variety Kumragoin transplanting at 1, 3, 6 and 9 seedlings hill^{-1}. The results revealed that panicle and grain yield did not differ significantly due to seedling number hill^{-1} (BRRI, 1999). Srinivasulu *et al.* (1999) conducted an experiment on rice hybrids APHR-1 and APHR-2 and the conventional variety Chaitanya, planted with 1 or 2 seedlings hill^{-1} and found that planting of two seedlings hill^{-1} of Chaitanya recorded significantly higher grain yield than one seedling hill^{-1} but in case of hybrids both the treatments were at par.

Asif *et al.* (1997) conducted an experiment with rice cv. Basmati 385 grown at 1, 2 or 3 seedlings hill^{-1} and observed that grain yield was highest at 2 seedlings hill^{-1}. Banik *et al.* (1997) conducted 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 and 8 seedlings hill^{-1}. They reported that yield was the highest with 4 seedlings hill^{-1} (4.22 t ha^{-1}).

Paraye and Kandalkar (1994) conducted an experiment with 3 rice cultivars and showed that similar grain yields were obtained from planting 3 or 6 seedlings hill^{-1}.

Experiment was conducted at BINA with the number of seedlings hill^{-1} of three rice varieties in *boro* season viz.; Iratom 24, BR14 and BR3 and three number of seedlings hill^{-1} viz.; 1, 2 and 3 seedlings hill^{-1}. It was found that number of seedlings hill^{-1} produced significant effect on filled grains panicle^{-1} and significant higher yield by planting 4-5 seedlings hill^{-1} compared to 2-3 seedlings hill^{-1} (BINA, 1993). Chowdhury *et al.* (1993) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield components of rice cv. BR23 and Pajam during the *aman* season. They reported that 6 seedlings hill^{-1} gave the highest grain and straw yields. Rao and Reddy (1993) conducted a field experiment with rice cv. Rasi in the Kharif (Monsoon) season at 33, 44, 50, 67 and 200 hills m^{-2} with 1, 2, 4, 6 and 8 hill^{-1}. They reported that grain yield increased with decreasing spacing from 33-200 hills m^{-2} with 1 seedling hill^{-1}, when 10 seedlings hill^{-1} were planted yield decreased at the widest spacing.

An experiment was conducted at BRRI with a local variety Kumaragoir at 25 cm x 15 cm and 25 cm x 45 cm spacing and 1, 3, 6 and 9 seedlings hill^{-1}. The results showed that with any spacing, seedling mortality decreased markedly with an increase in the number of seedlings hill^{-1}, but spacing appraised to have no marked effect on seedling mortality. The number of panicles m^{-2} was generally greater with a closer spacing and fewer seedlings hill^{-1}. As regards yield, it was interesting about the same for all the spacing number combinations (BRRI, 1992). Prasad *et al.* (1992) conducted an experiment with 2, 3, 4 and 5 seedlings hill^{-1} to study their effect on yield and yield components of rice cv. Sarjoo-52 and found that for all factors 4 seedlings hill^{-1} were better for grain yield. Singh and Singh (1992) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield and yield components of rice cv. Madhukar and found that for all factors 4 seedlings hill^{-1} were better for grain yield.

BRRI (1991) conducted another study to find out the effect of seedling number (2, 3, 4 and 5 seedlings hill^{-1}) on the grain yield and yield components of BR3, BR9 and BR14. The results showed that there was no significant effect of seedling number on the yield of BR3 and BR14. Planting of 4-5 seedlings hill^{-1} gave significantly higher yield in BR9 than 2-3 seedlings hill^{-1} although such differences were not apparent in yield components.

BRRI (1990) conducted an experiment to find out the optimum plant population required for a satisfactory grain yield of rice both at Joydebpur and Habiganj at the combination of different plant spacing with 2-3 and 5-6 seedlings hill^{-1} and significantly the highest grain yield was obtained by using 5-6 seedling hill^{-1} in both the places . Increase in seedlings number from 2-3 to 5-6 seedling hill^{-1} produced grain yield in most cases. Zhang and Huang (1990) studied the effects of seedlings hill^{-1} of medium duration rice variety, transplanted at 1-5 seedlings hill^{-1} and found that 2 or 3 seedlings hill^{-1} gave best yield with increasing grain yield but harvest index were unaffected by the different number of seedlings hill^{-1}. On the other hand Budhar *et al.* (1989) observed paddy yield, yields in early maturing rice cv. CR666-18 grown with 2 or 4 seedlings hill^{-1} though the yield difference was not significant.

In an experiment of Karim *et al.* (1987), Nizershail was planted with 1, 2, 3, 4 and 5 seedlings hill^{-1} and observed that highest grain yield of Nizershail was obtained with 4 followed by 3 seedlings hiil^{-1} while 1 seedling hill^{-1} yielded the lowest.

Sarma *et al.* (1979) observed increased grain yield when seedling(s) $hill^{-1}$ was increased from 2 to 4 seedlings $hill^{-1}$.

Kang and Choi (1978) reported that rice cultivar Tongil when grown with 1, 3, 5 and 7 seedlings $hill^{-1}$, shortened the growth duration and increased the ripened grain ratio with increasing number of seedlings $hill^{-1}$. But the effect was not found significant in the early season. Increasing the number of seedlings $hill^{-1}$ increased grain yields in Tongil, especially in late-season crops but not in cv. Milyang 15. For early, 3-5 seedlings $hill^{-1}$ and for late 5-6 seedlings $hill^{-1}$ produced maximum yield.

Shahi and Gill (1976) observed that there was no significant difference in paddy yields of dwarf rice cultivar Jaya grown at a spacing of 20 cm X 20 cm or 15 cm X 15 cm with 1-4 seedlings $hill^{-1}$.Yield tended to be the highest at 20 cm X 20 cm and with 2 seedlings $hill^{1}$.

2.2 Influence of inbred and hybrid rice on growth and yield

2.2.1 Effect on growth characters

2.2.1.1 Plant height

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines of rice and showed that plant height differed significantly among the varieties and Pusa Basmati gave the highest plant height in each line.

Om *et al.* (1998) in an experiment with hybrid rice cultivars ORI 161 and PMS 2A x IR 31802 found taller plants, more productive tillers, in ORI 161 than in PMS 2A x IR 31802.

Miah *et al.* (1990) conducted an experiment where rice cv. Nizershail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizershail.

2.1.1.2 Tillering pattern

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2(KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded IR20. In IR20, the tiller number was higher than that of KRH2.

2.1.1.3 Leaf area index

Swain *et al.* (2006) evaluated in a field experiment the performance of rice hybrids NRH1, NRH3, NRH4, NRH5, PA6111, PA6201, DRRH1, IR64, CR749-20-2 and Lalat conducted in Orissa, India during 1999-2000. Among the hybrids tested, PA 6201 recorded the highest leaf area index.

2.1.1.4 Total dry matter production

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo regardless of plant density.

2.1.2 Effect on yield contributing characters

2.1.2.1 Effective tillers hill^{-1}

Devaraju *et al.* (1998) in a study with hybrid rice cultivar KRH2 and IR20 as a check variety having different levels of N from 0 to 200 kg N ha^{-1} found that KRH2 out yielded IR20 at all levels of N. The increased grain yield of KRH2 was mainly attributed to the higher number of productive tillers hill^{-1}.

2.1.2.2 Panicle length, filled grains panicle $^{-1}$, unfilled grains panicle^{-1}, filled grain percentage, 1000-grain weight

Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1}) on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Pandey and Awasthi (2001) studied genetic variability in 21 genotypes of aromatic rice for yield contributing traits. Significant genetic variability was observed among the 21 genotypes for the entire yield contributing traits. They concluded that panicle length, number of grains per panicle and test weight play a major role in the enhancement of production of grain yield.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of filled grains panicle^{-1} (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07g) and number of panicles m^{-2} than other tested varieties.

2.1.3 Effect on grain yield and straw yield

Swain *et al.* (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was at par with hybrid PA6201.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding cultivars (HYV) as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the best yield (7.0 t ha^{-1}).

Dongarwar *et al.* (2003) conducted an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and reported that KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains panicle^{-1} and greater seed weight.

Julfiquar *et al.* (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *boro* season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Julfiquar *et al.* (1998) also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during the *boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}. Rajendra *et al.* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields of Pusa 834 and Pusa HR3 were 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively.

Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced an average yield of 7.1 t ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9.

Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih. Chandra *et al.* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025Ax 1R35366-62-1-2-2-3R.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to April 2009 to study the influence of population density on growth and yield of inbred and hybrid *boro* rice. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

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

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix I.

3.1.3 Climate

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

3.2 Test crops

BRRI dhan28, BRRI dhan29, BRRI hybrid dhan2 and ACI hybrid dhan2 was used as the test crop in this experiment. Among the variety BRRI dhan28, BRRI dhan29, BRRI hybrid dhan2 was developed at the Bangladesh Rice Research Institute. It is recommended for *boro* season and ACI hybrid dhan2 was developed by private organization ACI company Ltd. Incase of BRRI dhan28 it takes 130-140 days for maturity & gives an average grain yield of $5tha^{-1}$. Incase of BRRI dhan29 it takes155-160 days for maturity & gives an average grain yield of$7.5tha^{-1}$. Incase of BRRI hybrid dhan2 it takes 140-150 days for maturity & gives an average grain yield of $8.5tha^{-1}$. Incase of ACI hybrid dhan2 it takes 150-160 days for maturity & gives an average grain yield of $8.5tha^{-1}$.

3.3 Experimental details

3.3.1 Treatments

The experiment comprised as two factors.

Factor A: Inbred and hybrid- 4 (2 inbred and 2 hybrid)

i. V_1: BRRI dhan 28

ii. V_2: BRRI dhan 29

iii. V_3: BRRI hybrid dhan2

iv. V_4: ACI hybrid dhan2

Factor B: Population density- 4 levels

i. S_1: 1 seedling hill^{-1}

ii. S_2: 2 seedlings hill^{-1}

iii. S_3: 3 seedlings hill^{-1}

iv. S_4: 4 seedlings hill^{-1}

Therefore there were 16 (4 × 4) treatment combinations viz. V_1 S_1, V_2S_1, V_3S_1, V_4S_1, V_1S_2, V_2 S_2, V_3S_2, V_4S_2, V_1S_3, V_2S_3, V_3 S_3, V_4S_3, V_1S_4,V_2S_4,V_3S_4 andV_4S_4.

3.3.2 Experimental design and layout

The experiment was laid out in two factors Randomized Complete Block Design with three replications. The layout of the experiment was done for distributing the combination of population density and variety of rice. There were 16 plots of size 4 m × 3 m in each of 3 replications. The 16 treatment combination of the experiment was assigned at random into 16 plots of each replication (Figure 1).

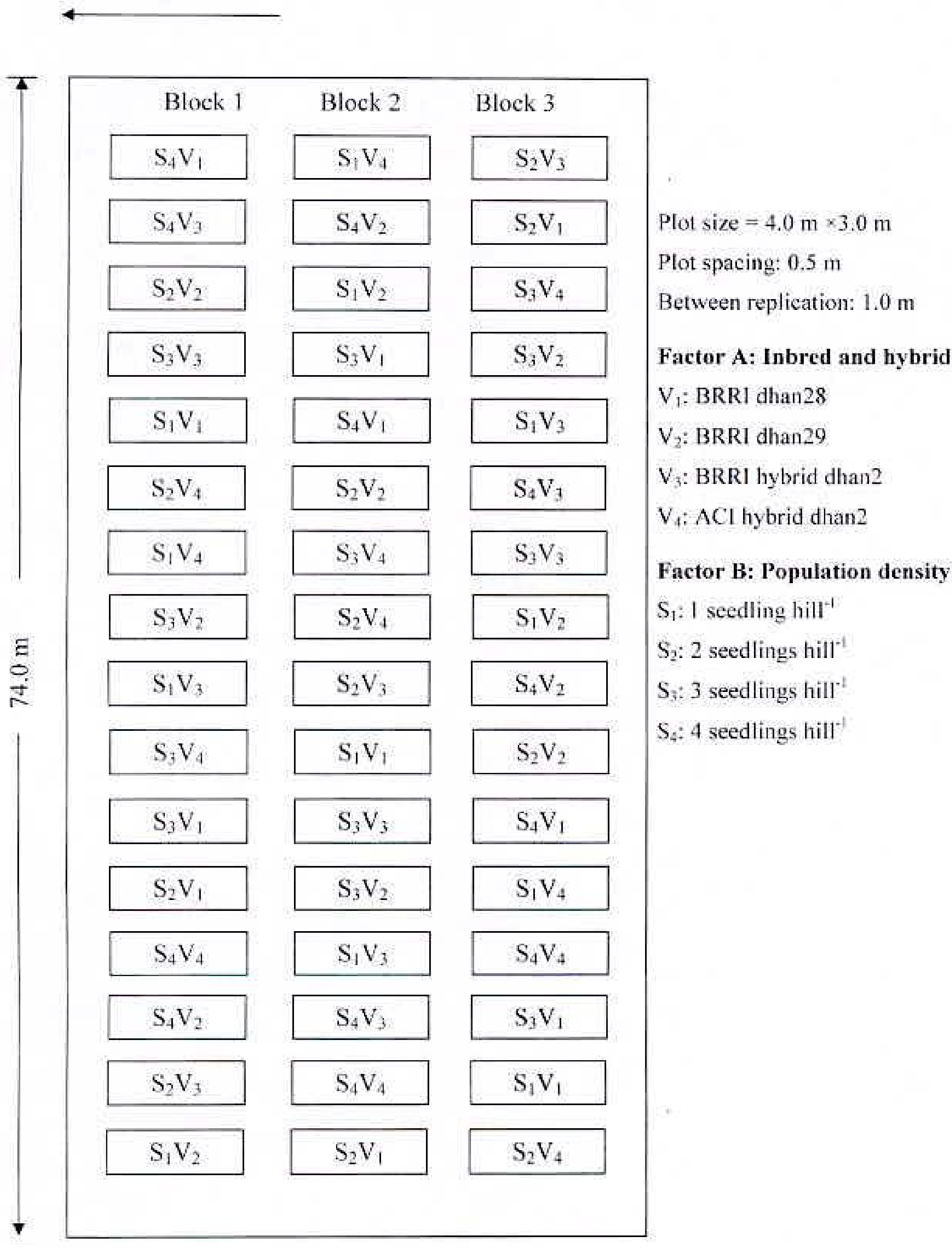


Figure 1. Field layout of two factors experiment in the Randomized Complete Block Design (RCBD)

3.4 Growing of crops

3.4.1 Raising of seedlings

3.4.1.1 Seed collection

The seeds of the BRRI d13.0 m, BRRI dhan29, BRRI hybrid dhan2 were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur and ACI hybrid2 were collected from local ACI seed dealer.

3.4.1.2 Seed sprouting

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

3.4.1.3 Preparation of seedling nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 4 December, 2008 in order to transplanting the seedlings in the main field.

3.4.2 Preparation of the main field

The plot selected for the experiment was opened in the last week of December 2008 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable soil condition for transplanting of seedlings.

3.4.3 Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, Gypsum and borax, respectively were applied. One third of urea and entire amount of TSP, MP, Gypsum, Zinc sulphate and borax were applied during the final land preparation. Rest of urea was applied in two equal installments at tillering and panicle initiation stage. The dose and method of application of fertilizer are shown in Table 1.

Table 1. Dose and method of fertilizers application in rice field

Fertilizers	Dose (kg/ha)	Application (%)		
		Basal	1st installment	2nd installment
Urea	160	33.33	33.33	33.33
TSP	100	100	--	--
MP	100	100	--	--
Gypsum	60	100	--	--
Borax	10	100	--	--

Source: Adunik Dhaner Chash, BRRI, Joydebpur, Gazipur

3.4.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 4 January 2009 for transplant on the date of 5 January 2009 without causing much mechanical injury to the roots.

3.4.5 Transplanting of seedlings in the field

On the scheduled dates as per experiment the rice seedlings were transplanted in lines each having a line to line distance of 25cm and plant to plant distance 15 cm in the well prepared plot.

3.4.6 After care

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

3.4.6.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.4.6.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT).

3.4.6.3 Weeding

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

3.4.6.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments. The fertilizers were applied uniformly in broadcast method.

3.4.6.5 Plant protection

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

3.5 Sample collection

Sample was collected from the centre 2 m^2 of each plot crop which was harvested depending upon the maturity of plant by manually.

3.6 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done from the centre 2 m^2 of each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice grain. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.7 Data recording

3.7.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 45, 60, 75 DAT (Days after transplanting) and at harvest. Data were recorded as the average of 10 plants selected at random out side the effective harvesting area of each plot. The height was measured from the ground level to the tip of the tiller.

3.7.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of 30, 45, 60 and75 DAT by counting total tillers. Data were recorded as the average of 10 hills selected at random from the pre selected hills of each plot.

3.7.3 Leaf area index

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

3.7.4 Dry matter plant^{-1}

Total dry matter plant^{-1} was recorded at 30, 45, 60, 75DAT and at harvest by drying plant sample. Data were recorded as the average of 10 sample hill^{-1} selected at random from the out side the effective harvesting area of each plot and it was expressed in gram.

3.7.5 Effective tillers hill^{-1}

The total number of effective tiller hill^{-1} was counted as the number of panicle bearing hill plant^{-1}. Data on effective tiller hill^{-1} were counted from 10 selected hills at harvest and average value was recorded.

3.7.6 Non-effective tillers hill^{-1}

The total number of non effective tillers hill^{-1} was counted as the number of non panicle bearing tillers plant^{-1}. Data on non effective tiller hill^{-1} were counted from 10 selected hills at harvest and average value was recorded.

3.7.7 Total tillers hill^{-1}

The total number of tillers hill^{-1} was counted by adding effective and non-effective tillers hill^{-1}. Data on total tiller hill^{-1} were counted from 10 selected hills at harvest and average value was recorded.

$$\text{Total tillers hill}^{-1} = \text{Effective tillers hill}^{-1} + \text{Non-effective tillers hill}^{-1}$$

3.7.8 Length of panicle

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

3.7.9 Filled grain panicle^{-1}

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

3.7.10 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from 10 randomly selected plants of a plot on the basis of not grain in the spikelet and then average number of unfilled grains panicle^{-1} was recorded.

3.7.11 Total grains panicle^{-1}

The total number of grains was recorded by adding filled and unfilled grains from selected 10 plants of a plot on the basis and then average number of total grains panicle^{-1} was recorded.

$$\text{Total grains panicle}^{-1} = \text{Filled grains panicle}^{-1} + \text{Unfilled grains panicle}^{-1}$$

3.7.12 Weight of 1000 seeds

One thousand seeds were counted randomly from the total cleaned harvested seeds of each individual plot and then weighed in grams at 14% of moisture and recorded.

3.7.13 Grain yield

Grains obtained from 2 m^2 of each unit plot were sun-dried and weighed carefully and finally converted to t ha^{-1}.

3.7.14 Straw yield

Straw obtained from 2 m^2 of each unit plot were sun-dried and weighed carefully and finally converted to t ha^{-1}.

3.7.15 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.7.16 Harvest index

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

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

3.8 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

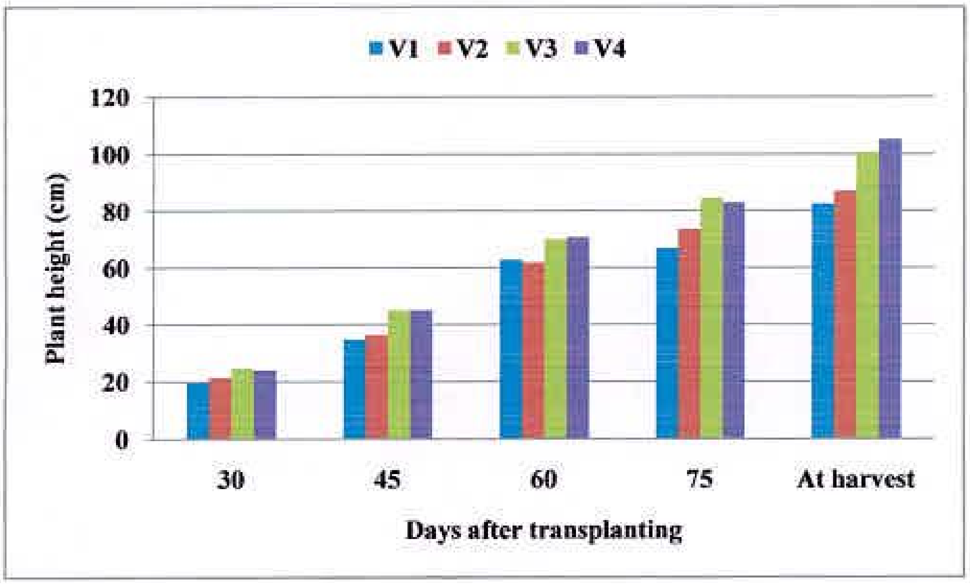
RESULTS AND DISCUSSION

The experiment was conducted to determine the influence of population density on growth and yield of inbred and hybrid *boro* rice. Data on different growth parameter, yield attributes and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-IV. The results have been presented with the help of graphs and table and possible interpretations given under the following headings:

4.1 Plant height

4.1.1 Effect of variety

Different inbred and hybrid *boro* rice showed significant differences on plant height at 30, 45, 60 and 75 DAT and at harvest (Figure 2 & Appendix III). At 30 DAT, the longest plant (24.77 cm) was observed from V_3 (BRRI hybrid dhan2)



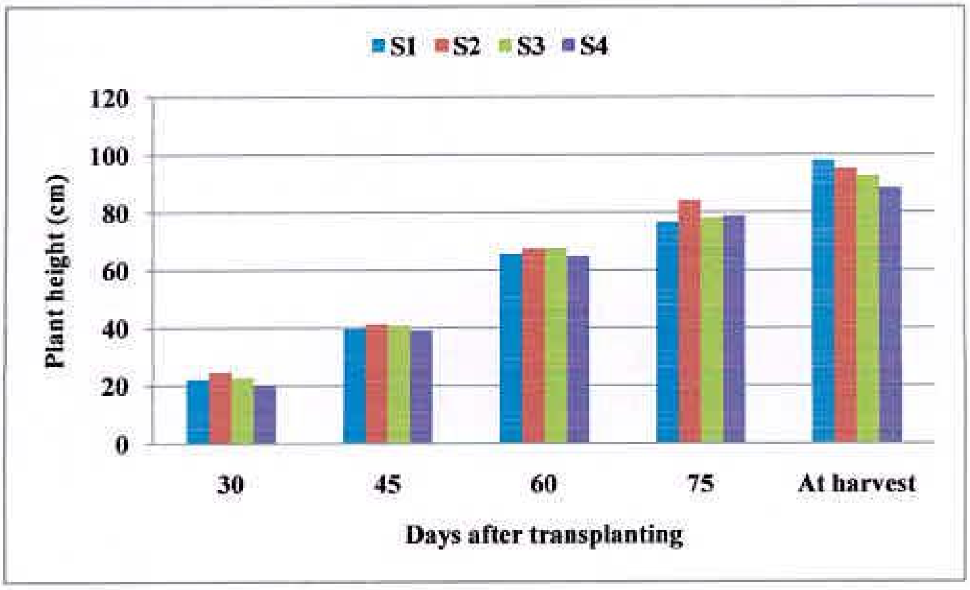
Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2

Figure 2. Effect of variety on plant height of *boro* rice at different days after transplanting ($LSD_{0.05}$=1.262, 3.115, 4.529, 4.155, 4.443 at 30, 45, 60 and 75 DAT and at harvest)

which was statistically identical (24.04 cm) with V_4 (ACI hybrid dhan2) and closely followed (21.41 cm) by V_2 (BRRI dhan29), and the shortest (19.65 cm) from V_1 (BRRI dhan28). At 45 DAT, the longest plant was observed from V_3 (45.05 cm) which was to by V_4 (45.05 cm) and the shortest plant was obtained from V_1 (34.35 cm) which was statistically similar with V_2 (36.36 cm). At 60 DAT, the longest plant was recorded in V_4 (70.75 cm), which was statistically identical with V_3 (70.15 cm) and the shortest plant was obtained from V_2 (61.86 cm) which was statistically similar with V_2 (61.86 cm). At 75 DAT, the longest plant was observed from V_3 (84.40 cm), which was statistically identical with V_4 (82.98 cm) and the shortest plant from V_1 (66.75 cm) which was followed by V_2 (73.67 cm). At harvest, the longest plant was observed from V_4 (105.1cm) and the shortest plant from V_1 (82.47 cm). Different inbred and hybrid produces different plant height on the basis of their varietal characters. Srivastava and Tripathi (2000) expressed remarkable superiority in case of hybrid over inbred cultivars by increased growth parameters. Probably the genetic make up of varieties was responsible for the variation in plant height. This confirms the reports Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

4.1.2 Effect of population density

Plant height of *boro* rice showed significant differences at 30, 75 DAT and harvest due to population density (Figure 3 & Appendix III). At 30 DAT, the longest plant (24.70 cm) was recorded from S_2 (2 seedlings hill^{-1}) which was closely followed (22.84 cm and 22.14 cm) by S_3 (3 seedlings hill^{-1}) and



Note: V_1: S_1: 1seedling $hill^{-1}$, S_2: 2 seedlings $hill^{-1}$, S_3: 3 seedlings $hill^{-1}$, S_4: 4 seedlings $hill^{-1}$

Figure 3. Effect of population density on plant height of *boro* rice at different days after transplanting ($LSD_{0.05}$=1.262, 3.115, 4.529, 4.155, 4.443 at 30, 45, 60 and 75 DAT and at harvest)

S_1 (1 seedlings $hill^{-1}$), while the shortest plant (20.18 cm) was observed from S_4 (4 seedlings $hill^{-1}$). At 45 DAT, the longest plant was obtained from S_2 (41.30 cm) whereas the shortest plant was found from S_4 (39.08 cm). At 60 DAT, the longest plant was recorded from S_2 (67.50 cm) while the shortest plant was recorded from S_4 (64.96 cm). At 75 DAT, the longest plant was recorded from S_2 (84.17 cm) which again, the shortest plant was found from S_4 (68.86 cm). At harvest, the longest plant was observed from S_1 (98.93 cm) which was closely followed by S_2 (95.31 cm) and S_3 (92.69 cm), while the shortest plant was recorded from S_4 (88.36 cm). The above mentioned results revealed that population density had significant effect on plant height. Probably 1 seedlings $hill^{-1}$ ensured the favorable condition for growth of *boro* rice with optimal sharing of light, temperature, nutrients etc. and the ultimate results is the tallest plant than the others population density under the trial. Masum *et al.* (2008), Miah *et al.* (2004) and Shah *et al.* (1991) who stated that plant height increased with decrease in seedling number $hill^{-1}$.

4.1.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety showed significant differences on plant height at 30 and 75 DAT (Table 2). At 30 DAT, the longest plant (28.51 cm) was recorded from the treatment combination of V_3 S_2 (2 seedlings $hill^{-1}$ with BRRI hybrid dhan2), whereas, the shortest (18.50 cm) was found from the treatment combination of V_1S_3 (3 seedlings $hill^{-1}$ with BRRI dhan28). At 45 DAT, the longest plant was recorded from the treatment combination of V_3S_3 (46.20 cm) and the shortest from the treatment combination of V_1 S_4 (32.80). At 60 DAT, the longest plant was recorded from the treatment combination of V_3S_3 (72.70 cm) and the shortest from the treatment combination of V_2S_4 (57.33 cm). At 75 DAT, the longest plant was found from the treatment combination of V_3S_2 (98.10 cm) and the shortest from the treatment combination of V_3S_4 (63.92). At harvest, the longest plant was found from the treatment combination of V_4S_1 (109.3 cm) and the shortest from the treatment combination of V_1 S_4 (75.57 cm).

Table 2. Interaction effect of population density on plant height of inbred and hybrid *boro* rice

Treatments	Plant height (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
V_1S_1	19.30	34.00	64.00	68.38	86.27
V_1S_2	20.95	37.40	65.67	72.53	86.70
V_1S_3	24.92	33.20	59.80	84.77	81.37
V_1S_4	23.40	32.80	61.60	80.92	75.57
V_2S_1	21.01	35.33	60.70	69.08	93.90
V_2S_2	23.56	36.80	63.60	80.87	86.17
V_2S_3	28.51	38.00	65.80	98.10	87.93
V_2S_4	25.72	35.30	57.33	88.63	80.00
V_3S_1	18.50	44.00	68.60	64.90	106.3
V_3S_2	21.76	45.80	69.47	74.20	103.5
V_3S_3	27.11	46.20	72.70	90.82	98.47
V_3S_4	24.00	44.20	69.83	82.58	94.50
V_4S_1	19.78	45.00	69.33	64.65	109.3
V_4S_2	19.35	45.20	71.27	67.08	104.9
V_4S_3	18.53	46.00	71.33	63.92	103.0
V_4S_4	23.04	44.00	71.07	79.80	103.4
$LSD_{0.05}$	0.523	8.311	9.057	8.885	8.311
$S_{\bar{x}}$	0.8742	2.877	3.136	3.076	2.877
CV(%)	6.74	9.29	8.18	6.92	5.31

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

4.2 Number of total tillers hill^{-1}

4.2.1 Effect of variety

Different inbred and hybrid *boro* rice differed significantly in terms of number of tillers hill^{-1} at 30, 45, 60 and 75 DAT (Table 3). At 30 DAT, the maximum number of tillers hill^{-1} (4.48) was observed from V_3 (BRRI hybrid dhan2) which was statistically identical (4.23) with V_4 (ACI hybrid dhan2) and closely followed (4.23 cm) by V_2 (BRRI dhan29), and the minimum number (3.79) was found from V_1 (BRRI dhan28). At 45 DAT, the maximum number of tillers hill^{-1} was observed from V_3 (9.21) which was statistically identical with V_4 (9.02) and V_2 (8.67), while the minimum number was found from V_1 (7.63). At 60 DAT, the maximum number of tillers hill^{-1} was recorded from V_4 (18.03) which was statistically identical with V_3 (17.88) and closely followed by V_2 (16.42) while the minimum number was obtained from V_1 (15.33). At 75 DAT, the maximum number of tillers hill^{-1} was recorded from V_3 (17.03) which was statistically identical with V_4 (16.74) and closely followed by V_2 (14.88) whereas the minimum number was found from V_1 (13.27). Anon. (1998a and 1998b) and Yoshida (1972) reported that hybrid variety had more tillering capacity than inbred variety.

4.2.2 Effect of population density

Statistically significant variation was recorded for number of tillers hill^{-1} of *boro* rice at 30, 45, 60 and 75 DAT due to population density (Table 3). At 30 DAT, the maximum number of tillers hill^{-1} (4.55) was found from S_2 (2 seedlings hill^{-1}) which was statistically similar (4.31) with S_3 (3 seedlings hill^{-1}) and the minimum

Table 3. Effect of inbred and hybrid *boro* rice variety and population density on number of tillers hill^{-1}

Treatments	Number of tillers hill^{-1} at			
	30 DAT	45 DAT	60 DAT	75 DAT
Inbred and hybrid boro rice				
V_1	3.79	7.63	15.33	13.27
V_2	4.23	8.67	16.42	14.88
V_3	4.48	9.21	17.88	17.03
V_4	4.23	9.02	18.03	16.74
$LSD_{0.05}$	0.2597	0.6245	0.9720	1.051
Sx	0.089	0.216	0.337	0.364
Population density				
S_1	4.25	8.96	17.27	15.28
S_2	4.55	9.43	18.15	17.08
S_3	4.31	9.06	17.66	15.63
S_4	3.63	7.08	14.58	13.93
$LSD_{0.05}$	0.260	0.625	0.972	1.051
$S_{\bar{x}}$	0.089	0.216	0.337	0.364
CV(%)	7.42	8.68	6.89	8.14

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

number (3.63) was observed from S_4 (4 seedlings hill^{-1}) which was closely followed by (4.25) S_1 (1 seedlings hill^{-1}). At 45 DAT, the maximum number of tillers hill^{-1} was obtained from S_2 (9.43) which was statistically identical with S_3 (9.06) and S_1 (8.96) and the minimum number was recorded from S_4 (7.08). At 60 DAT, the maximum number of tillers hill^{-1} was obtained from S_2 (18.15) which was statistically similar with S_3 (17.66) and S_1 (17.27) and the minimum number was found from S_4 (14.58). At 75 DAT, the maximum number of tillers hill^{-1} was found from S_2 (17.08) which was closely followed by S_3 (15.63) and S_1 (15.28) and the minimum number was recorded from S_4 (13.93). It reveals that planting excess seedlings (more than two) in a single hill does not affect the tiller production. Hasanuzzaman *et al.* (2009), Nakano and Mizushima (1994) also observed similar findings.

4.2.3 Interaction effect of variety and population density

Population density and inbred and hybrid of *boro* rice showed statistically significant interaction effect for number of tillers hill^{-1} at 30, 45, 60 and 75 DAT (Table 4). At 30 DAT, the maximum number of tillers hill^{-1} (5.19) was found from the treatment combination of V_4S_2 (2 seedlings hill^{-1} with BRRI hybrid dhan-2), whereas, the minimum number (3.30) was recorded from the treatment combination of V_3S_4 (4 seedlings hill^{-1} with BRRI hybrid2). At 45 DAT, the maximum number of tillers hill^{-1} was found from the treatment combination of V_3S_2 (10.47) and the minimum number was obtained from the treatment combination of V_3S_4 (6.40). At 60 DAT, the maximum number of tillers hill^{-1} was recorded from the treatment combination of V_3S_2 (19.87), while the minimum number was observed from the treatment combination of V_4S_2 (13.90). At 75 DAT, the maximum number of tillers hill^{-1} was recorded from the treatment combination of V_3S_2 (19.77) and the minimum number was found from the treatment combination of V_4S_2 (11.19).

Table 4. Interaction effect of inbred and hybrid *boro* rice variety and population density on number of tillers hill^{-1}

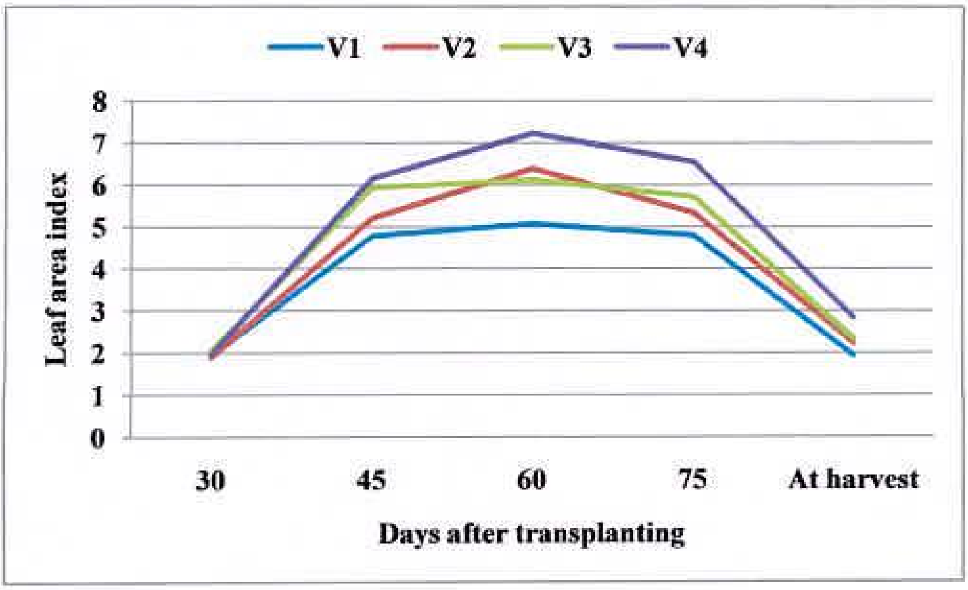
Treatments	Number of tillers hill^{-1} at			
	30 DAT	45 DAT	60 DAT	75 DAT
V_1S_1	3.77	7.57	15.23	13.07
V_1S_2	3.90	7.93	15.83	14.07
V_1S_3	3.73	7.40	14.77	12.67
V_1S_4	3.77	7.63	15.50	13.27
V_2S_1	4.33	9.10	17.20	14.70
V_2S_2	4.67	9.63	17.63	16.27
V_2S_3	4.40	9.23	17.07	14.97
V_2S_4	3.53	6.70	13.80	13.60
V_3S_1	4.70	9.80	18.30	17.07
V_3S_2	5.10	10.47	19.87	19.77
V_3S_3	4.83	10.17	19.43	18.37
V_3S_4	3.30	6.40	13.90	12.93
V_4S_1	4.20	9.37	18.37	16.30
V_4S_2	5.19	6.64	8.93	11.19
V_4S_3	4.27	9.43	19.37	16.53
V_4S_4	3.93	7.60	15.10	15.93
$LSD_{0.05}$	0.5193	1.249	1.944	2.103
$S_{\bar{x}}$	0.180	0.432	0.673	0.728
CV(%)	7.42	8.68	6.89	8.14

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

4. 1.3 Leaf Area Index (LAI)

4.1.3.1 Effect of variety

Leaf area index (LAI) or the surface area of green leaves produced by rice plants unit area^{-1} of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. Except 30 DAT LAI was significantly affected by variety at all the sampling dates (Figure 4 and Appendix IV). The LAI as a normal phenomenon increased with the advancement of plant age and declined after attaining its maximum value with time. Figure 4 shows that irrespective of varieties, LAI increased sharply after transplanting attaining a peak at around 60 DAT. At 60 DAT, ACI hybrid dhan2 showed much higher LAI of 7.23, closely followed by BRRI dhan29 and lowest from BRRI dhan28 LAI of 5.07. This was attributed to lower LAI Ahmed *et al.* (1996) and Turner *et al.* (1986). Takeda *et al.* (1983) observed that high-yielding rice varieties had higher LAI.

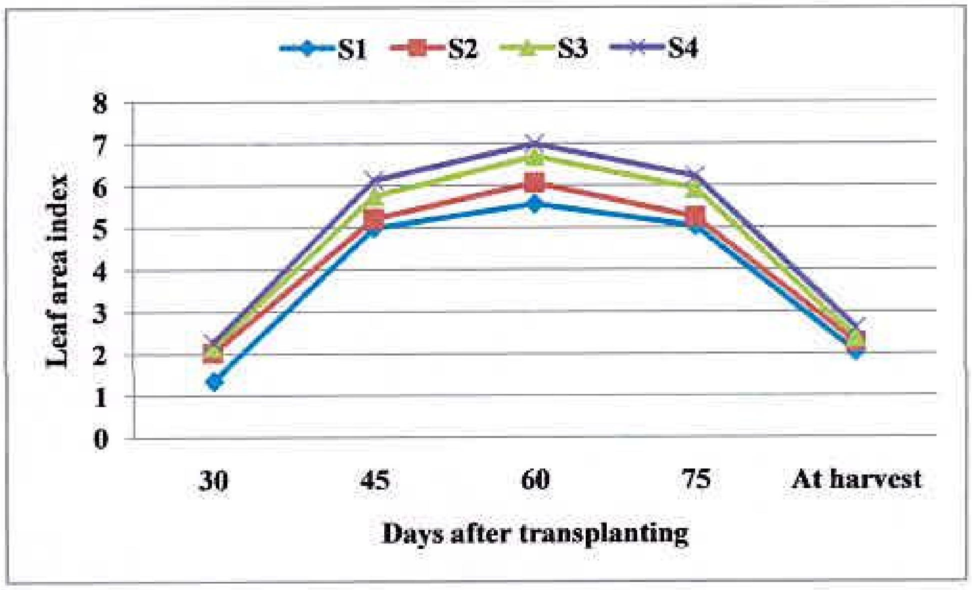


Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2

Figure 4. Effect of variety on leaf area index at different days after transplanting ($LSD_{0.05}$=0.339, 0.512, 0.229, 0.166, 0.285 at 30, 45, 60 and 75 DAT and at harvest)

4.1.3.2 Effect of population density

Population density had remarkable influence on leaf area index (LAI). There were significant variations among different seedling hill^{-1} treatments observed at 30, 45, 60 and 75 DAT but insignificant at harvest (Figure 5 and Appendix IV). At 30 DAT, maximum leaf area index (2.27) was obtained from 4 seedlings hill^{-1} followed by 3 seedlings hill^{-1} (2.17) that followed by 2 seedlings hill^{-1} (02.03). Minimum leaf area index (1.35) was counted at single seedling hill^{-1}. The similar trend was also continued up to 75 DAT where single seedling showed significantly the lowest LAI. The highest LAI (6.99) was recorded from 4 seedlings followed by 3 seedlings (6.69) then 2 seedlings (6.06) and after then 1 seedling (5.56) at 60 DAT. The findings are in agreement with Hasanuzzaman *et al.* (2009), Masum *et al.* (2008), Miah *et al.* (2004) and Obulamma *et al.* (2002) who stated the highest LAI at 4 and 3 seedlings $hill^{-1}$ respectively.



Note: S_1: 1seedling $hill^{-1}$, S_2: 2 seedlings $hill^{-1}$, S_3: 3 seedlings $hill^{-1}$, S_4: 4 seedlings $hill^{-1}$

Figure 5. Effect of population density on leaf area index at different days after transplanting ($LSD_{0.05}$=0.339, 0.512, 0.229, 0.166, 0.285 at 30, 45, 60 and 75 DAT and at harvest)

4.1.3.4 Interaction effect of variety and population density

It was observed from Table 5 that except at 75 DAT LAI was not significantly affected by the interaction of variety and population density at rest sampling dates. AT 30 DAT maximum LAI (2.67) was observed from ACI hybrid dhan2 in combination with 4 seedlings hill^{-1} and minimum (1.27) from BRRI dahan29 in combination with 1 seedling hill^{-1}. At 45 DAT numerically maximum (6.73) LAI was found from ACI hybrid dhan2 in combination with 4 seedlings hill^{-1} and minimum (4.10) from BRRI Dhan28 in combination with 2 seedling hill^{-1}. The similar trend was also continued at 60 DAT. At 75 DAT maximum (7.00) LAI observed from ACI hybrid dhan2 in combination with 4 seedlings hill^{-1} which was statistically similar with same variety combination with 3 seedlings hill^{-1} and minimum (4.50) from BRRI Dhan28 in combination with 1 seedling hill^{-1} which was statistically similar with same variety in combination with 2 seedlings hill^{-1}. At harvest numerically maximum (3.20) LAI observed from ACI hybrid dhan2 in combination with 4 seedlings hill^{-1} and minimum (1.54) from BRRI Dhan28in combination with 1 seedling hill^{-1}.

Table 5. Interaction effect of variety and population density on leaf area index at different days after transplanting

Treatments	Leaf area index at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
V_1S_1	1.37	4.47	4.77	4.50	1.54
V_1S_2	2.07	4.10	4.57	4.60	1.97
V_1S_3	2.00	5.00	5.37	4.90	2.03
V_1S_4	2.47	5.53	5.57	5.20	2.17
V_2S_1	1.27	4.27	5.50	4.70	1.90
V_2S_2	1.90	4.73	6.23	4.57	2.10
V_2S_3	2.27	5.87	6.73	5.83	2.30
V_2S_4	2.13	5.97	7.10	6.27	2.63
V_3S_1	1.27	5.63	5.70	4.93	2.20
V_3S_2	2.40	5.80	6.47	5.20	2.27
V_3S_3	2.30	6.03	6.90	6.33	2.40
V_3S_4	2.20	6.30	7.40	6.40	2.47
V_4S_1	1.50	5.60	6.27	5.97	2.53
V_4S_2	1.77	6.20	6.97	6.63	2.80
V_4S_3	2.10	6.10	7.77	6.60	2.77
V_4S_4	2.67	6.73	7.90	7.00	3.20
$LSD_{0.05}$	NS	NS	NS	0.961	NS
$S_{\bar{x}}$	0.235	0.355	0.456	0.333	0.198
CV(%)	20.77	11.12	12.48	10.29	14.68

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling $hill^{-1}$, S_2: 2 seedlings $hill^{-1}$, S_3: 3 seedlings $hill^{-1}$, S_4: 4 seedlings $hill^{-1}$

4.3 Dry matter production plant^{-1}

4.3.1 Effect of variety

Dry matter plant^{-1} varied significantly for different inbred and hybrid *boro* rice at 30, 45, 60 and 75 DAT and at harvest (Table 6). At 30 DAT, the highest dry matter plant^{-1} (5.15 g) was obtained from V_3 (BRRI hybrid dhan2) which was statistically identical (4.78 g and 4.75 g) with V_4 (ACI hybrid dhan2) and V_2 (BRRI dhan29), while the lowest (4.02 g) was recorded from V_1 (BRRI dhan28). At 45 DAT, the highest dry matter plant^{-1} was observed from V_3 (6.28 g) which was statistically identical with V_4 (6.11 g) and V_2 (5.94 g), whereas the lowest was found from V_1 (5.24 g). At 60 DAT, the highest dry matter plant^{-1} was observed from V_4 (8.12 g) which was statistically identical with V_3 (8.08 g) and closely followed by V_2 (7.29 g), and the lowest was observed from V_1 (6.43 g). At 75 DAT, the highest dry matter plant^{-1} was recorded from V_3 (10.48 g) which was statistically identical with V_4 (10.44 g) and the lowest was found from V_1 (8.60 g) which was statistically similar to V_2 (9.07 g). At harvest, the highest dry matter plant^{-1} was obtained from V_3 (12.64 g) which was closely followed by V_4 (11.84 g) and the lowest was recorded from V_1 (9.14 g) which was closely followed by V_2 (10.82 g). This confirms the reports of Amin *et al.* (2006) and Son *et al.* (1998) that dry matter production differed due to varietal variation.

4.3.2 Effect of population density

Dry matter plant^{-1} of *boro* rice showed statistically significant variation at 30, 45, 60 and 75 DAT and harvest for population density (Table 6). At 30 DAT, the highest dry matter plant^{-1} (5.23 g) was obtained from S_2 (2 seedlings hill^{-1}) which was statistically identical (4.87 g) with S_3 (3 seedlings hill^{-1}) and closely followed (4.80 g) by S_1 (1 seedlings hill^{-1}), and the lowest (3.79 g) was recorded from S_4 (4 seedlings hill^{-1}). At 45 DAT, the highest dry matter plant^{-1} was recorded from S_2 (6.47 g) which was statistically identical with S_3 (6.19 g) and S_1 (6.13 g),

Table 6. Effect of population density on dry matter plant^{-1} of inbred and hybrid *boro* rice

Treatments	Dry matter plant^{-1} (g) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Inbred and hybrid *boro* rice					
V_1	4.02	5.24	6.43	8.60	9.14
V_2	4.75	5.94	7.29	9.07	10.82
V_3	5.15	6.28	8.08	10.48	12.64
V_4	4.78	6.11	8.12	10.44	11.84
$LSD_{0.005}$	0.40	0.4185	0.9702	0.6007	0.7564
Sx	0.140	0.145	0.179	0.208	0.262
Population density					
S_1	4.80	6.13	7.71	9.47	11.16
S_2	5.23	6.47	8.21	10.57	12.14
S_3	4.87	6.19	7.87	9.77	11.37
S_4	3.79	4.78	6.13	8.78	9.77
$LSD_{0.005}$	0.403	0.419	0.970	0.601	0.756
Sx	0.140	0.145	0.179	0.208	0.262
CV(%)	10.34	8.52	6.30	7.47	8.16

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

while the lowest was obtained from S_4 (4.78 g). At 60 DAT, the highest dry matter plant^{-1} was recorded from S_2 (8.21 g) which was statistically identical with S_3

(7.87 g) and S_1 (7.71 g), while the lowest was observed from S_4 (6.13 g). At 75 DAT, the highest dry matter plant^{-1} was found from S_2 (10.57 g) which was closely followed by S_3 (9.77 g) and S_1 (9.47 g), while the lowest was found from S_4 (8.78 g). At harvest, the highest dry matter plant^{-1} was obtained from S_2 (12.14 g) which was closely followed by S_3 (11.37 g) and S_1 (11.16 g), whereas the lowest was found from S_4 (9.77 g).

4.3.3 Interaction effect of variety and population density

Dry matter plant^{-1} varied significantly due to the interaction effect of population density and inbred and hybrid of rice at 30, 45, 60 and 75 DAT and at harvest (Table 7). At 30 DAT, the highest dry matter plant^{-1} (6.14 g) was recorded from the treatment combination of V_3 S_2 (2 seedlings hill^{-1} with BRRI hybrid dhan2), whereas, the lowest (3.24 g) was recorded from the treatment combination of V_3 S_4 (4 seedlings hill^{-1} with BRRI hybrid dhan2). At 45 DAT, the highest dry matter plant^{-1} was recorded from the treatment combination of V_3S_2 (7.30 g), whereas, the lowest was observed from the treatment combination of V_3S_4 (4.11 g). At 60 DAT, the highest dry matter plant^{-1} was obtained from the treatment combination of V_3S_2 (9.32 g), whereas, the lowest was found from the treatment combination of V_3S_4 (5.62 g). At 75 DAT, the highest dry matter plant^{-1} was recorded from the treatment combination of V_3S_2 (11.65 g) and the lowest was observed from the treatment combination of V_3S_4 (7.97 g). At harvest, the highest dry matter plant^{-1} was obtained from the treatment combination of V_3S_2 (14.45 g) and the lowest was found from the treatment combination of V_2S_4 (9.18 g).

Table 7. Interaction effect of inbred and hybrid *boro* rice variety and population density on dry matter plant^{-1}

Treatments	Dry matter plant^{-1} (g) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
V_1S_1	4.03	5.31	6.50	8.40	8.89
V_1S_2	4.17	5.39	6.67	9.28	9.81
V_1S_3	3.88	5.02	6.02	8.04	8.64
V_1S_4	3.98	5.25	6.54	8.66	9.21
V_2S_1	4.94	6.19	7.64	8.78	11.07
V_2S_2	5.43	6.56	7.92	10.14	11.90
V_2S_3	5.02	6.26	7.49	9.14	11.13
V_2S_4	3.62	4.75	6.09	8.22	9.18
V_3S_1	5.50	6.67	8.36	10.77	12.97
V_3S_2	6.14	7.30	9.32	11.65	14.45
V_3S_3	5.72	7.03	9.02	11.53	13.73
V_3S_4	3.24	4.11	5.62	7.97	9.40
V_4S_1	4.74	6.36	8.35	9.93	11.70
V_4S_2	5.19	6.64	8.93	11.19	12.39
V_4S_3	4.88	6.44	8.94	10.36	11.98
V_4S_4	4.32	5.00	6.26	10.26	11.27
$LSD_{0.005}$	0.807	0.837	1.035	1.201	0.823
Sx	0.279	0.290	0.358	0.416	0.524
CV(%)	10.34	8.52	6.30	7.47	8.16

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

4.4 Effective tillers hill^{-1}

4.4.1 Effect of variety

Different inbred and hybrid *boro* rice varied significantly in terms of effective tillers hill^{-1} (Table 8). The maximum number of effective tillers hill^{-1} (12.43) was found from V_4 (ACI hybrid dhan2) which was statistically identical (12.28) with V_3 (BRRI hybrid dhan2) and closely followed (11.02) by V_2 (BRRI dhan29), and the minimum number (9.61) was obtained from V_1 (BRRI dhan28). This confirms the report of Sawant *et al.* (1986), who reported that variable effect of variety on the number of effective tillers hill^{-1}. Anon. (1998a) suggested that high yielding variety had more bearing tillers m^{-2} over the inbred variety.

4.4.2 Effect of population density

A significant variation was observed for effective tillers hill^{-1} due to population density of *boro* rice (Table 8). The maximum number of effective tillers hill^{-1} (13.19) was observed from S_2 (2 seedlings hill^{-1}) which was closely followed (11.77 and 11.42) by S_3 (3 seedlings hill^{-1}) and S_1 (1 seedlings hill^{-1}), while the minimum number (8.96) was recorded from S_4 (4 seedlings hill^{-1}). This confirms the report of Ashraf *et al.* (1999) who stated that transplanting of 2 and 3 seedlings hill^{-1} gave more promising results in terms of more productive tillers unit area^{-1}.

4.4.3 Interaction effect of variety and population density

Statistically significant interaction effect of population density and inbred and hybrid of *boro* rice variety was recorded for effective tillers hill^{-1} (Table 8). The maximum number of effective tillers hill^{-1} (15.13) was recorded from the treatment combination of V_3S_2 (2 seedlings hill^{-1} with BRRI hybrid dhan2). On the other hand, the minimum number (7.83) was found from the treatment combination of V_3S_4 (4 seedlings hill^{-1} with BRRI dhan28).

4.5 Non-effective tillers hill^{-1}

4.4.1 Effect of variety

Different inbred and hybrid *boro* rice varied significantly on non-effective tillers hill^{-1} (Table 8). The minimum number of non-effective tillers hill^{-1} (2.65) was observed from V_4 (ACI hybrid dhan2) which was statistically identical (2.83) with V_3 (BRRI hybrid dhan2) and the maximum number (3.53) from V_2 (BRRI dhan29) which was closely followed (3.52) by V_1 (BRRI dhan28).

4.5.2 Effect of population density

Non-effective tillers hill^{-1} of *boro* rice showed significant differences due to population density (Table 8). The minimum number of non-effective tillers hill^{-1} (2.78) was obtained from S_2 (2 seedlings hill^{-1}) which was statistically similar (2.83) by S_4 (4 seedlings hill^{-1}) and closely followed (3.31) by S_3 (3 seedlings hill^{-1}), and the maximum number (3.62) was recorded from S_1 (1 seedlings hill^{-1}).

Table 8. Effect of variety and population density and their interaction effect on effective tillers hill^{-1}, non effective tillers hill^{-1}, length of panicle, filled grains plant^{-1}, unfilled grains plant^{-1}, and 1000-grain weight

Treatments	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Length of panicle (cm)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	1000-grain weight (g)
Inbred and hybrid *boro* rice						
V_1	9.61	3.52	22.86	62.92	6.45	20.36
V_2	11.02	3.53	26.35	80.97	7.03	23.97
V_3	12.28	2.83	28.87	82.85	8.15	22.18
V_4	12.43	2.65	27.01	86.80	8.16	23.72
$LSD_{0.05}$	0.970	0.198	2.510	4.136	0.725	1.693
$S\bar{x}$	0.336	0.067	0.869	1.432	0.251	0.586
Population density						
S_1	11.42	3.62	27.06	85.90	7.74	23.50
S_2	13.19	2.78	29.43	80.38	8.40	22.60
S_3	11.77	3.31	27.70	79.15	8.02	22.71
S_4	8.96	2.83	20.90	68.12	5.62	21.42
$LSD_{0.05}$	0.970	0.198	2.510	4.136	0.725	1.693
$S\bar{x}$	0.336	0.067	0.869	1.432	0.251	0.586
Interaction of variety and population density						
V_1S_1	9.17	3.73	22.71	58.80	6.33	18.15
V_1S_2	10.43	3.37	23.44	62.13	6.83	21.97
V_1S_3	8.63	3.27	22.43	62.44	6.03	19.80
V_1S_4	10.20	3.70	22.8	68.33	6.60	21.51
V_2S_1	11.37	4.23	27.82	90.73	7.63	27.87
V_2S_2	12.83	2.83	30.69	83.60	7.97	22.67
V_2S_3	11.20	3.77	28.41	82.27	7.53	24.11
V_2S_4	8.67	3.27	18.49	67.30	4.97	21.24
V_3S_1	12.50	3.33	30.99	95.73	8.47	23.13
V_3S_2	15.13	2.60	34.35	86.60	9.73	22.26
V_3S_3	13.67	3.30	32.33	83.73	9.37	22.27
V_3S_4	7.83	2.10	17.80	65.35	5.03	21.08
V_4S_1	12.63	3.17	26.71	98.33	8.53	24.84
V_4S_2	14.37	2.30	29.26	89.20	9.07	23.52
V_4S_3	13.60	2.90	27.62	88.17	9.17	24.67
V_4S_4	9.13	2.23	24.44	71.50	5.87	21.83
$LSD_{0.05}$	1.940	0.3875	5.020	8.272	1.449	NS
$S\bar{x}$	0.672	0.134	0.869	2.864	0.502	1.172
CV(%)	10.27	7.43	11.46	6.33	11.67	9.00

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling hill^{-1}, S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1}, S_4: 4 seedlings hill^{-1}

4.5.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety differed significantly differences on non-effective tillers hill^{-1} (Table 8). The minimum number of non-effective tillers hill^{-1} (2.10) was obtained from the treatment combination of V_3S_4 (4 seedlings hill^{-1} with BRRI hybrid dhan2), whereas, the maximum number (4.23) was recorded from the treatment combination of V_2 S_1 (1 seedlings hill^{-1} with BRRI dhan29).

4.6 Length of panicle

4.6.1 Effect of variety

A significant difference was recorded due to different inbred and hybrid boro rice in terms of length of panicle (Table 8). The longest panicle (28.87 cm) was found from V_3 (BRRI hybrid dhan-2) which was statistically identical (27.01 cm and 26.35 cm) with V_4 (ACI hybrid dhan2) and V_2 (BRRI dhan29), whereas the shortest (22.86 cm) was observed from V_1 (BRRI dhan 28). Devaraju *et al.* (1998) in a study with hybrid rice cultivar KRH2 and IR20 as a check variety and reported that the increased grain yield of KRH2 was mainly attributed to the tallest panicle length. Idris and Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties.

4.6.2 Effect of population density

Length of panicle varied significantly due to population density under the present trial (Table 8). The longest panicle (29.43 cm) was recorded from S_2 (2 seedlings hill^{-1}) which was statistically similar (27.70 cm and 27.06 cm) by S_3 (3 seedlings hill^{-1}) and S_1 (1 seedlings hill^{-1}), while the shortest (20.90 cm) was recorded from S_4 (4 seedlings hill^{-1}). Sarker *et al.*, 1998 reported that seedling(s) hill^{-1} was not found to have no significant effect on panicle length, filled grains panicle^{-1}.

4.6.3 Interaction effect of variety and population density

Population density and inbred and hybrid of *boro* rice variety showed significant interaction effect on length of panicle (Table 8). The longest panicle (34.35 cm) was found from the treatment combination of V_3S_2 (2 seedlings hill^{-1} with BRRI hybrid dhan2), again the shortest panicle (17.80 cm) from the treatment combination of V_3S_4 (4 seedlings hill^{-1} with BRRI hybrid dhan2).

4.7 Filled grains panicle^{-1}

4.7.1 Effect of variety

Different inbred and hybrid *boro* rice varied significantly in terms of filled grains panicle^{-1} (Table 8). The maximum number of filled grains panicle^{-1} (86.80) was recorded from V_4 (ACI hybrid dhan2) which was statistically identical (82.85 and 80.97) with V_3 (BRRI hybrid dhan2) and V_2 (BRRI dhan29), again the minimum number (62.92) was observed from V_1 (BRRI dhan28). Murthy *et al.* (2004) recorded different number of filled grains for different variety.

4.7.2 Effect of population density

Filled grains panicle^{-1} of *boro* rice showed significant variation due to population density (Table 8). The maximum number of filled grains panicle^{-1} (85.90) was obtained from S_1 (1 seedlings hill^{-1}) and the minimum number (68.12) from S_4 (4 seedlings hill^{-1}). The result is in agreement with Hasanuzzaman *et al.* (2009), Shah *et al.* (1991) and Singh *et al.* (1987) who stated that number of filled grains panicle^{-1} increased with the decrease in seedling number hill^{-1}.

4.7.3 Interaction effect of variety and population density

Filled grains panicle^{-1} varied significantly due to the interaction effect of population density with inbred and hybrid of *boro* rice (Table 8). The maximum number of filled grains panicle^{-1} (98.33) was found from the treatment combination of V_4S_1 (1seedlings hill^{-1} with ACI hybrid dhan2) and the minimum number (58.80) was observed from the treatment combination of V_1S_1 (1 seedlings hill^{-1} with BRRI dhan28).

4.8 Unfilled grains panicle^{-1}

4.8.1 Effect of variety

Different inbred and hybrid *boro* rice showed significant differences on unfilled grains panicle^{-1} (Table 8). The minimum number of unfilled grains panicle^{-1} (6.45) was recorded from V_1 (BRRI dhan28) which was statistically identical (7.03) with V_2 (BRRI dhan29) again, the maximum number (8.16) was found from V_4 (ACI hybrid dhan2) which was statistically similar (8.15) with V_3 (BRRI hybrid dhan2).

BINA (1993) conducted an experiment with four varieties/advance lines (IRATOM24, BR14, BINA13 and BINA19) and reported significant variation in unfilled spikelets panicle^{-1}.

4.8.2 Effect of population density

A significant variation was observed due to unfilled grains panicle^{-1} of *boro* rice in context of population density (Table 8). The minimum number of unfilled grains panicle^{-1} (5.62) was recorded from S_4 (4 seedlings hill^{-1}). On the other hand the maximum number (8.40) from S_2 (4 seedlings hill^{-1}) which was statistically similar (8.02 and 7.74) by S_3 (3 seedlings hill^{-1}) and S_1 (1 seedlings hill^{-1}).

4.8.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety showed significant variation on unfilled grains panicle^{-1} (Table 8). The minimum number of unfilled grains panicle^{-1}(4.97) was found from the treatment combination of V_2S_4 (4 seedlings hill^{-1} with BRRI dhan29) and the maximum number (9.73) was recorded from the treatment combination of V_3 S_2(2 seedlings hill^{-1} with BRRI hybrid dhan2).

4.9 Weight of 1000 seeds

4.9.1 Effect of variety

Weights of 1000 seeds differ significantly for different inbred and hybrid *boro* rice under the experiment (Table 8). The highest weight of 1000 seeds (23.97 g) was observed from V_2 (BRRI dhan29) which was followed (23.72 g and 22.18 g) with V_4 (ACI hybrid dhan2) and V_3 (BRRI hybrid dhan2) and the lowest (20.36 g) was found from V_1 (BRRI dhan28). Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers and observed that IR36 gave the highest 1000-grain weight (21.07g).

4.9.2 Effect of population density

Population density significantly effect weight of 1000 seeds of *boro* rice (Table 8). The highest weight of 1000 seeds (23.50 g) was obtained from S_1(1 seedlings hill^{-1}) which was statistically identical (22.71 g) with S_3 (3 seedlings hill^{-1}) and (22.60 g) by S_2(2 seedlings hill^{-1}), closely followed the lowest (21.42 g) was observed from S_4 (4 seedlings hill^{-1}). Choudhury *et al.* (1995) reported that seed size was not affected by the seedling(s) number hill^{-1}.

4.9.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety showed non significant variation on weight of 1000 seeds (Table 8). The highest weight of 1000 seeds (27.87 g) was found from the treatment combination of V_2S_1 (1 seedling hill^{-1} with BRRI dhan29), while the lowest (18.15 g) was recorded from the treatment combination of V_1S_1 (1 seedlings hill^{-1} with BRRI dhan28).

4.10 Grain yield

4.10.1 Effect of variety

Different inbred and hybrid *boro* rice showed significant differences on grain yield (Table 9). The highest grain yield (7.66 t ha^{-1}) was observed from V_4 (ACI hybrid dhan2) which was closely followed by (6.238 t ha^{-1}) V_3 (BRRI hybrid dhan2) and the lowest (4.69t ha^{-1}) was found from V_1 (BRRI dhan28). Xie *et al.* (2007) reported different yield for different variety. Lafarge *et al.* (2004) reported that grain yield was significantly higher for hybrid rice as hybrid increased assimilates allocation towards productive tillers. Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding cultivars (HYV) as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the best yield (7.0 t ha^{-1}).

4.10.2 Effect of population density

Grain yield of *boro* rice showed statistically significant variation in terms of population density (Table 9). The highest grain yield (6.63 t ha^{-1}) was obtained from S_2 (2 seedlings $hill^{-1}$) which was statistically identical (6.48 t ha^{-1}) with S_1 (1 seedlings $hill^{-1}$) and closely followed (5.84 t ha^{-1}) by S_3 (3 seedlings $hill^{-1}$) . On the other hand the lowest (5.15 t ha^{-1}) was recorded from S_4 (4 seedlings $hill^{-1}$). Hasanuzzaman *et al.* (2009) reported that grain yield was decreased with transplanting more than 2 seedlings $hill^{-1}$. Ghosh *et al.* (1998) also observed that increasing seedlings $hill^{-1}$ at a constant level did not influence on grain yield production, but after that grain yield decreased. Likewise, Srinivasulu *et al.* (1999)

noted that planting 1 seedling $hill^{-1}$ of rice gave grain yield comparable to that of 2 seedlings $hill^{-1}$. Whereas, Shrirame *et al.* (2000) found similar grain yield under 1, 2 and 3 seedlings $hill^{-1}$.

4.10.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety showed significant differences on grain yield (Table 9). The highest grain yield (8.58 t ha^{-1}) was recorded from the treatment combination of V_4S_2 (2 seedlings $hill^{-1}$ with ACI hybrid dhan2), whereas, the lowest (4.61t ha^{-1}) was found from the treatment combination of V_1S_4 (4 seedlings $hill^{-1}$ with BRRI dhan28).

4.11 Straw yield

4.11.1 Effect of variety

Different inbred and hybrid *boro* rice showed significant differences on straw yield (Table 9). The highest straw yield (8.68 t ha^{-1}) was observed from V_4 (ACI hybrid dhan2) which was closely followed (7.39 t ha^{-1} and 7.58 t ha^{-1}) V_2 (BRRI dhan29) and V_3 (BRRI hybrid dhan2) and the lowest (6.09 t ha^{-1}) was found from V_1. The result is in agreement with the findings of Panda and Leeuwrik (1971) who reported that the straw yield could be assigned to plant height. Dongarwar *et al.* (2003) reported differences for different genotypes of rice.

4.11.2 Effect of population density

Statistically significant variation was recorded for straw yield of *boro* rice due to population density (Table 9). The highest straw yield (8.01 t ha^{-1}) was observed from S_3 (3 seedlings $hill^{-1}$)which was statistically similar (7.87 t ha^{-1} and 7.71 t ha^{-1}) with S_4 (4 seedlings $hill^{-1}$) and S_2 (2 seedlings $hill^{-1}$) and the lowest (7.03 t ha^{-1}) was recorded from S_1 (1seedlings $hill^{-1}$). This result was in agreement with Miah *et al.* (2004). Sarker *et al.* (1998) reported that straw yield increased with increasing seedlings $hill^{-1}$. Karim *et al.* (1987) also reported that 4 seedlings $hill^{-1}$ produced higher straw than 1 seedling $hill^{-1}$.

4.11.3 Interaction effect of variety and population density

Population density and inbred and hybrid of *boro* rice variety showed non significant interaction effect on straw yield (Table 9). Numerically the highest straw yield (8.85 t ha^{-1}) was found from the treatment combination of V_4S_2 (2 seedlings $hill^{-1}$ with ACI hybrid dhan2). On the other hand the lowest (6.38 t ha^{-1}) was observed from the treatment combination of V_1S_1 (1 seedling $hill^{-1}$ with BRRI dhan28).

4.12 Biological yield

4.12.1 Effect of variety

Statistically significant variation was recorded for different inbred and hybrid *boro* rice on biological yield under the present experiment (Table 9). The highest biological yield (16.34 t ha^{-1}) was observed from V_4 (ACI hybrid dhan2) which was significantly different form V_3(13.82)and V_2(12.90) while the lowest (11.64 t ha^{-1}) was recorded from V_1 (BRRI dhan28). Rahman (2001) reported that hybrid produced higher biological yield compared to the inbred varieties which was supported by Singh and Gangwer (1989).

4.12 .2 Effect of population density

Biological yield of *boro* rice varied significantly due to population density (Table 9). The highest biological yield (14.34 t ha^{-1}) was obtained from S_2 (2 seedlings $hill^{-1}$) which was closely followed (13.85 t ha^{-1} and 13.52t ha^{-1}) by S_3 (3 seedlings $hill^{-1}$) and S_1 (1 seedlings $hill^{-1}$) whereas the lowest (13.01 t ha^{-1}) was found from S_4 (4 seedlings $hill^{-1}$). Nair *et al.*, (1971) obtained highest biological yield by planting 2 seedlings $hill^{-1}$ over 4 or 6 seedlings $hill^{-1}$.

4.12.3 Interaction effect of variety and population density

Interaction effect of population density and inbred and hybrid of *boro* rice variety showed non significant variation on biological yield (Table 9). The highest biological yield (17.43 t ha^{-1}) was found from the treatment combination of $V_4 S_2$ (2 seedlings $hill^{-1}$ with ACI hybrid dhan2) and the lowest (10.86 t ha^{-1}) from the treatment combination of $V_1 S_4$ (4 seedlings $hill^{-1}$ with BRRI dhan28).

4.13 Harvest index

4.13.1 Effect of variety

Harvest index varied insignificantly due to different inbred and hybrid *boro* rice (Table 9). Numerically the highest harvest index (46.72%) was observed from V_4 (ACI hybrid dhan2) which was identical (44.90%) with V_3 (BRRI hybrid dhan2) and closely followed (42.65%) by V_2 (BRRI dhan29). On the other hand, the lowest (40.04%) was recorded from V_1 (BRRI dhan28). Rahman (2001) also observed highest harvest index in hybrid than the inbred varieties. Similar result was also reported by Cui *et al.* (2000).

Table 9. Effect of variety and population density and their interaction effect on grain yield, straw yield, biological yield and harvest index

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Effect of variety				
V_1	4.69	6.96	11.64	40.04
V_2	5.51	7.39	12.90	42.65
V_3	6.24	7.58	13.82	44.90
V_4	7.66	8.68	16.34	46.72
$LSD_{0.05}$	0.819	0.603	1.069	NS
Sx	0.284	0.209	0.370	0.013
Effect of population density				
S_1	6.48	7.03	13.52	47.46
S_2	6.63	7.71	14.34	45.70
S_3	5.84	8.01	13.85	41.65
S_4	5.15	7.87	13.01	39.50
$LSD_{0.05}$	0.819	0.603	1.069	0.373
S_x	0.2836	0.2088	0.3700	0.01291
Interaction effect of variety and population density				
V_1S_1	4.79	6.38	11.17	42.98
V_1S_2	4.89	7.06	11.95	40.79
V_1S_3	4.61	7.99	12.60	35.61
V_1S_4	4.86	6.40	10.86	40.77
V_2S_1	5.95	6.51	12.46	47.85
V_2S_2	5.95	7.46	13.41	44.13
V_2S_3	5.20	7.86	13.06	39.73
V_2S_4	4.95	7.73	12.68	38.90
V_3S_1	6.85	7.00	13.85	48.89
V_3S_2	7.10	7.45	14.55	48.61
V_3S_3	6.00	7.37	13.37	45.08
V_3S_4	5.00	8.51	13.51	37.04
V_4S_1	8.34	8.25	16.59	50.14
V_4S_2	8.58	8.85	17.43	49.26
V_4S_3	7.56	8.80	16.36	46.18
V_4S_4	6.17	8.82	14.99	41.29
$LSD_{0.05}$	1.632	NS	NS	NS
S_x	0.5672	0.4175	0.7400	0.02582
CV(%)	16.30	9.45	9.37	10.92

Note: V_1: BRRI dhan28, V_2: BRRI dhan29, V_3: BRRI hybrid dhan2, V_4: ACI hybrid dhan2
S_1: 1seedling $hill^{-1}$, S_2: 2 seedlings $hill^{-1}$, S_3: 3 seedlings $hill^{-1}$, S_4: 4 seedlings $hill^{-1}$

4.13.2 Effect of population density

Statistically significant variation was recorded for harvest index due to population density in the present context (Table 9). The highest harvest index (47.46%) was obtained from S_1 (1 seedlings hill^{-1}) which was statistically similar with S_2 (2 seedlings hill^{-1}) and lowest (39.50%) from S_4 (4 seedlings hill^{-1}) which was statistically similar with S_3 (3 seedlings hill^{-1}). The result is in agreement with the findings of Shrirame *et al.* (2000) who reported that harvest index significantly affected by seedlings number hill^{-1}.

4.13.3 Interaction effect of variety and population density

Non Significant interaction effect of population density and inbred and hybrid of *boro* rice variety were recorded for harvest index (Table 9). Numerically the highest harvest index (50.14%) was recorded from the treatment combination of V_4S_1 (1 seedling hill^{-1} with ACI hybrid dhan2), whereas, the lowest (35.61%) was observed from the treatment combination of V_1S_3 (3 seedlings hill^{-1} with BRRI dhan28

Chapter 5
Summary and conclusion

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to April 2009 to study the influence of population density on growth and yield of inbred and hybrid *boro* rice. The experiment comprised as two factors. Factor A: Inbred and hybrid- 4 (2 inbred and 2 hybrid) viz. V_1: BRRI dhan28; V_2: BRRI dhan29; V_3: BRRI hybrid dhan2 and V_4: ACI hybrid dhan2. Factor B: Population density- 4 levels viz. S_1: 1 seedling hill^{-1}; S_2: 2 seedlings hill^{-1}, S_3: 3 seedlings hill^{-1} and S_4: 4 seedlings hill^{-1}. The experiment was laid out in two factors Randomized Complete Block Design with three replications. Data on different growth parameter, yield contributing characters and yield were recorded.

At harvest, the longest plant was observed from V_4 (105.1 cm) and the shortest plant from V_1 (82.47 cm). At 75 DAT, the maximum number of tillers hill^{-1} was recorded from V_3 (17.03) whereas the minimum number was found from V_1 (13.27). At 60 DAT, V_4 showed the highest LAI of 7.23 and the lowest from V_1LAI of 5.07. At harvest, the highest dry matter plant^{-1} from V_3 (12.64 g) and the lowest was recorded from V_1 (9.14 g). The maximum number of effective tillers hill^{-1} (12.43) was found from V_4, and the minimum number (9.61) was obtained from V_1. The minimum number of non-effective tillers hill^{-1} (2.65) was observed from V_4 and the maximum number (3.53) from V_2. The longest panicle (28.87 cm) was found from V_3 whereas the shortest (22.86 cm) was observed from V_1. The maximum number of filled grains panicle^{-1} (86.80) was recorded from V_4 and the minimum number (62.92) was observed from V_1. The minimum number of unfilled grains panicle^{-1} (6.45) was recorded from V_1 and the maximum number (8.16) was found from V_4. The highest weight of 1000 seeds (23.97 g) was observed from V_2 and the lowest (20.36 g) was found from V_1. The highest grain yield (7.66 t ha^{-1}) was observed from V_4 and the lowest (6.09 t ha^{-1}) was found from V_2. The highest straw yield (7.57 t ha^{-1}) was observed from V_3 again the lowest (4.69 t ha^{-1}) was found from V_1. The highest harvest index (46.72%) was observed from V_4 and the lowest (40.04%) was recorded from V_1.

At harvest, the longest plant was observed from S_1 (98.93 cm) while the shortest plant was recorded from S_4 (88.36 cm). At 75 DAT, the maximum number of tillers hill^{-1} was found from S_2 (17.08) and the minimum number was recorded from S_4 (13.93). The highest LAI (6.99) was recorded from 4 seedlings followed by 3 seedlings (6.69) then 2 seedlings (6.06) and after then 1 seedling (5.56) at 60 DAT. At harvest, the highest dry matter plant^{-1} was obtained from S_2 (12.14 g) whereas the lowest was found from S_4 (9.77 g). The maximum number of effective tillers hill^{-1} (13.19) was observed from S_2, while the minimum number (8.96) was recorded from S_4. The minimum number of non-effective tillers hill^{-1} (2.78) was obtained from S_2, and the maximum number (3.62) was recorded from S_1. The longest panicle (29.43 cm) was recorded from S_2, while the shortest (20.90 cm) was recorded from S_4. The maximum number of filled grains panicle^{-1} (85.90) was obtained from S_1 and the minimum number (68.12) was found from S_4. The minimum number of unfilled grains panicle^{-1} (5.62) was recorded from S_4 and the maximum number (8.40) was obtained from S_2. The highest weight of 1000 seeds (23.50 g) was obtained from

S_1, whereas the lowest (21.42 g) was observed from S_4. The highest grain yield (6.63 t ha^{-1}) was obtained from S_2 and the lowest (5.15 t ha^{-1}) was recorded from S_4. The highest straw yield (8.01 t ha^{-1}) was observed from S_3 and the lowest (7.03 t ha^{-1}) was recorded from S_1. The highest harvest index (47.46%) was obtained from S_1, while the lowest (39.50%) from S_4.

At harvest, the longest plant was found from the treatment combination of V_4S_1 (109.3 cm) and the shortest from the treatment combination of V_1S_4 (75.57). At 75 DAT, the maximum number of tillers $hill^{-1}$ was recorded from the treatment combination of V_3S_2 (19.77) and the minimum number was found from the treatment combination of V_3 S_4 (12.93). At 75 DAT maximum (7.00) LAI observed from V_4S_4 and minimum (4.50) fromV_1S_1. At harvest, the highest dry matter $plant^{-1}$ was obtained from the treatment combination of V_3S_2 (14.45 g) and the lowest was found from the treatment combination of V_2S_4 (9.18 g). The maximum number of effective tillers $hill^{-1}$ (15.13) was recorded from the treatment combination of V_3S_2 and the minimum number (7.83) was found from the treatment combination of V_3S_4. The minimum number of non-effective tillers $hill^{-1}$ (2.10) was obtained from the treatment combination of V_3S_4, whereas, the maximum number (4.23) was recorded from the treatment combination of V_2S_1. The longest panicle (34.35 cm) was found from the treatment combination of V_3S_2 again the shortest panicle (17.80 cm) from the treatment combination of V_3S_4. The maximum number of filled grains $panicle^{-1}$ (98.33) was found from the treatment combination of V_4S_1 and the minimum number (58.80) was observed from the treatment combination of V_1S_1. The minimum number of unfilled grains $panicle^{-1}$ (9.73) was found from the treatment combination of V_3S_2 and the maximum number (4.97) was recorded from the treatment combination of V_2S_4. The highest weight of 1000 seeds (27.87 g) was found from the treatment combination of V_2S_1 while the lowest (18.15 g) was recorded from the treatment combination of V_1S_1. The highest grain yield (8.58 t ha^{-1}) was recorded from the treatment combination of V_4S_2 whereas, the lowest (4.46 t ha^{-1}) was found from the treatment combination of V_1S_4. The highest harvest index (50.14%) was recorded from the treatment combination of V_4S_1 whereas, the lowest (35.61%) was observed from the treatment combination of V_1S_3.

Based on the result of the present study the following conclusion may be drawn-

- Hybrid dhan was superior in respect of all growth character and ACI hybrid dhan2 was the best variety among the tested varieties
- Transplanting of 2 seedlings $hill^{-1}$ always was superior in respect of growth, yield contributing characters and yield of *boro* rice
- Transplanting 1 seedling $hill^{-1}$ with ACI hybrid dhan2 was found a promising practice in *boro* season

However, to reach a specific conclusion and recommendation, more research work on variety and seedling numbers $hill^{-1}$ should be done over different Agro-ecological zones.

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Appendices

APPENDICES

Appendix I. Characteristics of Agronomy Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: SRDI

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from November 2008 to April 2009

Month	*Air temperature (^{0}c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
Noverber 2008	21.3	12.5	71	00	6.3
December 2008	22.4	13.5	74	00	6.3
January 2009	24.5	12.4	68	00	5.7
February 2009	27.1	16.7	67	30	6.7
March, 2009	31.4	19.6	54	11	8.2
April, 2009	34.2	23.4	61	112	8.1

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 121

Appendix III. Analysis of variance of the data on plant height as influenced by population density and inbred and hybrid *boro* rice

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.533	11.404	26.693	2.278	45.331
Inbred and hybrid Rice (A)	3	41.886**	384.104**	267.246**	475.979**	1401.273**
Population density (B)	3	67.373**	13.114**	19.415**	826.668**	237.857**
Interaction (A×B)	9	11.065**	3.612	17.751	110.574**	16.286
Error	30	2.290	13.959	29.503	28.393	24.840
CV(%)		6.74	9.29	8.18	6.92	5.31

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on leaf area index as influenced by population density and inbred and hybrid boro rice

Source of variation	Degrees of freedom	Mean square				
		Leaf Area Index at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.179	1.841	0.398	0.020	0.774
Inbred and hybrid Rice (A)	3	0.050	4.950**	9.932**	6.491**	1.668**
Population density (B)	3	2.056**	3.221**	4.951**	3.735**	0.674
Interaction (A×B)	9	0.111	0.325	0.153	0.318**	0.038
Error	30	0.165	0.377	0.623	0.332	0.117
Cv(%)		20.77	11.12	12.48	10.29	14.68

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability