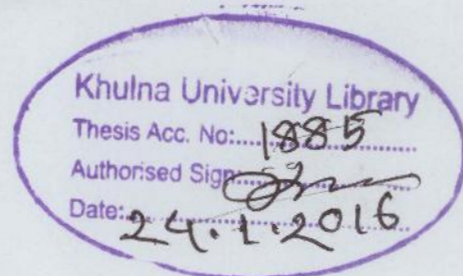


**EFFECT OF PLANTING DENSITY ON THE PERFORMANCE OF
RICE VARIETY BRRI dhan47**

A Thesis
Submitted to



**AGROTECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
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BANGLADESH**

By

Sharif Md. Ismail Hossain
Examination Roll: MS 100817

In partial Fulfillment of the Requirements
for the Degree of

**MASTER OF SCIENCE (M. S.)
IN
AGRONOMY**

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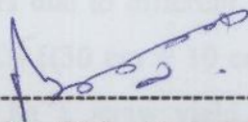
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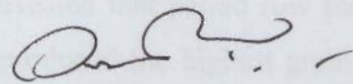
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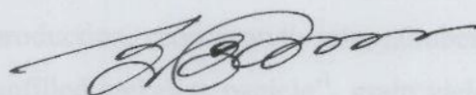
MASTER OF SCIENCE IN AGRONOMY



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OCTOBER, 2012

***DEDICATED
TO
MY FAVOURITE TEACHERS***

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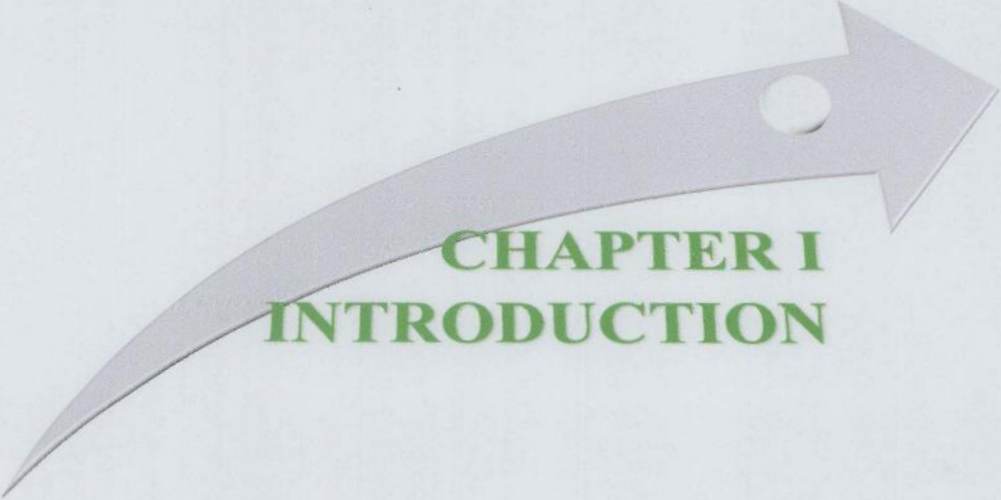
ABBREVIATIONS AND ACRONYMS

ANOVA	= Analysis of variance
AEZ	= Agro-Ecological Zone
Anon.	= Anonymous
Atm.	= Atmospheric
a. m.	= ante meridiem
BAU	= Bangladesh Agricultural University
BARI	= Bangladesh Agricultural Research Institute
BBS	= Bangladesh Bureau of Statistics
BRRI	= Bangladesh Rice Research Institute
CARE	= Co-Operative for American Relief Everywhere
CGR	= Crop growth rate
cm	= Centimeter
CV%	= Percent coefficient of variance
cv.	= Cultivar
DAT	= Days after transplanting
DMRT	= Duncan's New Multiple Range Test
DM	= Dry matter
dSm ⁻¹	= Decisimen per meter
e.g.	= Example given
<i>et al.</i>	= <i>et alia</i> and others
Fig.	= Figure
g	= Gram
HI	= Harvest index
Hr	= Hour(s)
ha ⁻¹	= Per hectare
hill ⁻¹	= Per hill
Intl.	= International
IRRI	= International Rice Research Institute
i.e.	= That is
K ₂ O	= Potassium oxide
Kg	= Kilogram



ABBREVIATIONS AND ACRONYMS (Contd.)

LSD	= Least significant difference
lb	= Pound
m ²	= Square meter
m ⁻²	= Per square meter
mm	= Millimeter
MoP	= Muriate of Potash
N	= Nitrogen
No.	= Number
NS	= Not significant
p.m.	= post meridiem
P ₂ O ₅	= Phosphorus penta oxide
RGR	= Relative growth rate
S	= Sulphur
SRDI	= Soil Resources and Development Institute
t	= Ton
TDM	= Total dry matter
TSP	= Triple Super Phosphate
<i>Var.</i>	= Variety
<i>viz.</i>	= Namely
<i>wt.</i>	= Weight
t ha ⁻¹	= Ton per hectare
°C	= Degree centigrade
%	= Percent
@	= At the rate of



CHAPTER I INTRODUCTION



INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Graminae and sub-tribe oryzinae. It is the staple food for more than half of the world population. Rice grows in more than 100 countries. About 80% of the world rice is produced in China, India, Indonesia, Bangladesh, Thailand and Vietnam. Among the rice growing countries of the world, Bangladesh ranked fourth in both area and production (BRRI, 2010). In Bangladesh rice is the synonym for food. In Bangladesh rice accounts for 94.40% of the annual cereal production (AIS, 2012). It provides nearly 40% of the total national employment (48% of the total rural employment). It also provides about 75% of total calories and 55% of the total protein intake of an average of people of the country (Bhuiyan *et al.*, 2002). Bangladesh has attained near self-sufficiency in food production. The UN General Assembly declared 2004 as the International Year of Rice which reflects the importance of rice in global concerns regarding food security, poverty alleviation, preserving cultural heritage, and sustainable development.

In Bangladesh, the agriculture sector contributes 19.95% of gross domestic product (AIS, 2012). Rice occupies 72.24 % of total cropped area (BBS, 2010); in which boro rice is cultivated in 47.70 lakh ha in 2010-'11 (AIS, 2012). The total production of rice in Bangladesh is 335.41 lakh m ton (AIS, 2012). During the last three decades rice production in Bangladesh increased more than 2.5 folds. The growth in production came mainly from reallocation of land from traditional to high yielding modern varieties. Modern varieties at present cover 98.95 % of boro, 71.58 % of aus and 69.16 % of transplanted aman rice area (AIS, 2012). Population of Bangladesh was 146.67 million in the year of 2011, which increases at a rate of 1.36 % per annum (AIS, 2012). A modest estimate (Zaman, 1996) suggests that for the growing population, the demand for rice in

Bangladesh will increase by over 80% in the next 20 years. To produce the required quantity additional land area that could be planted to rice is scarce. Therefore, the only option remains open is to increase production unit area⁻¹.

The cropping intensity of Bangladesh is 172.64% (BBS, 2010). The average production of rice in Bangladesh is 4.01 t ha⁻¹ (BRRI, 2010) where the average production of rice in China, Japan and Korea is 5-6 t ha⁻¹. There is a big yield gap between the potential and actual yield. It is mainly due to lack of potential variety and management practices (Islam *et al.*, 2009). It has been estimated that through the existing technologies it is possible to increase yield of modern rice by 2 t ha⁻¹. Rice scientists have been working to develop new and modern varieties since 1968. Starting with the IRRI dwarf varieties the BRRI has so far released 57 modern rice varieties and 04 hybrid rice varieties for cultivation in different growing seasons.

Desired number of plant population per unit area is an essential factor for getting higher yield in rice. Population density has more influence on grain yield of rice (Islam, 1986). The crop plants depend largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional requirements. The plant density influences leaf area index, crop growth rate, net assimilation rate, specific leaf area, photosynthesis, respiration and ultimately yield. Optimum planting density enables the rice plant to grow properly both in its aerial and underground parts by utilizing maximum radiant energy, space and water which ultimately leads to boost crop production (Miah *et al.*, 1990). When the planting density exceeds an optimum level, competition among plants for light or nutrients become severe consequently the plant growth slows down and the grain yield decreases. On the contrary, sparsely populated fields with wide spacing lead to uneconomic utilization of space, profuse growth of weeds and reduction of grain yield. The maximum benefit of rice can be obtained from a field, if it is spaced properly.

Several studies on yield-density relationship (Donald, 1963; Willey and Health, 1996) using a number varieties of crops were done, but the concept of optimum population density for maximum yield has not yet been figured out in many cases (Duncan, 1986). In contrast to the earlier proposition that closer spacing increases intra-specific competition and affects grain yield (BRRI, 1990) and quality (Karim *et al.*, 1992). Several studies revealed that closer spacing increases grain yield (Islam *et al.*, 1994; Aragones and Wada, 1989). There is a third school of thought which advocated that grain yield is unaffected by plant density (Balsubramanian and Palaniappan, 1991). A number of reports (Fagade and De Datta, 1971; Counce *et al.*, 1989) also indicated a curvilinear relationship between plant population density and rice grain yield. Under transplanted condition, grain yield plateau has been found to reach with 25 to 200 plants m^{-2} (Akita, 1982). Works conducted at BRRI (Anonymous, 1992) suggested that within a range of 16 to 67 plant m^{-2} , grain yield increases with the increase of plant density irrespective of varieties.

Planting pattern is an important agronomic management factor that determines the yield and quality of rice. Proper row and hill arrangements may help better nutrient uptake and receive the maximum isolation thereby increasing photosynthesis and yield of rice. In Bangladesh, modern rice varieties are generally transplanted in single row with 25cm x 15 cm spacing. It is generally agreed that higher yields are obtained from appropriate closer spacing (Ali, 2005).

BRRI (1982) reported that rice yield was significantly higher in 10 cm x 10 cm spacing than in either 30 cm x 30 cm or 20 cm x 20 cm spacing. Besides the single row, rice can be transplanted in paired row arrangements. BRRI (1981) reported that the paired row systems of rice planting improved grain yield. Singh *et al.* (1986) observed that among single, double and triple row arrangements the maximum LAI, CGR from flowering to maturity, the maximum numbers of panicles m^{-2} and the highest grain yield were in three

row sets of 10/30 cm pattern and the lowest yield in three row sets of 20/50 cm pattern. Rice variety has certain tiller producing capacity and adequate number of effective tillers unit area⁻¹ exerts a role in producing panicles and spikelet and ultimately grain yield (Miller *et al.*, 1991). Optimum number of tillers per unit area is a prerequisite for obtaining maximum yield and rice yield increases with increased number of panicles per unit area (BRRI, 1995). Higher yield potential of hybrid rice is primarily attributed to profuse tillering, large number of panicles and higher spikelet density. It is expected that BRRI dhan47 may also yield higher if higher number of panicles per unit area with more or equal to 100 filled spikelets per panicle are ensured.

Among the cultural technology, planting density is one of the important components manipulation of which could lead for optimizing yield. Various experiments and work on the spacing of transplanted rice have been carried out in Bangladesh as well as in the world to find out the suitable spacing in order to get maximum yield. With these in view, an experiment was designed and conducted to find out the optimum planting density for getting higher yield of boro rice variety BRRI dhan47. Under the above circumstances the present study was undertaken with the following objectives:

- To find out the optimum planting density for getting higher yield of BRRI dhan47
- To determine the effect of planting density on yield and yield contributing characters of BRRI dhan47
- To observe the growth and yield performance of BRRI dhan47 at different planting densities and planting patterns.

CHAPTER II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Rice has a wide adaptability to different environmental conditions as it is widely distributed in the world. Research on rice has been extensive by the researchers through the world on various practices. Rice plants are usually grown in community. Yield of rice is greatly influenced by environmental factors like photoperiod, temperature, humidity, agronomic practices like planting density, time of cultivation, fertilization, irrigation etc. Planting density is one of the most important factors, which is responsible for the yield of rice. Planting densities determines not only the intensity of intra-varietal competition for light, water and nutrient but also the DM partitioning between the organs. Spacing changes the canopy structure of a crop, controlling CGR and HI. Wide spacing makes available more nutrients for a plant than narrow spacing between the hills for a transplanted conventional high yielding, semi dwarf variety. Higher planting density increased the yield by promoting early growth and by increasing the number of panicles and sink. Higher planting density limited vegetative growth after anthesis and thereby growth rate of the panicle increased.

An attempt has been made in this chapter to review the literatures and research findings done by different researchers in the world.

2. Effect of Planting Density

2.1 Effect on growth parameters

2.1.1 Plant height

Plant height is a genetically controlled character of rice plant. Modern rice cultivars are generally short to intermediate stature, whereas the traditional cultivars are taller (Hossain *et al.*, 1991). Management practices influence plant height as well. Although the effect of

plant density on plant height is well recognized there still remain differences in opinions whether wider spacing increases plant height or closer spacing does it.

Thakar *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India showed that plant population of 25 and 33 hills m^{-2} produced taller plant than population of 44 hills m^{-2} .

Haque (2002) carried out an experiment with the spacing of 20 cm x 20 cm, 30 cm x 30 cm, 30 cm x 40 cm and 40 cm x 40 cm and found tallest plant from wider spacing.

Khisha (2002) stated that the highest plant height (122.52 cm) was obtained from 12 days old seedling hill⁻¹ with 40 cm x 35 cm spacing and lowest plant height (109.9 cm) was found in normal practice which was thirty days old 2 seedlings hill⁻¹ with 25 cm x 15 cm spacing.

Zadesh and Mirlohi (1998) conducted a field trial in summer with rice at row spacing of 15, 25 and 35 cm and hill spacing of 10, 15 and 20 cm and found that variation in row spacing influenced the plant height significantly at heading and anthesis stages. From the study they concluded that wider row spacing enhanced days to heading and anthesis and consequently grain filling and ripening stages. Although number of tillers unit area⁻¹ increased, tillers plant⁻¹ decreased as row spacing was reduced. Narrow row spacing limited vegetative growth after anthesis and thereby growth rate of the panicle increased. With reduction of row spacing, without any change in the percentage of filled grains panicle⁻¹ and grain weight, number of panicles unit area⁻¹ increased but number of grains panicle⁻¹ decreased. At greater row spacing, grain yield unit area⁻¹ decreased although grain yield plant⁻¹ and harvest index increased. Step wise regression and path-coefficient analysis revealed that number of panicles unit area⁻¹ was the most important yield component. It also showed that indirect effects of panicle number unit area⁻¹ on yield

through its association with grain number panicle⁻¹ prevented real effects of grain number panicle⁻¹ on yield. The maximum yield was obtained at a spacing of 15 cm x 15 cm and was recommended for rice production in Isfahan.

Akita and Tanaka (1992) conducted an experiment where rice cv. Nipponbare seedlings were transplanted at 1 seedling hill⁻¹ on the square at 9-100 hills m⁻² or in rows at 10-100 hills m⁻². At panicle formation plant height was the greatest of 49 hills m⁻² but at heading and maturity the tallest plants were found at low plant densities. When planted on the square number of culms at panicle formation was the greatest at 100 hills m⁻² but at heading it was the greatest at 64 hills m⁻².

Shah *et al.* (1991) conducted an experiment where rice cv. K39 was grown at 15 cm x 15 cm and 10 cm x 10 cm plant spacing and 3, 4, 5 and 6 seedlings hill⁻¹. Plant height and number of grains panicle⁻¹ increased with decrease in seedling number hill⁻¹. Plant height and harvest index were the greatest with 15 cm x 15 cm spacing and tiller number m⁻² and straw yield were highest with 10 cm x 10 cm spacing. The highest grain yield of 2.7 t ha⁻¹ was obtained from 6 seedlings hill⁻¹ at 15 cm x 15 cm.

Ayub *et al.* (1987) stated the number of tillers hill⁻¹, number of panicle bearing tillers hill⁻¹ and 1000 grain weight decreased with increasing plant density but plant height, number grains m⁻² and grain yield remained unaffected.

2.1.2 Tiller dynamics

Plant density is probably the most important factor affecting tillering (Counce *et al.*, 1992) since it affects competition among the plants for light, nutrient and moisture which in turn affects tiller production (Liang *et al.*, 1986). The higher the spacing the smaller the number of hills unit area⁻¹. Again, higher the space allowed to individual hill the greater is

scope for production of tillers. It is common that increasing planting density will likely increase total number of tillers unit area⁻¹.

Mahmud (2006) conducted an experiment with twelve treatments, which were divided into two distinct patterns single row and paired row. Planting densities were 40 hills m⁻², 27 hills m⁻², 20 hills m⁻² and 16 hills m⁻². Standard management practices were followed in raising crops. The rice variety BRRI dhan28 differed considerably in terms of crop growth characters as well as yield and yield contributing characters. Results revealed that higher planting density produced higher yield where 40 hills m⁻² produced highest yield, which is statistically similar with that of 27 hills m⁻². Paired row planting showed better performance than single row planting. Plant height, grains panicle⁻¹, sterile spikelets panicle⁻¹, 1000 grain weight, grain yield were found better in paired row planting. Paired row planting at a spacing of (35 cm + 15 cm) x 10 cm produced the highest grain yield (4.81 t ha⁻¹) and single row planting at a spacing of 25 cm x 25 cm produced the lowest (2.97 t ha⁻¹).

Sarker (2003) carried out an experiment on rice cv. BRRI dhan39 with three row arrangements viz. single, double and triple row and reported that leaf dry matter, stem dry matter and total dry matter were significantly highest in triple row arrangement. On the other hand, plant height and total tillers hill⁻¹ were the highest in single row arrangements but grain yield and harvest index were highest in double row arrangements.

Yang-Fu *et al.* (1999) conducted an experiment with rice cv. Jinongda 3 under different planting densities and observed that tiller number and growth period increased as density increased. The optimum plant density was 20 hills m⁻² at which yields reached 8.7 t ha⁻¹.

Bisht *et al.* (1999) studied the plant population requirement of hybrid rice in the Tarai region of Uttar Pradesh, India during 1996 and 1997 wet seasons, rice cv. PRH 1 and Pant

Sankar dhan-1 were grown at 20 cm x 20 cm and 15 cm x 15 cm hill spacing, with 1, 2 or 3 plants per hill. They reported that grain yield, panicle m^{-2} , spikelets m^{-2} were higher in dense transplanting (15 cm x 15 cm) in the both years. Reduction of plant density without any change in the percentage of filled grains panicle $^{-1}$ and grain weight, the number of panicles unit area $^{-1}$ increased but number of grains panicle $^{-1}$ decreased (Zadeh and Mirlohi, 1998). Modern varieties produce more tillers than local varieties, which is one of the most important characters for higher yield.

Tillering is one of the most important developmental stage of rice, since it has a decisive bearing on yield. Tiller number, particularly effective tiller is strongly affected on grain yield, depending on the cultivar and crop environment. The number of tiller is regulated by tillering duration, which varies with cultivars, seedling age, environmental conditions, availability of nutrients in the soil etc. (Roy and Satter, 1992).

Saa *et al.* (1980) argued that number of tiller increased in a closer spacing along with the increasing rate of added N and decreased at a wider spacing. However, tiller production also depends on the number of seedling planted in individual hill since higher number of seedlings hill $^{-1}$ are likely to contribute to higher number of tillers (Ayub *et al.*, 1987 and Muhammad *et al.*, 1987). Although total number of tillers unit area $^{-1}$ increases with increasing population density, important aspect is the number of effective tillers (panicle bearing tillers) which are the essential determinants in grain yield.

Murty and Murty (1981) found that the closer spacing increased number of tillers and spikelets and dry matter (DM) production m^{-2} . The results agreed with those of Madhavan *et al.* (1986) and Kim *et al.* (1990).

Miller *et al.* (1991) showed that tiller density increase with increasing plant density, while above ground biomass production does not vary much with plant population. This

result was also reflected later in the findings of Zadesh and Mirlohi (1998) where they showed increased number of tillers unit area⁻¹, but decreased tillers plant⁻¹ with higher plant population. The important question in this regard is the amount of biomass converted to economic yield, which is manifested by the production of effective tillers unit area⁻¹. The number of effective tillers hill⁻¹ decreases with increasing plant density, and it is evident from several earlier studies (Muhammad *et al.*, 1987; Maula *et al.*, 1988). However, some studies also revealed that spacing and seeding density do not affect grain yield considerably except decrease in effective tillers hill⁻¹ with increasing plant density (Srinivasan and Purushothaman, 1990).

Different plant varieties show optimum tillers m⁻² at different densities. Experiments conducted at BRRI (1988) indicated no significant interaction between varieties and planting density, which was later reconfirmed by Mannan *et al.* (1991).

At maximum tillering stage there is nearly a three-fold difference in tiller hill⁻¹ between low and high density treatments. The trend continues almost throughout the growing period. However, Munnujan (1994) observed that the high tillering ability of sparsely planted seedling could not compensate for moderate density in terms of tiller density. The results agreed well with those of Hassan (1991) but differed with the findings of Miller *et al.* (1991) who reported that the number of actively growing tillers declined until reaching a constant tiller density by heading. According to Roy and Satter (1992), the mortality rate of secondary and tertiary tillers is much during the late phases of growth.

2.1.3 Number of leaves

Ogháló (2011) conduct an experiment in the forest Savana transition zone during the 2003 cropping season at the Teaching and Research Farm, Ambrose Alli University, Ekpoma on a study to evaluate the appropriate spacing (Population density) for upland

rice. He showed that variety and spacing had significant effects on plant height, tiller numbers, leaves numbers and leaf length.

Thakar *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India showed that plant population of 25 and 33 hills m^{-2} produced taller plant, whereas population of 44 hills m^{-2} recorded significantly higher LAI.

Shrirame *et al.* (2000) reported that the wider spacing of 20 cm x 15 cm produces the maximum number of functional leaves hill^{-1} , maximum leaf area hill^{-1} and total number of tillers hill^{-1} but plant height, grain and straw yield and harvest index were not affected.

Rao and Reddy (1992) reported that LAI at flowering varied at different spacing as well as with number of seedlings hill^{-1} and higher population maintained per hill contributed to lower LAI and inhibit tillering within a hill. Leaf area is an important index used to study the plant growth, assimilation and transpiration as to utilization of solar radiation. Yield is always related to the growth and development of the plant. Thus, the effect of plant population on leaf area index is viewed with emphasis. Increasing LAI through higher population density or other cultural practices is likely to lead to high yield potential. Higher LAI value can usually be achieved by increasing plant population density (Kim *et al.*, 1990)

LAI at flowering and dry matter production from early growth stages was also found to have a close association with seed yield (Majumdar, 1989).

Ghosh *et al.* (1979) found from an experiment on rice cv. Pankaj and transplanted at 10 cm x 10 cm, 15 cm x 15 cm, 20 cm x 20 cm, 25 cm x 25 cm and 30 cm x 30 cm in the wet season of 1977. LAI at ear emergence and dough stage was related to yield and was higher with closer plant spacing. Yield decreased with plant spacing at 30 cm x 30 cm.



2.1.4 Total dry matter production

Thakar *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India, showed that increased plant population produce decreased dry weight plant⁻¹ as a result of decreased harvest index with increased plant population.

Islam (2003) conducted an experiment at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur to find out the best modification of SRI technique in terms of spacing, seedling age and seedling density hill⁻¹ on growth and yield of boro rice *cv.* BRRI dhan29. The experiment comprised of three spacing *viz.* 25 cm x 25 cm, 30 cm x 30 cm and 40 cm x 40 cm; three seedling ages *viz.*, 15, 25 and 35 day old seedlings and two densities *viz.* 1 and 3 seedlings hill⁻¹. The result revealed that LAI, CGR and TDM increased with the increase of plant age whereas RGR decreased. The maximum value of LAI, CGR and TDM was obtained from the spacing of 25 cm x 15 cm and 30 cm x 30 cm, 15 day old seedlings and 1 seedling hill⁻¹. Number of tillers hill⁻¹ was gradually increased starting from 20 DAT up to 95 DAT and then showed a decreasing trend. The yield components such as number of total tillers hill⁻¹, bearing tillers hill⁻¹, grains panicle⁻¹ and weight of 1000 grains were highest in case of 30cm x 30cm spacing x 15 day old seedlings x 1 seedling hill⁻¹ combination. Grain, straw and biological yields were also highest in the same combination.

Haque (2002) conducted an experiment on SRI during boro season with *cv.* BINA dhan6. Results found from that experiment that early stage of crop growth the older seedlings produced higher dry matter hill⁻¹ and at mature stage the younger one produced higher dry matter hill⁻¹.

Improvement in yield of crops can be achieved either by increasing the amount of total dry matter or by raising the proportion of economic portion. TDM production in local variety and high yielding variety of rice is almost same, but in high yielding varieties the

HI is greater compared to the traditional ones. Yoshida (1972) and Tanaka (1983) observed a high positive correlation between above ground DM and yield.

Tanaka (1983) reported that the total dry matter was a product of average growth rate and growth duration and was positively correlated with leaf area. Murty and Murty (1980) found that values for dry matter production, spikelets m^{-2} and paddy yields were the highest at a spacing of 10 cm x 10 cm and progressively decreased with increased spacing.

Murty and Murty (1981) found that the closer spacing increased number of tillers and spikelets and dry matter (DM) production m^{-2} .

Srinivasan and Purushothaman (1990) observed that in rice cv. Ponni and Bhavani when transplanted at 15 cm x 20 cm or 25 cm x 10 cm, plant DM at higher plant density in main and ratoon crops varied but had no significant effects on grain and straw yield of ratoon crops. The TDM of the plant increased with the advancement of plant growth stages. The initial increase was found slow, then again gradually decreased as the crop approached maturity. The yield was approximately the product of total dry matter and the panicle straw ratio. Spacing determines not only the intensity of intra - varietal competition for light, water and nutrient but also the DM partitioning between the organs. Spacing changes the canopy structure of a crop, controlling CGR and HI. Wide spacing makes available more nutrients for a plant than narrow spacing between the hills for a transplanted conventional high yielding, semi dwarf variety.

F₁ hybrid rice grown at IRRI with 20 cm x 20 cm spacing had the following features, big plant size (leaf, tiller and height), depressed heterosis for DM accumulation at heading (Yamauchi, 1994) and no heterosis for panicle number and tillering after seeding stage.

2.1.5 Crop growth rate

Crop growth rate (CGR) is the rate of dry matter production unit area⁻¹ of land and unit time⁻¹. It is a simple and important index of agricultural productivity (Hunt, 1978). Crop growth rate changes with growth (Tanaka, 1983) and reaches maximum at panicle emergence and decreases soon after panicle emergence (Wilson and Ellis, 1981).

Ray *et al.* (2000) evaluated five Basmati rice cultivars with three levels of spacing treatment during wet season of 1997 in the new Alluvial Zone of West Bengal. Growth attributing characters like LAI, dry matter accumulation and CGR were significantly influenced by different spacing treatments as well as by cultivars. The closer spacing 10 cm x 15 cm and cv. Pusa Basmati reported the highest CGR.

Talukder (1998) conducted an experiment with BRRI dhan29, IPK37008, Jugliboro and Kaliboro and reported that planting density caused marked changes in CGR in all varieties but did not influence the phase change. In both the traditional varieties, CGR values for the lowest density was low, while planting at 50 and 86 hill m⁻² showed nearly identical CGR in the beginning but sharp differences emerged during 44-58 DAT which persisted till 72 DAT in Kaliboro and throughout the season in Jugliboro. Population density exhibited consistently lower CGR in all the varieties throughout the season.

Yoshida (1983) reported that rice crop attained maximum leaf area index (values of 10 or higher) when planted at close spacing. CGR reached maximum at LAI of about 6 for IR8, which was an improved variety. The maximum CGR was usually around 30-36 g m⁻² day⁻¹, harvest index of improved semi-dwarf indica varieties were around 0.45-0.55. There were no optimum LAI for CGR (Rahman, 1991). The CGR reached maximum at a LAI of about 6 for IR8 and 4 for Peta beyond which it remains the same despite further increase in LAI which related to the plant density. The maximum CGR of erect leave IR8 was greater by 20 g m⁻² week⁻¹ than of droopy leaved Peta variety. High CGR at

vegetative stage originates from which high LAI and that CGR at reproductive and ripening stages is controlled by NAR (Yamauchi, 1994). The same was also observed by Haruhara *et al.* (1985) in the cold region of Japan.

Kabaki *et al.* (1992) conducted an experiment and studied the characteristics of Japonica Indica hybrid rice with reference to dry matter production, yield and tolerance of unfavorable environmental conditions. Result indicated highest heterosis (140-170%) on the CGR during the 30 DAT; CGR of Indica varieties declined markedly after heading.

2.1.6 Relative growth rate

Relative growth rate (RGR) is the rate of dry matter increased unit⁻¹ of total dry matter (TDM) unit⁻¹ time (Milthorpe and Moorby, 1979). Relative growth rate represents the efficiency of the plant as a producer of new material and gives a measure of the plants economy in working (Hunt, 1978).

Relative growth rate is the increase in plant weight per unit of weight already present and may be expressed as g (g of dry weight)⁻¹ day⁻¹ (Tesar, 1984). Relative growth rate decrease with plant age. This decrease is due to the fact that an increasing part of the plant is structural rather than metabolically active tissue and as such does not contribute to growth. The decrease is also due impart to shading and increased age of lower leaves.

Mia (2001) reported that RGR was highest in widest spacing (20 cm x 25 cm) and was lowest in closest spacing (16 cm x 20.8 cm) at all the DATs except the period of 75 to 90 DAT.

Kabir (1996) from an experiment conducted at the Bangladesh Agricultural University, reported that values of Relative Growth Rate (RGR) were 0.06 and 0.04 g g⁻¹ day⁻¹ when rice plants were planted at a spacing of 20 cm x 15 cm and 25 cm x 15 cm, respectively.

2.2 Effect on yield and yield components

2.2.1 Number of effective tillers m^{-2}

Thakar *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India showed that the number of effective tillers $hill^{-1}$ decreased significantly with increase in population.

Hossain (2002) reported that the highest number of effective tillers $hill^{-1}$ (11.31) was found in SRI practice with 15 day old seedlings and 25 cm x 15 cm spacing in BRRI dhan32.

Reddy *et al.* (2001) reported that planting of rice at a closer spacing of 15 cm x 10 cm resulted in higher grain yield (40.66 and 50.33 q ha^{-1} during 1996 and 1997, respectively) as compared to normal planting at a spacing of 20 cm x 10 cm (35.93 and 48.11 q ha^{-1} during 1996 and 1997, respectively) and recorded a mean increase of 7.6% higher grain yield over the normal spacing. Among the yield components, number of panicles unit area $^{-1}$ and grain number panicle $^{-1}$ have been influenced significantly by closer planting. Closer planting of seedlings (15 cm x 10 cm) also significantly increased the number of panicles m^{-2} (463) compared to the other treatments.

Halder *et al.* (2000) stated that closer spacing produces higher number of panicle, higher 1000 grain weight and yield than wider spacing.

Thangamuthu and Subramanian (1983) studied the effect of plant population of rice cv. Co 43 and found that the 20 cm x 15 cm spacing produced the highest grain yields of 5.2 and 6.6 t ha^{-1} during the wet and dry seasons, respectively. The number of panicles m^{-2} was higher in a conventional planting at 15 cm x 10 cm spacing during the wet season but higher at 15 cm x 20 cm spacing in the dry season.



Oliveira *et al.* (1977) raised two rice cultivars between row spacing of 30, 50 or 70 cm at 58, 116 and 174 plants m^{-2} . The highest grain yield was obtained with rows of 30 cm apart. The grain yields increased as distance between rows decreased. The increase was being due to mainly increase number of panicle m^{-2} .

Nair and George (1972) stated that the paddy yield was increased from 4.92 t ha^{-1} in 15 cm x 15 cm spacing to 5.64 t ha^{-1} in 10 cm x 10 cm spacing, mainly due to a corresponding increase in the number of panicles m^{-2} with decrease in spacing irrespective of N- levels.

Mannan *et al.* (1991) reported that modern rice varieties BR1, BR3, BR12, BR14 and BR20 were planted at 25 cm x 30 cm, 25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm, 15 cm x 10 cm spacing. The number of tillers, panicles and grain yield per unit area increased with the increase in plant density. Planting at 25 cm x 10 cm and 15 cm x 10 cm spacing gave significantly higher grain yield. Among the tested varieties, BR14 yielded the highest grain with 150-155 days duration.

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

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

Verma *et al.* (2002) found that seedlings planted at 20 cm x 20 cm and 20 cm x 15 cm spacing produced higher number of productive tillers than the seedlings planted at 20 cm x 10 cm gave higher sterility percentage than wider spacing.

2.2.2 Flag leaf length

Oghalo (2011) conducted an experiment to evaluate the appropriate spacing (population density) for upland rice in the forest/Savanna transition zone was carried out during the 2003 cropping season at the Teaching and Research Farm, Ambrose Alli University, Ekpoma. Three spacing (40 cm x 30 cm, 30 cm x 30 cm and 20 cm x 30 cm) equivalent to three population densities (83, 333, 111, 111 and 166, 666 plants haG) and three varieties of upland rice (ITA 315; ITA 323 and a local variety) were used. The experimental design was a 3 x 3 factorial scheme replicated four times. Variety and spacing had significant effects on plant height, tiller numbers, leaves numbers and leaf length. There was no significant interaction between spacing and variety for these traits, except for tiller numbers. Spacing and variety also significantly affected panicle length. Plant population density of 111, 111, plants haG and ITA 315 produced the highest yield.

2.2.3 Panicle length

Hasan (2008) conducted an experiment at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen sources and spacing on the growth and yield of T. aman rice of BRRI dhan31. The experiment comprised of five spacing viz. 15 cm x 15 cm, 20 cm x 15 cm, 25 cm x 15 cm, 30 cm x 15 cm and 35 cm x 15 cm. The effect of spacing was significant for all the crop characters except 1000 grain weight. Plant height, number of tillers hill⁻¹, dry weight plant⁻¹, effective tillers hill⁻¹, straw yield and biological yield were higher with widest spacing (35 cm x 15 cm). But

number of filled grains panicle⁻¹ (102.2), panicle length (27.17 cm), grain yield (4.76 t ha⁻¹) and harvest index (45.97) were maximum in 25 cm x 15 cm spacing.

Kalita *et al.* (1997) observed that closer spacing decreased yield components including grains panicle⁻¹, panicle length and panicle weight but increased panicle numbers m⁻².

Rekhashri *et al.* (1997) reported that closer spacing decreased yield components including number of grains panicle⁻¹, panicle length and panicle weight but increased panicle numbers m⁻² which slightly increased grain yield.

Shirakawa *et al.* (1992) reported that in rice cv. Koshinikari, plant height and panicle length decreased with a decreased in grain yield as plant density increased from 6-32 plants m⁻².

Wei and Liu (1986) concluded that the higher planting density increased the grain yield of rice by 42% due to increased number of panicle unit area⁻¹.

Liou (1987) found that the closer spacing of 12.5 cm x 12.5 cm decreased panicle length of rice plants as compared to 25 cm x 25 cm spacing.

2.2.4 Number of spikelets panicle⁻¹

Ghosh *et al.* (1998) obtained the highest number of grains panicle⁻¹ at a spacing of 30 cm x 30 cm over closer spacing of 20 cm x 20 cm and 20 cm x 25 cm

Bhattacharyya (1981) found that the grain yield of rice had positive correlations with number of grains panicle⁻¹ and with number of panicles plant⁻¹.

Peng *et al.* (1998) conducted an experiment at IRRI to determine the effects of planting geometry and increased hill density on yield and yield components of IR68284H versus IR72. Seedlings were transplanted at 10 cm x 16 cm with 2 seedlings hill⁻¹. The control

plots were transplanted at 20 cm x 20 cm with 5 seedlings hill⁻¹. Both treatments had the same plant density of 125 seedlings m⁻². They observed that rectangular and high hill density increased the total sink size of IR68284H because of the increase in both panicle m⁻² and spikelet panicle⁻¹. The increase in sink size was not significant for IR72. Planting geometry and hill density did not affect grain filling percentage significantly. Rectangular planting and high hill density increased filled spikelet weight m⁻². Therefore, rectangular planting and increased hill density improved grain of hybrid rice.

2.2.5 Number of filled spikelets panicle⁻¹

BRRI (2001) conducted two experiments at the BRRI farm, Gazipur to study the yield potentiality of SRI method for yield maximization of boro and transplant aman rice. According to their report, higher number of filled grains panicle⁻¹ was obtained from 10 day old seedlings with 40 cm x 40 cm spacing and 15 day old seedlings with 30 cm x 30 cm spacing the lowest number of filled grains panicle⁻¹ (77) was produced with 20 cm x 20 cm spacing.

Dunand *et al.* (1982) found from an experiment with rice cv. Saturn labella and Starbonnet planted at various plant density from 1-30 plant ft⁻² and found that increase in plant density decreased tillering, plant weight and panicle weight plant⁻¹.

2.2.6 Number of unfilled spikelets panicle⁻¹

Mahmud (2006) conducted an experiment with twelve treatments, which were divided into two distinct patterns single row and paired row. Planting densities were 40 hills m⁻², 27 hills m⁻², 20 hills m⁻² and 16 hills m⁻². Standard management practices were followed in raising crops. The rice variety BRRI dhan28 differed considerably in terms of crop growth characters as well as yield and yield contributing characters. Results revealed that closer spacing produced higher yield where 40 hills m⁻² produced highest yield, which is statistically similar with that of 27 hills m⁻². Paired row planting showed better

performance than single row planting. Plant height, grains panicle⁻¹, sterile spikelets panicle⁻¹, 1000 grain weight, grain yield were found better in paired row planting. Paired row planting at a spacing of (35 cm + 15 cm) x 10 cm produced the highest grain yield (4.81 t ha⁻¹) and single row planting at a spacing of 25 cm x 25 cm produced the lowest (2.97 t ha⁻¹).

Islam (1999) stated that in the SRI method with plant spacing of 25 cm x 25 cm or 20 cm x 20 cm, yields were about the same (9.5 t ha⁻¹ and 9.2 t ha⁻¹, respectively) but with spacing of 30 cm x 30 cm, the yield increased up to 10.5 t ha⁻¹ which was 4.5 t ha⁻¹ more than the current national highest average yield of 6.0 t ha⁻¹. The highest sterility (39%) was occurred by 15 day old seedlings with 20 cm x 20 cm spacing and the lowest (28%) was by 15 day old seedling with 50 cm x 50 cm spacing. In *T. aman* season, the highest grain yield (3.88 t ha⁻¹) was obtained from 15 day old seedlings at 40 cm x 40 cm spacing, the lowest grain yield (3.01 t ha⁻¹) was obtained from 10 day old seedlings at 20 cm x 20 cm spacing. The highest sterility (49%) was observed in 10 day old seedlings at 20 cm x 20 cm spacing and the lowest (35%) was in 15 day old seedlings at 30 cm x 30 cm spacing in *T. aman*.

2.2.7 1000 grain weight

Uddin (2009) reported that rice *var.* BRRI dhan29 gave the highest grain yield (7.58 t ha⁻¹), biological yield, 1000 grain weight and harvest index at spacing 25cm x 15cm among the spacing 25 cm x 10 cm, 25 cm x 15 cm, 25 cm x 20 cm and 25 cm x 25 cm. He also reported that closer spacing showed maximum leaf area index.

Wang *et al.* (2002) reported that in SRI technique 1000 grain weight (g) were 26.53, 26.72, 26.96 and 26.7 with spacing distance of 25 cm x 25 cm, 25 cm x 15 cm, 30 cm x 30 cm or 30 cm x 15 cm, respectively.

Yan (2002) reported that rice *var.* Yazal gave a maximum yield of 12.79 t ha⁻¹, had 240 effective panicles m⁻² and 198 grains panicle⁻¹ with a 1000 grain weight of 27.5 g when plant spacing was 50 cm x 50 cm in SRI technique.

Shah *et al.* (1996) revealed that the lowest filled spikelet m⁻² (27816) and grain yield (5.30 t ha⁻¹) were obtained at 30 cm x 30 cm spacing and comparable at 20 cm x 20 cm and 10 cm x 10 cm spacing. But 1000 grain weight decreased with decreasing spacing. In case of grain yield 20 cm x 20 cm spacing gave comparable yield to that of 10 cm x 10 cm spacing but significantly higher than 30 cm x 30 cm.

Karim *et al.* (1992) reported from an experiment where two Basmati lines were grown at 118560, 160550 and 197600 plants ha⁻¹ in two cropping season 1000 grain weight, cooked grain length, total milling recovery and head rice recovery were found to decrease with increasing plant density.

Quddus and Huda (1975) found that in Chandina variety of rice wider plant spacing of 15 cm x 20 cm had significant effect on tiller formation, number of total grains panicle⁻¹, weight of 1000 grains and grain yield plot⁻¹. Closer spacing of 15 cm x 10 cm induced higher grain yield. The highest 1000 grain weight (26.0 g) was obtained from 10 day old seedlings at 20 cm x 20 cm and 40 cm x 40 cm spacing and the lowest was at 50 cm x 50 cm spacing or from 15 day old seedling with 30 cm x 30 cm spacing. In Boro season, the highest 1000 grain weight (21.5 g) was obtained from 10 day old seedlings with 30 cm x 30 cm spacing. The highest grain yield (6.83 t ha⁻¹) was obtained from 10 day old seedlings with 20 cm x 20 cm spacing followed by 15 day old seedling with the same spacing while the lowest (2.9 t ha⁻¹) was obtained from 50 cm x 50 cm spacing of the same seedling with same spacing.

2.2.8 Grain yield

Santos *et al.* (2006) conducted an experiment in Minas Gerais, Brazil to evaluate the response of rice cultivars Canastra and Confianca on different spacing (20, 30 and 40 cm) and seed densities (50, 70 and 90 seeds m⁻²) under sprinkler irrigation. Spacing at 30 and 40 cm significantly increased crop yield.

Wanjari *et al.* (2006) found that a single seedling hill⁻¹ with the spacing of 15 cm x 15 cm in hybrid rice gave the highest yield.

Ali (2005) conduct an experiment with 12 planting patterns (4 single row and 8 paired row arrangements) revealed that paired row arrangement with higher plant population produced higher grain yield. The highest and the lowest plant population (37.2 and 20 hills m⁻², respectively) reduced grain yield. Planting patterns (35 cm + 15 cm) x 15 cm, (35 cm + 15 cm) x 12.5 cm and 25 cm x 12.5 cm were found better. Total dry matter, crop growth rate, and leaf area index were influenced considerably due to N source and planting pattern.

Sarker (2003) carried out an experiment on rice cv. BRRI dhan39 with three row arrangements viz. single, double and triple row and reported that leaf dry matter, stem dry matter and total dry matter were significantly highest in triple row arrangement. On the other hand, plant height and total tillers hill⁻¹ were the highest in single row arrangement but grain yield and harvest index were highest in double row arrangement.

Rajesh and Thanunathan (2003) observed that spacing of 40 day old seedlings at 2 seedlings hill⁻¹ with a spacing of 20 cm x 25 cm recorded the maximum grain yield of 2.85 t ha⁻¹ and 2.65 t ha⁻¹ in experiment I and II, respectively.

BRRI (2002) conducted experiment at the BRRI Farm, Satkhira. In this experiment seven different planting densities were used as treatment: spacing 10 cm x 10 cm, 10 cm x 15

cm, 15 cm x 15 cm, 15 cm x 20 cm, 15 cm x 25 cm, 20 cm x 25 cm, 25 cm x 30 cm and double row with 15 cm x 30 cm spacing. Result indicated that the highest average grain yield was observed 6.6 t ha⁻¹, 6.7 t ha⁻¹, 6.4 t ha⁻¹ in BRRI dhan40, BRRI dhan41, BRRI dhan28, respectively when transplanting was done in 15 cm x 20 cm and double row with 15 cm x 30 cm spacing in all varieties and followed by 15 cm x 25 cm spacing. Grain yield increased by increasing spacing up to 15 cm x 20 cm and after that increasing planting spacing to decreased grain yield was found in closer spacing 10 cm x 10 cm. Again grain yield decreased with increasing spacing from 20 cm x 25 cm to 25cm x 30cm.

Neelam and Nisha (2000) conducted an experiment with scented rice *cv.* Pusa Basmati 1 cultivated under various plant spacing *viz.* 30 cm x 15 cm, 15 cm x 15 cm and 20 cm x 20 cm and found that spacing did not influence grain and straw yield.

BRRI (2000) reported that the effect of plant density at various nitrogen levels was studied to find out whether the loss of crop production in less fertile soil could be overcome by increasing plant density. Plant spacing were 40 cm x 20 cm, 25 cm x 25 cm, 25 cm x 10 cm and 20 cm x 10 cm. Grain yield increased with the increased in plant density up to 20 hill m⁻², further increasing plant density increase the transplanting cost by at least 65%.

Azad *et al.* (1995) stated that rice seedlings were transplanted at 20 cm x 10 cm, 25 cm x 15 cm and 30 cm x 20 cm spacing. Grain yield decreased by the widest plant spacing.

Planting density is one of the main factors that have important role on the yield of rice. Plant density is the essential factor that needs to be considered during transplanting of rice. Population density has profound influence on grain yield of rice (Islam, 1986) depending upon plant type and planting time.

Ghosh *et al.* (1960) reported that wide spacing affects yield adversely; although larger ear and more tillers plant⁻¹ were produced with a wider spacing but they could not compensate for the reduction in population density unit area⁻¹. Panicle weight and yield also found to be decreased at wider spacing despite of slightly higher panicle weight. (Rao *et al.*, 1990) and Miah *et al.* (1990) also agreed with those results.

Several experiments were conducted by BRRI (BRRI, 1992a) and concluded that closer spacing (10 cm x 10 cm) gives more yield than wider spacing. It was also in agreement with those of Gupta and Sharma (1990); Mannan *et al.* (1991) and Ramakrishna *et al.* (1992).

BRRI (1990) from an experiment reported higher grain yield in 20 cm x 20 cm spacing. However, higher number of seedlings hill⁻¹ (5-6) could be important in this regard as also reported by Shah *et al.* (1991).

Aragones and Wada (1989) while working with a short duration variety (IR66) and a medium duration advanced line IR36 892-163-12-2-1 at plant spacing of 5 cm x 5 cm, 20 cm x 10 cm and 20 cm x 30 cm found that closer spacing increased the yield by promoting early growth and by increasing the number of panicles and sink which more apparent in IR66. At different spacing grain yield and grain-straw ratio increased with closer spacing (Chavan *et al.*, 1989).

Balasubramanian (1985) conducted an experiment where rice cv. IR20 was planted at spacing of 10 cm x 10 cm, 15 cm x 10 cm and 20 cm x 10 cm and found that grain yield did not differ significantly due to plant spacing.

In another study Balasubramanian and Palaniappan (1991) rice cv. IR50 and IR64 were transplanted in kharif (rainy) and rabi (winter) seasons, respectively at plant densities of

66, 80 or 100 m⁻². Grain yields and yield components were unaffected by plant density. Generally in case of modern variety, one seedling is transplanted hill⁻¹ but in local variety, more than one seedling is transplanted hill⁻¹. Local transplanted rice variety Kumaragoir with 2 - 3 seedlings hill⁻¹ at 25 cm x 15 cm spacing appeared to be better in terms of yield than the local farmer's practices of planting at a wider spacing and with more seedlings hill⁻¹ (BRRI, 1992b).

Islam *et al.* (1994) found that closer spacing of 20 cm x 15 cm with 6 seedling hill⁻¹ produced 61% and 41% higher grain and straw yield, respectively over 40 cm x 40 cm spacing with 10 seedlings hill⁻¹. In closer spacing production hill⁻¹ is less than wider spacing but total production is higher (Reddy and Reddy, 1994).

Hegazy *et al.* (1995) showed that grain yield is not significantly affected by the plant density hill⁻¹ i.e seedling number hill⁻¹. Early maturing rice cv. CR 666-18 at a spacing of 10 cm x 8 cm with 2 and 4 seedlings hill⁻¹ (250 and 500 plant m⁻²) produced 3.8 and 4.4 t ha⁻¹, respectively (Budhur *et al.*, 1993) and there was no significant difference in respect of grain yield and it was in agreement with the findings of Om *et al.* (1993).

BRRI (1995) also experimented with spacing and seedlings number hill⁻¹ and results revealed that panicle production and grain yield differ significantly with spacing but not with seedlings hill⁻¹

Plant density is the most important means which can maximize yield (Babu and Mitra 1989; Villalobos *et al.*, 1994). Plant density is achieved by varying the row spacing. Plant density, species proportion and spatial arrangements are important considerations that mediate the influence of environmental biological factors (Radosevich, 1987). Plant density also has self thinning affect on yield and quantity (Vander Werf *et al.*, 1995).

The growth and survival of each individual plant depends upon the local density (Mack and Harper, 1977). Density is important in determining yield because the resources available to the plant stand as a whole are restricted. But the probability of survival and mean yield of surviving plant decrease with increasing densities within plant monocultures. Hence plant density is the most important non-monetary input, which can be manipulated to attain the maximum production unit area⁻¹ (Jain and Chauhan, 1988). So, it can be said that in dense population per plant yield in maximum cases lower but total yield increases. On the other hand, if density decreases, per plant yield increases but total yield decreases. It was also seen that within a long ranges of population no variation in yields observed as in the case of sunflower, where seed yields were not affected by differences in plant populations ranging from 28700 to 73200 plants ha⁻¹ (Miller *et al.*, 1984).

Plant spacing is another important factor that needs to be considered during transplanting of rice. Improper spacing result in a reduction of 25-30 percent of the potential yield (IRRI, 1967). The optimum spacing ensures the plants to grow both in their aerial and underground parts through efficient utilization of solar radiation and nutrients. Spacing has a bearing on plant population per unit area. The higher the spacing the smaller are the number of hills planted unit area⁻¹. Again, higher space allowed to the individual hill the greater is the scope for production of tillers. Thus tiller production may compensate partially the original lower numbers of plants in wider spacing.

Parashar (1976) reported that rice cultivar IR8 grown in rows 7.5-30 cm apart between plant spacing of 7.5-30 cm or in paired rows 7.5 cm apart with inter rows strips 22.5 or 37.5 cm apart gave the highest paddy yields of 6.46 t ha⁻¹ in 7.5 cm x 7.5 cm spacing and the lowest yields of 3.8 t ha⁻¹ in 30 cm x 15 cm.

BRRI (1982) conducted several experiments to determine the effect of spacing and its interaction with nitrogen on the grain yield of rice. The three spacing were 30 cm x 30 cm, 20 cm x 20 cm and 10 cm x 10 cm. The seedlings of BR4 were transplanted and standard cultural practices were followed. The study revealed that 30 cm x 30 cm and 20 cm x 20 cm gave similar yields and had similar effects on yield contributing characters of rice. However, the yield was significantly higher in 10 cm x 10 cm spacing than either 30 cm x 30 cm or 20 cm x 20 cm spacing.

Amir *et al.* (1984) stated that rice *cv.* Basmati 370 was grown at spacing of 40 cm x 10 cm, 20 cm x 20 cm, 25 cm x 25 cm and 40 cm x 25 cm, the highest grain yield of 3.5 t ha⁻¹ was obtained of 20 cm x 20 cm plant spacing.

Verma *et al.* (1988) reported that rice grown at a spacing of 15 cm rows 15 or 25 cm apart (44 and 27 plants m⁻², respectively) gave 2 years average paddy yields of 5.38 and 4.61 t ha⁻¹, respectively.

In field trials on moderately fertile land rice *cv.* IR36 (30 day old seedlings) was spaced at 15 cm x 15 cm, 20 cm x 15 cm or 20 cm x 10 cm (44, 33 or 50 hills m⁻², respectively) and *cv.* CR 210-1018 (68 day old seedlings) was spaced at 15 cm x 15 cm, 20 cm x 15 cm or 20 cm x 10 cm (44, 33 or 50 hills m⁻², respectively). Plants were applied with 60 kg N + 30 kg P₂O₅ + 30 kg K₂O ha⁻¹ and need based application of 15 kg Carbofuran ha⁻¹ at 25 and 65 days after planting. The highest mean yields of *cv.* IR 36 and CR 210-1018 were 4.3 t ha⁻¹ (20 cm x 10 cm) and 4.02 t ha⁻¹ (15 cm x 15 cm), respectively (Nigam and Mannan, 1989)

Padmajaro (1995) observed that rice varieties Basmati370 and IET8580 were transplanted at 20 cm x 20 cm or 20 cm x 10 cm spacing (25, 33 and 50 plants m⁻², respectively); grain yield was highest at the close plant spacing.

Azad *et al.* (1995) observed that by transplanting rice seedlings at 20 cm x 10 cm spacing decrease in grain yield was observed by wider spacing.

Mustapha (2001) claimed that differences in population density in rice cv. IET3137 and ITA306 gave relatively similar grain yield between 20 cm x 20 cm and 30 cm x 30 cm spacing. Stover yield increased with an increasing planting density but that did not correspond to an increase in grain yield. Transplanting at a spacing of 40 cm x 40 cm gave the highest stover mass, but the grain yield was the lowest.

Ang *et al.* (2002) carried out an experiment with SRI techniques where varied plant spacing (33.3 cm x 33.3 cm and 40 cm x 40 cm) were used to observe the yield and yield components of rice var. Liangyoupei 9. They found that in case of 33.3 cm x 33.3 cm plant spacing the maximum number of tillers hill⁻¹ was 62.1, effective panicles hill⁻¹ was 200.2, filled grains panicle⁻¹ was 170.1, rate of seed setting (%) was 85.0, 1000 grain weight (g) was 25.5, actual yield (t ha⁻¹) was 12.15 and theoretical yield (t ha⁻¹) was 17.56. On the other hand, in case of 40 cm x 40 cm spacing maximum number of tillers hill⁻¹ was 68.2, effective panicles hill⁻¹ was 49.3, total grain panicle⁻¹ was 221.6, filled grains panicle⁻¹ 197.4, rate of seed setting (%) was 90.1, 1000 grain weight (g) was 26.1, actual yield (t ha⁻¹) was 11.25 and theoretical yield (t ha⁻¹) was 15.85.

Shao-hua *et al.* (2002) observed that in a field trail in Jiangyin city, Jiangsu province three planting densities as 30 cm x 20 cm, 25 cm x 25 cm, 30 cm x 30 cm under SRI cultivation plus the control with 30 cm x 12 cm planting density under conventional cultivation were used. Result indicated that spike number was highest (299.55) in case of 30 cm x 12 cm spacing. Grain number spike⁻¹ was highest (152.23) in case of 30 cm x 30 cm spacing. The highest 1000 grain weight (26.96 g) was obtained from 30 cm x 30 cm

spacing and the highest yield (8896.5 kg ha⁻¹) was observed in case of 30 cm x 12 cm spacing.

Yuan (2002) studied that in Sanya, China SRI trial was conducted by maintaining 33 cm x 33 cm spacing with super hybrid rice. In comparison to traditional spacing 16 cm x 16 cm SRI spacing gave higher yield and traditional method the panicles hill⁻¹ were 45.2 and 10.8, grains panicle⁻¹ were 170.1 and 184.0, 1000 grain weight was 25.5 g and 25.2 g, respectively.

Mian and Karim (1964) stated that grain yield showed linear trend of increase with the decrease of spacing in the case of transplanting and there was a linear trend of increase in number of tillers plant⁻¹ with the increase in spacing in each method of broadcasting and transplanting.

2.2.9 Straw yield

Rahman (2005) conduct an experiment with rice cv. BR26 with four spacing viz. 20 cm x 15 cm, 25 cm x 15 cm, 20 cm x 20 cm and 25 cm x 20 cm to find out the effect of spacing on yield attributes and yield and reported that the highest grain and straw yields were obtained from 20 cm x 15 cm spacing due to highest number of effective tillers m⁻².

Islam *et al.* (1994) stated that grain and straw yields increased with closer spacing in both row and hill. The closer spacing of 20 cm x 15 cm with six seedlings hill⁻¹ produced 61% and 44% higher grain yield and straw yield respectively over 40 cm x 30 cm spacing with 10 seedling hill⁻¹.

Eunus and Sadeque (1974) found that the number of panicles plant⁻¹ and straw yield were increased with increased plant spacing.

2.2.10 Biological yield

Haque (2002) carried out an experiment during boro season with cv. BINA dhan6 and found that the highest biological yield (14.24 t ha^{-1}) was obtained from 45 day old seedling with the spacing of 30 cm x 30 cm. The lowest biological yield (7.51 t ha^{-1}) was obtained from 45 day old seedling with 40 cm x 40 cm spacing.

Hossain (2002) conducted a field trial during aman season with cv. BRRI dhan32 and results revealed that the highest biological yield (11.65 t ha^{-1}) was obtained from SRI planting method which was a spacing of 25 cm x 15 cm and the lowest (7.94 t ha^{-1}) was in conventional planting method which was the spacing of 25 cm x 15 cm.

2.2.11 Harvest index

Harvest index or the capacity to convert biomass into harvestable organs has been recognized as an important selection criterion for many field crops (Donald, 1968). Dramatic changes in yields of cereal crops during the decades has been associated with the improvement of harvest index.

Thakar *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India, showed that decreased harvest index was produced with increase plant population.

Hossain (2002) conducted a field trial during aman season with cv. BRRI dhan32 and results revealed that the highest harvest index (48.62%) was obtained from SRI planting method which was 15 day old seedling with the spacing of 25 cm x 15 cm and the lowest harvest index (45.94%) obtain in conventional planting method which was 25 day old seedling and the spacing of 25 cm x 15 cm.

Kim *et al.* (1990) found that harvest index was increased in by dense planting.

Bhab *et al.* (1987) found that harvest index was higher with 25 cm x 15 cm spacing.

Shahi *et al.* (1976) reported that the effect of plant spacing and number of seedling hill⁻¹ on growth and yield of dwarf rice variety Joya. Plant spacing closer than 20 cm x 20 cm were not found helpful in augmenting grain yield of rice. The widest spacing produced significantly the tallest plant whereas the minimum row spacing produced the shortest plant. The harvest index declined with decreased spacing.

From the reviews cited above it is clear that planting density has pronounced influence on the growth, yield and yield contributing characters of rice plant. Thus there may have enough scope of investigating into the effect of planting density in favor of yield improvement on boro rice cultivation.

MATERIALS AND METHODS

A field experiment was carried out at Chalk Asankhali Mousa of Dumuria upazila under Khulna district of Bangladesh. The experiment was conducted during the boro season of 2011-'12. The experimental field was a typical farmer's field. This chapter describes the soil and climate of the experimental location, treatments, design, layout, land preparation, planting, intercultural operation, harvesting, threshing, data collection etc.

3.1 Description of the Experimental Site

3.1.1 Location

Geographically the experimental field is located at the 22°39' & 22°56' north latitude and 89°15' & 89°32' east longitude. The experimental site belongs to the Agro-Ecological zone Gopalganj Khulna Beels (AEZ 14) at an average height of 4 m from the mean sea level.

3.1.2 Soil

The experimental field was typical rice growing medium high land under physiographic unit of Gopalganj Khulna Beels Soil. The soil of the experimental field was silty-loam textured, neutral in reaction with pH value 7.1. The fertility level of the soil was medium. The salinity level of the soil was 2.0 dS m⁻¹ (non-saline). The physical and chemical properties of the soil have been presented in appendix III.

3.1.3 Climate and weather

The experimental site belongs to sub-tropical climate which is characterized by high temperature, high humidity, heavy rainfall during the kharif season (April-September) and scanty rainfalls with moderately low temperature during the rabi season (October-March). The monthly average air temperature, relative humidity, rainfall and sunshine during the period of experiment have been presented in appendix II.

seedling nursery. No chemical fertilizers were used in the nursery bed but composed was used.

3.6 Preparation of Experimental Land

The experimental land was first plowed with the help of a power tiller. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering. The field layout was done according to the design. Weeds and stubbles were cleaned off from individual plots and finally plots were leveled properly by wooden plank. The land was then ready for seedling transplanting.

3.7 Fertilizer Application

The experimental plots were fertilized with 92.74, 19.0, 13.75, 2.25 and 2.52 kg ha⁻¹ of N, P, K, S, and Zn, respectively according to soil test basis. The unit plots (4 m x 2.5 m) were fertilized with 201.25, 95.00, 27.50, 12.50 and 7.00 g of Urea, TSP, MoP, Gypsum and Zinc sulphate, respectively. One third of urea and full of other fertilizers were applied as basal dose at the time of final land preparation and thoroughly incorporated into the soil. The remaining two thirds of urea was top dressed in two equal installments at 20 and 35 days after transplanting (DAT).

3.8 Uprooting of Seedlings

The nursery bed was made wet by applying water in the morning on the previous day before uprooting the seedlings to reduce mechanical injury to the roots. The seedlings were uprooted and kept on soft mud in shade before they were transplanted. The seedlings similar in size having no injury were only used for transplanting.

3.9 Transplanting of Seedlings

The seedlings of rice variety BRRI dhan47 were hand transplanted at the age of 47 days, giving 3 seedlings in each hill. Row to row and hill to hill distance were given according to the treatment. The seedlings were transplanted on **16 January 2012**.

3.10 Intercultural Operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.10.1 Gap filling

Seedlings of some hills died off and these were replaced by using the seedlings from the same source. Gap filling was done after one week of transplanting. A very few seedlings were died off.

3.10.2 Weeding

The crop was kept weed free throughout the growing period. Three hand pulling were done at 20, 35 and 50 days after transplanting (DAT) to control weed infestation. Weed infestation appeared to be a severe problem during the early stage of crop establishment.

3.10.3 Irrigation and drainage

Irrigation was started after transplanting as soon as possible. In every week one time 8-10 cm irrigation was given. Irrigation stopped at the hard dough stage of crop. Twelve irrigation was given from transplanting to harvesting the crop. No drainage was needed due to excess rain fall or tidal flood. Source of irrigation water was only surface water from the river of the Moyur. Salinity problem was not noticed during the crop growing season.

3.10.4 Plant protection measures

Furadon 5G @ 10 kg ha⁻¹ was applied at 20 DAT to control rice ufra, stem brer, brown plant hopper and green leaf hopper. Virtaco 40 WG @ 75 g ha⁻¹ was applied at 42 DAT to control stem borer and Theovit 80 WG @ 2.5 kg h⁻¹ was used to control diseases infestation at 45 DAT.

3.11 General Observation of the Experimental Field

The plants of different plots were more vigorous and luxuriant. The green colors of plants of different plots were uniform. The plant size of different plots were also uniform. Incidence of stem borer was observed during the tillering stage and was controlled by using Virtaco 40 WG. The plant did not lodge in any plot. The shattering character of rice grain was observed.

3.12 Sampling and Data Collection

Data on different growth parameters, yield components and yield were collected following the procedure outlined below. Destructive plant samplings were done at 15 days interval to determine different plant growth parameters starting from 30 DAT and continued 45, 60, 75 DAT and at harvest. At each sampling day data were recorded from five randomly selected hills (4th, 7th, 10th, 13th and 16th lines within 20 lines) in each unit plot. The randomly selected hills were identified with bamboo sticks. To avoid border effect, plants were sampled from any of the inner rows.

3.13 Growth Parameters Studied

At each sampling date the following data were recorded.

3.13.1 Plant height (cm)

3.13.2 Number of tillers m⁻²

3.13.3 Number of leaves m⁻²

3.13.4 Dry matter accumulation m⁻²

3.13.5 Crop growth rate

3.13.6 Relative growth rate

3.13.1 Plant height

Plant height was measured from the base of the plant to the tip of the tallest leaf or panicle of each identified five hills from a plot. Then the mean of five hills were calculated. This was done in every plot and plant height was calculated.

3.13.2 Number of tillers

The number of tillers hill⁻¹ was recorded from 5 hills and the means were calculated. Then number of tillers m⁻² was calculated by multiplying the number of hills m⁻².

3.13.3 Number of leaves

The number of leaves hill⁻¹ was recorded from 5 hills and the average number of leaves were calculated. Then number of leaves m⁻² was calculated by multiplying the number of leaves hill⁻¹.

3.13.4 Dry matter accumulation

At each sampling date 4 hills were uprooted from each unit plot and fresh weight was taken and dried in the sun. Then oven dried at 70°C for 48 hours and weighed to calculate the dry matter accumulation m⁻².

3.13.5 Crop growth rate

Crop growth rate (CGR) is the rate of dry matter production unit area⁻¹ of land and unit time⁻¹. It is a simple and important index of agricultural productivity (Hunt, 1978). Crop growth rate changes with growth (Tanaka, 1983) and reaches maximum at panicle emergence and decreases soon after panicle emergence (Wilson and Ellis, 1981).

The crop growth rate was measured as per following formula (Radford, 1967)

$$\text{CGR} = 1/\text{GA} \times (W_2 - W_1) / (T_2 - T_1) \text{ g m}^{-2} \text{ day}^{-1}$$

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

3.15.1 Plant height

The plant height was measured from the ground level to the tip of the longest leaf or panicle.

3.15.2 Number of leaves

The number of green leaves hill^{-1} was calculated first then it was converted into m^{-2}

3.15.3 Total number of tillers

The number of tillers hill^{-1} counted first then it was calculated in number of tiller m^{-2} .

Tillers which had at least one leaf visible were counted included both effective and non effective tillers.

3.15.4 Number of effective tillers

Tillers having panicles which had at least one grain were considered as effective tillers.

3.15.5 Number of non effective tillers

Tillers having no panicle and grain were considered as non effective tillers.

3.15.6 Length of flag leaf

Flag leaf length was measured from the basal node of the leaf to the apex of each leaf.

3.15.7 Panicle length

Panicle length was measured from the basal node of the rachis to the apex of each panicle

3.15.8 Number of spikelets panicle⁻¹

Spikelets were separated from panicles and number of spikelets panicle^{-1} was counted manually.

3.15.9 Number of filled spikelets panicle⁻¹

Presence of any food material in the spikelet was considered as filled spikelet and such spikelets were counted.

3.15.10 Number of unfilled spikelets panicle⁻¹

The spikelets lacked any food material inside were considered as sterile spikelets and such spikelets present on each panicle was counted.

3.15.11 1000 grain weight

One thousand clean dried grains from the seed stock of each plot were counted separately and weighed by an electronic balance and expressed in g. The weight was adjusted at 14% moisture content.

3.15.12 Grain yield

Grain yield were recorded from whole plot basis. The grain weight of each plot was recorded carefully after proper drying in the sun. Then 200 g of grain was taken from each plot then oven dried at 70°C for 48 hours. The oven dried grain weight were recorded again and adjusted to 14% moisture level. The grain yield was first converted to kg plot⁻¹ and then t ha⁻¹. Yield of selected five hills and yield of other hills that are used for dry matter measurement are added with the total grain yield. The grain and straw adjusted at 14% moisture with the following formula:

$$\text{Adjusted grain weight} = 100 M / 86 \times W$$

Where,

M = Moisture percentage of harvested grain or straw

W = Fresh weight of harvested grain or straw.

3.15.13 Straw yield

Straw yield were recorded carefully from whole plot basis. The straw weight of each plot was recorded after proper drying in the sun. Then 200 g of straw was taken from each plot then oven dried at 70°C for 48 hours. The oven dried straw weight were recorded again and adjusted to 14% moisture level. The straw yields were converted to kg plot⁻¹

and then $t\ ha^{-1}$. Yield of selected five hills and yield of other hills that are used for dry matter measurement are added with total straw yield.

3.15.14 Biological yield

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated using the following formula:

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

3.15.15 Harvest index

The harvest index (HI) was computed as the ratio of economic yield (grain yield) to the biological yield (grain yield + straw yield).

$$\text{HI (\%)} = \text{Economic yield / Biological yield} \times 100 \text{ (Gardner et al, 1985)}$$

3.16 Dry Matter Accumulation at Harvest

At each plot selected 5 hills were uprooted for collection of various data. At first fresh weight was taken and various data were collected. Then oven dried at 70°C for 48 hours and weighed to calculate the dry matter accumulation m^{-2} . The weight was adjusted at 14% moisture.

3.17 Meteorological Data

Monthly average of maximum and minimum air temperature, relative humidity rainfall and sunshine hour were obtained from Bangladesh Meteorological Department, Khulna Region, Khulna during the entire period of study and presented in appendix II.

3.18 Statistical Analysis

The collected data were statistically analyzed following the analysis of variance (ANOVA) technique and the significance of the mean difference were adjudged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a statistical computer package program MSTAT- C.

CHAPTRR IV
RESULTS & DISCUSSION

RESULTS AND DISCUSSION

Results were obtained from the present study regarding the effect of planting density on different growth parameters, yield and yield contributing characters of BRRI dhan47 is presented and discussed parameter wise in this chapter. The results of the study have been presented in table 1 to 7, figure 1 to 3 and appendices I to VII.

4.1 Effect of Planting Density on Growth Parameters

4.1.1 Plant height

Plant height was significantly affected by planting densities at all the sampling dates (Table 1). Plant height increased up to harvest irrespective of treatments and reached a plateau.

The result revealed that at 30 DAT, the tallest plant (46.20 cm) was obtained from the planting density D_9 {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} which was statistically similar to D_3 {20 cm x 20 cm (24 hills m⁻²)} (44.27 cm). The lowest plant height (40.27 cm) was obtained from the planting density D_1 {20 cm x 10 cm (50 hills m⁻²)} which was statistically similar to D_4 {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (40.87 cm) and D_7 {(30 cm x 10 cm) x 10 cm (50 hills m⁻²)} (41.07 cm), respectively.

At 45 DAT, the highest plant height (67.87 cm) was obtained from the planting density D_3 {20 cm x 20 cm (50 hills m⁻²)} which was statically similar to D_9 {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (64.67 cm). The lowest plant height (60.20 cm) was obtained from the planting density D_7 {(30 cm x 10 cm) x 10 cm (50 hills m⁻²)} which was statically similar to D_4 {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (60.53 cm), D_1 {20 cm x 10 cm (50 hills m⁻²)} (60.73 cm), D_5 {(25 cm + 15 cm) x 15 cm (32 hills m⁻²)} (61.33 cm), D_2 {20 cm x 15 cm (32 hills m⁻²)} (62.80 cm) and D_8 {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (62.93 cm), respectively.

At 60 DAT, the tallest plant height (84.67 cm) was obtained from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (83.87 cm), D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (83.53 cm), D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (82.93 cm), D_2 $\{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (82.60 cm) and D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (82.20 cm), respectively. The lowest plant height (76.93 cm) was obtained from the planting density D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ preceded by D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (80.07 cm).

At 75 DAT, the highest plant height (100.7cm) was obtained from the planting density D_3 $\{20 \text{ cm} \times 20 \text{ cm} (50 \text{ hills m}^{-2})\}$ and D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statically similar to D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (100.3 cm), D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (99.60 cm), D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (99.30 cm) and D_2 $\{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (99.07 cm), respectively. The lowest plant height (97.20 cm) was obtained from D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statically similar to D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (97.73 cm) and D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (98.27 cm), respectively.

At harvest, the tallest plant height (102.8 cm) was obtained from the planting density D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statically similar to D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (102.5 cm), D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (102.3 cm), D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (101.2 cm), D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (101.0 cm) and D_2 $\{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (100.7 cm), respectively. The shortest plant height (99.07 cm) was obtained from the planting density D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statically similar to D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (100.0 cm) and D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (100.2 cm), respectively.

It was observed that lower planting density increased plant height than higher planting density. It might be due to more space, sunlight and nutrients available to wider spaced plants. It is generally agreed that lower planting density results taller plants (Shah *et al.*, 1991 and Zadeh and Mirlohi, 1998). It was also observed that paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration. Planting pattern D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} performed better and planting pattern D₁ {20 cm x 10 cm (50 hills m⁻²)} performed poor.

Table 1. Effect of planting density on plant height of BRRI dhan47 at different days after transplanting

Planting densities	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
D ₁	40.27 d	60.73 c	76.93 d	97.20 c	100.00 c
D ₂	43.80 b	62.80 bc	82.60 abc	99.07 abc	100.70 abc
D ₃	44.27 ab	67.87 a	83.87 ab	100.70 a	102.30 ab
D ₄	40.87 cd	60.53 c	80.07 c	97.73 bc	99.07 c
D ₅	42.53 bc	61.33 bc	82.20 abc	99.30 ab	101.20 abc
D ₆	43.13 b	63.27 bc	83.53 ab	100.30 a	102.80 a
D ₇	41.07 cd	60.20 c	81.60 bc	98.27 bc	100.20 bc
D ₈	42.33 bc	62.93 bc	82.93 ab	99.60 ab	101.00 abc
D ₉	46.20 a	64.67 ab	84.67 a	100.70 a	102.50 a
Significance level	0.01	0.01	0.01	0.05	0.05
CV (%)	2.12	2.45	1.53	1.19	1.33

□ Green color denotes highest value

□ Pink color denotes lowest value

D₁ = 20 cm x 10 cm (50 hills m⁻²), D₂ = 20 cm x 15 cm (32 hills m⁻²), D₃ = 20 cm x 20 cm (24 hills m⁻²), D₄ = (25 cm + 15 cm) x 10 cm (50 hills m⁻²), D₅ = (25 cm + 15 cm) x 15 cm (32 hills m⁻²), D₆ = (25 cm + 15 cm) x 20 cm (24 hills m⁻²), D₇ = (30 cm + 10 cm) x 10 cm (50 hills m⁻²), D₈ = (30 cm + 10 cm) x 15 cm (32 hills m⁻²) and D₉ = (30 cm + 10 cm) x 20 cm (24 hills m⁻²)

4.1.2 Tiller dynamics

Significant variation of number of tillers m⁻² was found due to different planting densities of BRRI dhan47 at all the sampling dates (Table 2). Tiller number in all the treatments

increased almost exponentially up to 45 DAT. After 45 DAT onwards, a sharp decline in tiller number was noticed.

The result revealed that at 30 DAT, the highest number of tillers (273.3 m^{-2}) was recorded from the planting density D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ followed by D_7 $\{(30 \text{ cm} \times 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ (250.0 m^{-2}). The lowest number of tillers (121.6 m^{-2}) was recorded from D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ which was statistically similar to D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ (123.2) and D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ (128.0 m^{-2}), respectively.

At 45 DAT, the highest number of tillers (553.3 m^{-2}) was recorded from the planting density D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ followed by D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ (490.0 m^{-2}). The lowest number of tillers (294.4 m^{-2}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ preceded by D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ (321.0 m^{-2}).

At 60 DAT, the highest number of tillers (460.0 m^{-2}) was recorded from the planting density D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ followed by D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ (436.7 m^{-2}). The lowest number of tillers (252.8 m^{-2}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ preceded by D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ (281.6 m^{-2}).

At 75 DAT, the highest number of tillers (403.3 m^{-2}) was recorded from the planting density D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ which was statistically similar to D_7 $\{(30 \text{ cm} \times 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ (393.3 m^{-2}) and D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills } \text{m}^{-2})\}$ (376.7 m^{-2}), respectively. The lowest number of tillers (292.8 m^{-2}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills } \text{m}^{-2})\}$ which was statistically similar to D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills } \text{m}^{-2})\}$ (311.5 m^{-2}), D_2 $\{20$

Table 2. Effect of planting density on tiller dynamics of BRRI dhan47 at different days after transplanting

Planting densities	Number of tillers m ⁻²				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
D ₁	240.0 b	553.3 a	460.0 a	376.7 a	370.0 a
D ₂	160.0 d	366.9 de	324.3 d	320.0 bc	298.7 bc
D ₃	128.0 e	321.0 fg	281.6 e	321.6 bc	290.9 bc
D ₄	273.3 a	490.0 b	436.7 b	403.3 a	386.7 a
D ₅	153.6 d	392.5 cd	339.2 d	343.5 b	305.1 b
D ₆	121.6 e	321.6 fg	283.2 e	323.2 bc	288.0 bc
D ₇	250.0 b	423.3 c	406.7 c	393.3 a	363.3 a
D ₈	183.5 c	349.1 ef	322.1 d	311.5 c	292.3 bc
D ₉	123.2 e	294.4 g	252.8 f	292.8 c	275.2 c
Significance level	0.01	0.01	0.01	0.01	0.01
CV (%)	4.77	4.23	2.97	4.02	3.28

D₁ = 20 cm x 10 cm (50 hills m⁻²), D₂ = 20 cm x 15 cm (32 hills m⁻²), D₃ = 20 cm x 20 cm (24 hills m⁻²), D₄ = (25 cm + 15 cm) x 10 cm (50 hills m⁻²), D₅ = (25 cm + 15 cm) x 15 cm (32 hills m⁻²), D₆ = (25 cm + 15 cm) x 20 cm (24 hills m⁻²), D₇ = (30 cm + 10 cm) x 10 cm (50 hills m⁻²), D₈ = (30 cm + 10 cm) x 15 cm (32 hills m⁻²) and D₉ = (30 cm + 10 cm) x 20 cm (24 hills m⁻²)

4.1.3 Number of leaves

Significant variation of number of leaves m⁻² was found due to different planting densities of BRRI dhan47 at all the sampling dates (Table 3). Leaf number in all the treatments increased almost exponentially up to 60 DAT. From 75 DAT, a decreasing trend in leaf number was noticed.

The result revealed that at 30 DAT, the highest number of leaves (886.7 m⁻²) was recorded from the planting density D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (853.3 m⁻²). The lowest number of leaves (376.0 m⁻²) was recorded from the planting density D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} preceded by D₃ {20 cm x 20 cm (24 hills m⁻²)} (420.8 m⁻²).

At 45 DAT, the highest number of leaves (2183.0 m⁻²) was recorded from the planting density D₁ {20 cm x 10 cm (50 hills m⁻²)} which was statistically similar to D₄ {(25 cm +

15 cm) x 10 cm (50 hills m⁻²) (1937 m⁻²) and D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (1793 m⁻²), respectively. The lowest number of leaves (900.8 m⁻²) was recorded from the planting density D₃ {20 cm x 20 cm (24 hills m⁻²)} which was statistically similar to D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (1126 m⁻²) and D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (1242 m⁻²), respectively.

At 60 DAT, the highest number of leaves (2250.0 m⁻²) was recorded from the planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₁ {20 cm x 10 cm (50 hills m⁻²)} (2197.0 m⁻²) and D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (2163 m⁻²), respectively. The lowest number of leaves (1356.0 m⁻²) was recorded from the planting density D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} which was statistically similar to D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (1392.0 m⁻²) and D₃ {20 cm x 20 cm (24 hills m⁻²)} (1421.0 m⁻²), respectively.

At 75 DAT, the highest number of leaves (1533.0 m⁻²) was recorded from the planting density D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (1523.0 m⁻²) and D₁ {20 cm x 10 cm (50 hills m⁻²)} (1463.0 m⁻²), respectively. The lowest number of leaves (1107.0 m⁻²) was recorded from the planting density D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} which was statistically similar to D₂ {20 cm x 15 cm (32 hills m⁻²)} (1148.0 m⁻²), D₈ {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (1214.0 m⁻²) and D₃ {20 cm x 20 cm (24 hills m⁻²)} (1216.0 m⁻²), respectively.

At harvest, the highest number of leaves (936.7 m⁻²) was recorded from the planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₁ {20 cm x 10 cm (50 hills m⁻²)} (853.3 m⁻²) and D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (836.7 m⁻²), respectively. The lowest number of leaves (625.6 m⁻²) was recorded

from the planting density D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (646.3 m^{-2}), D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (651.1 m^{-2}) and D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (708.8 m^{-2}), respectively.

It was observed that higher planting density produced higher number of leaves m^{-2} . It might be due to higher population density that increased the total number of tillers unit area⁻¹. This result was in agreement with the findings of Oghalo (2011) who reported that spacing significantly affect number of leaves and leaf length. Number of leaves m^{-2} found better in paired row than those of single rows. It might be due to get more sunlight and available aeration.

Table 3. Effect of planting density on number of leaves of BRRI dhan47 at different days after transplanting

Planting densities	Number of leaves m^{-2}				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
D_1	766.7 b	2183.0 a	2197.0 a	1463.0 ab	853.3 ab
D_2	580.8 c	1501.0 bc	1734.0 b	1148.0 c	759.5 bc
D_3	420.8 e	900.8 d	1421.0 cd	1216.0 bc	708.8 cd
D_4	853.3 a	1937.0 ab	2250.0 a	1523.0 a	936.7 a
D_5	526.9 d	1622.0 bc	1687.0 b	1306.0 abc	740.3 bc
D_6	376.0 f	1242.0 cd	1356.0 d	1358.0 abc	625.6 d
D_7	886.7 a	1793.0 ab	2163.0 a	1533.0 a	836.7 ab
D_8	552.5 cd	1491.0 bc	1514.0 c	1214.0 bc	646.3 cd
D_9	430.4 e	1126.0 cd	1392.0 cd	1107.0 c	651.1 cd
Significance level	0.01	0.01	0.01	0.01	0.01
CV (%)	3.26	15.34	3.99	10.17	6.70

$D_1 = 20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_2 = 20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})$, $D_3 = 20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})$, $D_4 = (25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_5 = (25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})$, $D_6 = (25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})$, $D_7 = (30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_8 = (30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})$ and $D_9 = (30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})$

4.1.4 Total dry matter production

Significant variation on dry matter (DM) production (g m^{-2}) was found due to different planting densities of BRRI dhan47 at all the sampling dates (Table 4).

The result revealed that at 30 DAT, the highest dry matter production (145.0 g m^{-2}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (135.7 g m^{-2}) and D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (132.3 g m^{-2}), respectively. The lowest DM production (85.0 g m^{-2}) was recorded from the planting density D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (88.33 g m^{-2}) and D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (90.0 g m^{-2}), respectively.

At 45 DAT, the highest dry matter production (670.0 g m^{-2}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ followed by D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (603.3 g m^{-2}). The lowest DM production (330.0 g m^{-2}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (370.0 g m^{-2}) and D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (370.0 g m^{-2}).

At 60 DAT, the highest dry matter production (1297.0 g m^{-2}) was recorded from D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (1177.0 g m^{-2}). The lowest DM production (973.3 g m^{-2}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (1010.0 g m^{-2}), D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (1017.0 g m^{-2}), D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (1067.0 g m^{-2}) and D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (1093.0 g m^{-2}), respectively.

At 75 DAT, the highest dry matter production (1540.0 g m^{-2}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (1533 g m^{-2}) and D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10$

cm (50 hills m^{-2}) (1443.0 g m^{-2}), respectively. The lowest DM production (1317.0 g m^{-2}) was recorded from the planting density D_9 {(30 cm + 10 cm) x 20 cm (24 hills m^{-2})} which was statistically similar to D_8 {(30 cm + 10 cm) x 15 cm (32 hills m^{-2})} (1327 g m^{-2}), D_3 {20 cm x 20 cm (24 hills m^{-2})} (1340 g m^{-2}), D_6 {(25 cm + 15 cm) x 20 cm (24 hills m^{-2})} (1357 g m^{-2}), D_5 {(25 cm + 15 cm) x 15 cm (32 hills m^{-2})} (1357 g m^{-2}) and D_2 {20 cm x 15 cm (32 hills m^{-2})} (1380 g m^{-2}), respectively.

At harvest, the highest dry matter production (1657.0 g m^{-2}) was recorded from D_7 {(30 cm + 10 cm) x 10 cm (50 hills m^{-2})} and D_1 {20 cm x 10 cm (50 hills m^{-2})} which was statistically similar to D_2 {20 cm x 15 cm (32 hills m^{-2})} (1593.0 g m^{-2}) and D_4 {(25 cm + 15 cm) x 10 cm (50 hills m^{-2})} (1590.0 g m^{-2}), respectively. The lowest DM production (1463.0 g m^{-2}) was recorded from the planting density D_9 {(30 cm + 10 cm) x 20 cm (24 hills m^{-2})} which was statistically similar to D_3 {20 cm x 20 cm (24 hills m^{-2})} (1477.0 g m^{-2}), D_8 {(30 cm + 10 cm) x 15 cm (32 hills m^{-2})} (1797 g m^{-2}), D_6 {(25 cm + 15 cm) x 20 cm (24 hills m^{-2})} (1503.0 g m^{-2}) and D_5 {(25 cm + 15 cm) x 15 cm (32 hills m^{-2})} (1520 g m^{-2}), respectively.

From these results it was revealed that dry matter increased with increase in planting density. It might be due to more tillers and more leaves in higher planting density. Paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration.

Contribution of population to higher dry matter production is well recognized and was revealed by many authors (Murty and Murty, 1980., Murty and Murty, 1981 and Srinivasan and Purushothaman, 1990). They reported that the closer spacing increased number of tillers and dry matter production m^{-2} . Spacing determines not only the intensity of intra-varietal competition for light, water and nutrient but also the DM partitioning

between the organs. Spacing changes the canopy structure of a crop, controlling crop growth rate and harvest index.

Paired row planting pattern, D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} perform well followed by single row pattern D₁ {20 cm x 10 cm (50 hills m⁻²)} and paired row pattern D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)}. But paired row planting pattern D₉ {(30 cm + 10 cm) x 20 cm (50 hills m⁻²)} showed poor performed.

Table 4. Effect of planting density on dry matter production of BRRI dhan47 at different days after transplanting

Planting densities	Dry matter (g m ⁻²) production				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
D ₁	135.7 a	586.7 b	1297.0 a	1533.0 a	1657.0 a
D ₂	106.7cd	466.7 d	1147.0 b	1380.0 bc	1593.0 ab
D ₃	85.0 e	370.0 e	1067.0 bc	1340.0 bc	1477.0 b
D ₄	132.3 ab	603.3 b	1177.0 ab	1443.0 ab	1590.0 ab
D ₅	105.0 d	500.0 cd	1017.0 c	1357.0 bc	1520.0 b
D ₆	88.3e	370.0 e	1010.0 c	1357.0 bc	1503.0 b
D ₇	145.0 a	670.0 a	1157.0 b	1540.0 a	1657.0 a
D ₈	120.0 bc	533.3 c	1093.0 bc	1327.0 bc	1497.0 b
D ₉	90.0 e	330.0 e	973.3 c	1317.0 c	1463.0 b
Significance level	0.01	0.01	0.01	0.01	0.01
CV (%)	5.74	4.74	5.06	3.91	3.77

D₁ = 20 cm x 10 cm (50 hills m⁻²), D₂ = 20 cm x 15 cm (32 hills m⁻²), D₃ = 20 cm x 20 cm (24 hills m⁻²), D₄ = (25 cm + 15 cm) x 10 cm (50 hills m⁻²), D₅ = (25 cm + 15 cm) x 15 cm (32 hills m⁻²), D₆ = (25 cm + 15 cm) x 20 cm (24 hills m⁻²), D₇ = (30 cm + 10 cm) x 10 cm (50 hills m⁻²), D₈ = (30 cm + 10 cm) x 15 cm (32 hills m⁻²) and D₉ = (30 cm + 10 cm) x 20 cm (24 hills m⁻²)

4.1.5 Crop growth rate

Crop growth rate (g m⁻² day⁻¹) was recorded from 30 DAT to 75 DAT with 15 days interval and after 75 DAT to harvest it was recorded with 25 days interval (Table 5). At 45-60 DAT, crop growth rate was higher and at 30-45 DAT it was second higher. Crop growth rate in all the treatments increased almost exponentially up to 60 DAT after that crop growth rate started to decrease.

It was observed that at 30-45 DAT, the highest crop growth rate ($35.0 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_7 \{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ followed by $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($31.40 \text{ g m}^{-2} \text{ day}^{-1}$). The lowest crop growth rate ($16.0 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to $D_6 \{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($18.78 \text{ g m}^{-2} \text{ day}^{-1}$) and $D_3 \{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($19.0 \text{ g m}^{-2} \text{ day}^{-1}$), respectively.

At 45-60 DAT, the highest crop growth rate ($47.33 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_1 \{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to $D_3 \{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($46.44 \text{ g m}^{-2} \text{ day}^{-1}$), $D_2 \{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ ($45.33 \text{ g m}^{-2} \text{ day}^{-1}$), $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($42.89 \text{ g m}^{-2} \text{ day}^{-1}$), $D_6 \{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($42.67 \text{ g m}^{-2} \text{ day}^{-1}$) and $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($38.22 \text{ g m}^{-2} \text{ day}^{-1}$), respectively. The lowest crop growth rate ($32.44 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_7 \{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to $D_5 \{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ ($34.44 \text{ g m}^{-2} \text{ day}^{-1}$) and $D_8 \{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ ($37.33 \text{ g m}^{-2} \text{ day}^{-1}$), respectively.

At 60-75 DAT, the highest crop growth rate ($25.56 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_7 \{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ followed by $D_6 \{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($23.11 \text{ g m}^{-2} \text{ day}^{-1}$). The lowest crop growth rate ($15.56 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density $D_2 \{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ and $D_8 \{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ preceded by $D_1 \{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($15.78 \text{ g m}^{-2} \text{ day}^{-1}$).

At 75 DAT-harvest, the highest crop growth rate ($8.53 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density D_2 $\{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ followed by D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ ($6.80 \text{ g m}^{-2} \text{ day}^{-1}$). The lowest crop growth rate ($4.67 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ preceded by D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($4.93 \text{ g m}^{-2} \text{ day}^{-1}$).

It was observed that higher planting density increases crop growth rate. It might be due to more tiller and more leaves in higher planting density. These results agreed with (Ray *et al.* 2000 and Talukder, 1998). It was also found that paired row planting performed better than single row planting. It might be due to receive more sunlight and available aeration. Although, the higher the population density higher the CGR, and this trend also reported by Hunt, (1978) and Wilson and Ellis (1981).

Table 5. Effect of planting density on Crop growth rate of BRRI dhan47 at different days after transplanting

Planting densities	Crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$)			
	30 - 45 DAT	45 - 60 DAT	60 - 75 DAT	75 DAT - Harvest
D_1	30.07 bc	47.33 a	15.78	4.93
D_2	24.00 d	45.33 ab	15.56	8.53
D_3	19.00 e	46.44 ab	18.22	5.47
D_4	31.40 b	38.22 abcd	17.78	5.87
D_5	26.33 d	34.44 cd	22.67	6.53
D_6	18.78 e	42.67 abc	23.11	5.87
D_7	35.00 a	32.44 d	25.56	4.67
D_8	27.56 cd	37.33 bcd	15.56	6.80
D_9	16.00 e	42.89 abc	22.89	5.87
Significance level	0.01	0.01	NS	NS
CV (%)	6.20	10.49	23.04	42.23

$D_1 = 20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_2 = 20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})$, $D_3 = 20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})$, $D_4 = (25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_5 = (25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})$, $D_6 = (25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})$, $D_7 = (30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})$, $D_8 = (30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})$ and $D_9 = (30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})$

4.1.6 Relative growth rate

Relative growth rate g ($\text{g of dry weight}^{-1} \text{ day}^{-1}$) was recorded from 30 DAT to 75 DAT with 15 days interval and after 75 DAT to harvest it was recorded with 25 days interval (Table 6). The relative growth rate was higher at 30-45 DAT then started to decrease gradually up to harvest. This result agreed with (Tesar, 1984) who stated that relative growth rate decrease with plant age. This decrease is due to the fact that an increasing part of the plant is structural rather than metabolically active tissue and as such does not contribute to growth. The decrease is also due impart to shading and increased age of lower leaves.

It was observed that at 30-45 DAT, the highest relative growth rate ($0.253 \text{ g g}^{-1} \text{ day}^{-1}$) was recorded from the planting density D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ followed by D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($0.241 \text{ g g}^{-1} \text{ day}^{-1}$). The lowest relative growth rate ($0.177 \text{ g g}^{-1} \text{ day}^{-1}$) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ preceded by D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($0.213 \text{ g g}^{-1} \text{ day}^{-1}$).

At 45-60 DAT, the highest relative growth rate ($0.130 \text{ g g}^{-1} \text{ day}^{-1}$) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ which was statistically similar to D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ ($0.125 \text{ g g}^{-1} \text{ day}^{-1}$). The lowest relative growth rate ($0.0486 \text{ g g}^{-1} \text{ day}^{-1}$) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ preceded by D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ ($0.063 \text{ g g}^{-1} \text{ day}^{-1}$).

At 60-75 DAT, the highest relative growth rate ($0.024 \text{ g g}^{-1} \text{ day}^{-1}$) was recorded from the planting density of D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ followed by ($0.023 \text{ g g}^{-1} \text{ day}^{-1}$) D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. The lowest relative growth rate

(0.012 g g⁻¹ day⁻¹) was recorded from the planting density D₁ {20 cm x 10 cm (24 hills m⁻²)} preceded by (0.014 g g⁻¹ day⁻¹) D₂ {20 cm x 15 cm (32 hills m⁻²)}.

At 75 DAT- harvest the highest relative growth rate (0.006 g g⁻¹ day⁻¹) was recorded from the planting density D₂ {20 cm x 15 cm (32 hills m⁻²)} followed by D₈ {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (0.005 g g⁻¹ day⁻¹). The lowest relative growth rate (0.003 g g⁻¹ day⁻¹) was recorded from the planting density D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} and D₁ {20 cm x 10 cm (24 hills m⁻²)} preceded by D₃ {20 cm x 20 cm (24 hills m⁻²)} (0.004 g g⁻¹ day⁻¹), D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (0.004 g g⁻¹ day⁻¹), D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (0.004 g g⁻¹ day⁻¹) and D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (0.004 g g⁻¹ day⁻¹).

It was observed that lower planting density increases relative growth rate and higher planting density decrease it. It might be due to get more nutrient and more light in lower planting density and opposite in higher planting density. It was also shown that paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration.

These results agreed with Mia (2001) who reported that relative growth rate was highest in widest spacing and lowest in closest spacing.

Table 6. Effect of planting density on Relative growth rate of BRRI dhan47 at different days after transplanting

Planting densities	Relative growth rate g (g of dry weight) ⁻¹ day ⁻¹			
	30 - 45 DAT	45 - 60 DAT	60 - 75 DAT	75 DAT - Harvest
D ₁	0.222 d	0.080 d	0.012	0.003
D ₂	0.226 cd	0.097 c	0.014	0.006
D ₃	0.224 d	0.125 a	0.017	0.004
D ₄	0.237 b	0.063 e	0.015	0.004
D ₅	0.253 a	0.069 e	0.022	0.005
D ₆	0.213 e	0.115 b	0.023	0.004
D ₇	0.241 b	0.048 f	0.022	0.003
D ₈	0.229 c	0.070 e	0.015	0.005
D ₉	0.177 f	0.130a	0.024	0.004
Significance level	0.05	0.01	NS	NS
CV (%)	9.79	12.07	27.27	44.47

D₁ = 20 cm x 10 cm (50 hills m⁻²), D₂ = 20 cm x 15 cm (32 hills m⁻²), D₃ = 20 cm x 20 cm (24 hills m⁻²), D₄ = (25 cm + 15 cm) x 10 cm (50 hills m⁻²), D₅ = (25 cm + 15 cm) x 15 cm (32 hills m⁻²), D₆ = (25 cm + 15 cm) x 20 cm (24 hills m⁻²), D₇ = (30 cm + 10 cm) x 10 cm (50 hills m⁻²), D₈ = (30 cm + 10 cm) x 15 cm (32 hills m⁻²) and D₉ = (30 cm + 10 cm) x 20 cm (24 hills m⁻²)

4.2 Effect of Planting Density on Yield and Yield Contributing Characters

4.2.1 Number of effective tillers m⁻²

Significant variation in number of effective tillers m⁻² was found due to different planting density of BRRI dhan47 (Table 7 and Figure 1). The number of effective tillers progressively increased with increasing population density unit area⁻¹ up to a certain limit above which it was decreased.

The result revealed that the highest number of effective tillers (386.7 m⁻²) was recorded in paired row planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₁ {20 cm x 10 cm (50 hills m⁻²)} (370.0 m⁻²) and D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (363.3 m⁻²), respectively. The lowest number of effective tillers (275.2 m⁻²) was recorded from paired row planting density D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} which was statistically similar to D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (288.0 m⁻²), D₃ {20 cm x 20 cm (24 hills m⁻²)} (290.9 m⁻²), D₈ {(30 cm + 10

cm) x 15 cm (32 hills m⁻²)} (292.3 m⁻²) and D₂ {20 cm x 15 cm (32 hills m⁻²)} (298.7 m⁻²), respectively.

In the present study, it was observed that higher planting density performed better than lower planting density. It might be due to higher population density would increase total number of tillers unit area⁻¹. Paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration.

In paired row planting pattern D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} planting density shown good result followed by D₁ {20 cm x 10 cm (50 hills m⁻²)} and D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)}. On the other hand the lowest number of effective tillers was obtained from D₉ {(30 cm + 10 cm) x 20 cm (50 hills m⁻²)}.

This result was in agreement with the findings of Reddy *et al.* (2001) and Mannan *et al.* (1991), they reported that highest number of panicle unit area⁻¹ increased with the increase in planting density and decreased with the decrease in planting density.

4.2.2 Flag leaf length

Flag leaf length was significantly influenced by planting density (Table 7 and Figure 2). The longest flag leaf length (29.10 cm) was produced by the paired row planting density D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} which was statically similar to single row planting density D₁ {20 cm x 10 cm (50 hills m⁻²)} (28.33 cm) and paired planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (28.10 cm), respectively. The shortest length (23.87 cm) was recorded from the paired row planting density D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} preceded by the single row planting density by D₃ {20 cm x 20 cm (24 hills m⁻²)} (25.07 cm).

In the present study it was found that higher planting density performed better than lower planting density and planting pattern that includes 50 hills m⁻² also performed better than

32 hills m^{-2} and 24 hills m^{-2} . The reasons might be due to that competition for growth resources was more in closer spacing and to support more assimilate production flag leaf length was higher in closer spacing. It was also observed that the paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration.

Similar results were observed by Oghalo (2011) who stated that increase population density increase leaf number and leaf length.

.2.3 Panicle length

Panicle length was significantly influenced by planting density (Table 7). The longest panicle length (24.65 cm) was recorded from the single row planting density D_3 {20 cm x 20 cm (24 hills m^{-2})} which was statically similar to D_6 {(25 cm + 15 cm) x 20 cm (24 hills m^{-2})} (24.30 cm), D_5 {(25 cm + 15 cm) x 15 cm (32 hills m^{-2})} (24.10 cm), D_9 {(30 cm + 10 cm) x 20 cm (24 hills m^{-2})} (24.01 cm) and D_2 {20 cm x 15 cm (32 hills m^{-2})} (23.93 cm), respectively. The shortest panicle length (22.44 cm) was recorded from the paired row planting density D_4 {(25 cm + 15 cm) x 10 cm (50 hills m^{-2})} which was statistically similar to D_7 {(30 cm + 10 cm) x 10 cm (50 hills m^{-2})} (22.93 cm).

In the present study, it was observed that higher population density produced shorter panicles. The plants grow in lower planting density get more sunlight, space, air and nutrients which stimulate positively towards panicle development than higher planting density. Single row planting performed better than paired row planting and planting density 24 hills m^{-2} also shown better results than 50 hills m^{-2} .

Similar results were observed by Kalita *et al.* (1997), Rekhashri *et al.* (1997) and Liou (1987). They stated that closer spacing decreased panicle length.

4.2.4 Number of spikelets panicle⁻¹

Number of spikelets panicle⁻¹ was significantly influenced by planting density (Table 7). The result revealed that the highest number of spikelets panicle⁻¹ (144.6) was recorded from the single row planting density D₃{20 cm x 20 cm (24 hills m⁻²)} which was statistically similar to D₆{(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (138.4), D₉{(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (133.1), D₅{(25 cm + 15 cm) x 15 cm (32 hills m⁻²)} (131.5) and D₂{20 cm x 15 cm (32 hills m⁻²)} (130.5), respectively. The lowest number of spikelets panicle⁻¹ (113.5) was recorded from the paired row planting density D₄{(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₁{20 cm x 10 cm (50 hills m⁻²)} (116.1), D₇{(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (119.3) and D₈{(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (120.3), respectively.

It was found that number of spikelets panicle⁻¹ decreased with increasing planting density. The reasons might be due to that competition for growth resources was more in closer spacing, at the same time assimilate production as well as translocation was also poor in overcrowded stands. In number of spikelets panicle⁻¹, single row planting performed better than paired row planting and 24 hills m⁻² also shown better result than 32 and 50 hills m⁻².

This result was in agreement with the findings of Ghosh *et al.* (1998) and Zadeh and Mirlohi (1998). They reported that number of spikelets panicle⁻¹ increased with the decrease in planting density and decreased with the increase in planting density.

4.2.5 Number of filled spikelets panicle⁻¹

Filled spikelets panicle⁻¹ was significantly affected by the planting density (Table 7). The result revealed that the highest number of filled spikelets panicle⁻¹ (129.9) was recorded from the single row planting density D₃{20 cm x 20 cm (24 hills m⁻²)} which was statistically similar to D₆{(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (124.3), D₉{(30 cm +

10 cm) x 20 cm (24 hills m⁻²) (123.1), D₅ {(25 cm + 15 cm) x 15 cm (32 hills m⁻²)} (118.0) and D₂ {20 cm x 15 cm (32 hills m⁻²)} (117.9), respectively. The lowest number of filled spikelets panicle⁻¹ (99.33) was recorded from the paired row planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to D₁ {20 cm x 10 cm (50 hills m⁻²)} (101.3), D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} (106.1) and D₈ {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (108.7), respectively .

Among the planting densities it was found that number of filled spikelets panicle⁻¹ decreased with increasing planting density and 24 hills m⁻² also shown better result than 32 and 50 hills m⁻². This might be due to competition for growth resources was more in higher planting density, at the same time assimilate production as well as translocation was also poor in overcrowded stands. In regard to number of filled grain panicle⁻¹, single row planting performed better than paired row.

This result was in agreement with the findings of BRRI (1998) who reported that the number of filled spikelets panicle⁻¹ increased with the decrease in planting density and decreased with the increase in planting density.

4.2.6 Number of unfilled spikelets panicle⁻¹

Number of unfilled spikelets panicle⁻¹ was found not to be influenced by planting density (Table 7). From the results, it was observed that numerically the highest number of unfilled spikelets panicle⁻¹ (14.87) was obtained from the single row planting density D₁ {20 cm x 10 cm (50 hills m⁻²)} followed by D₃ {20 cm x 20 cm (24 hills m⁻²)} (14.67). The lowest number of unfilled spikelets panicle⁻¹ (10.07) was obtained from the paired row planting density D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} preceded by D₈ {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (11.67). In the present study, it was observed that the single row planting performed better than paired row planting. Planting pattern that includes 50 hills m⁻² also performed better than 32 hills m⁻² and 24 hills m⁻². The reasons

might be due to that competition for growth resources was more in higher planting density, at the same time assimilate production as well as translocation was also poor in overcrowded stands. The present finding was confirmed by Mahmud (2006) and Islam (1999). They stated that higher planting density produced the higher number of unfilled spikelets panicle⁻¹.

4.2.7 1000 grain weight (g)

Weight of 1000 grain was not influenced by the planting density (Table 7). However, numerically the highest weight of 1000 grain (28.52 g) was recorded from the planting density D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} followed by D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (28.37 g). The lowest weight of 1000 grain (27.66 g) was recorded from the single row planting density D₁ {20 cm x 10 cm (50 hills m⁻²)} preceded by D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (27.85 g).

In the present study, it was observed that lower planting density performed better than higher planting density. The reasons might be due to that competition for growth resources was more in higher planting density, at the same time assimilate production as well as translocation was also poor in overcrowded stands. It was also observed that the paired row planting performed better than single row planting. It might be due to get more sunlight and available aeration.

The present finding was confirmed by Shah *et al.* (1996) that 1000 grain weight increases with decrease in planting density.

4.2.8 Grain yield

Grain yield was significantly influenced by planting densities was recorded from BRRI dhan47 (Table 7 and Figure 1-3). The result revealed that the highest grain yield (10.91 t ha⁻¹) was recorded from the paired row planting density D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} which was statistically similar to the single row planting density D₁ {20 cm x

10 cm (50 hills m^{-2}) (10.25 t ha^{-1}). Higher grain yield in D_7 {(30 cm + 10 cm) x 10 cm (50 hills m^{-2})} might be attributing to higher numbers of panicle m^{-2} and higher number of leaves m^{-2} , total dry matter production m^{-2} which ultimately helped to produce higher yield. Closer spacing increased the yield by promoting early growth and by increasing the number of panicles and sink (Aragones and Wada, 1989). Increasing LAI through higher population density or other cultural practices is likely lead to high yield potential (Rao and Reddy, 1992). Narrow row spacing limited vegetative growth after anthesis and thereby growth rate of the panicle increase (Zadesh and Mirlohi, 1998).

The lowest grain yield (8.98 t ha^{-1}) was recorded from the planting density D_9 {(30 cm + 10 cm) x 20 cm (24 hills m^{-2})} which was statistically similar to the planting density D_6 {(25 cm + 15 cm) x 20 cm (24 hills m^{-2})} (9.08 t ha^{-1}), D_3 {20 cm x 20 cm (24 hills m^{-2})} (9.23 t ha^{-1}), D_2 {20 cm x 15 cm (32 hills m^{-2})} (9.31 t ha^{-1}) and D_8 {(30 cm + 10 cm) x 15 cm (32 hills m^{-2})} (9.47 t ha^{-1}), respectively. The poor performance of these treatments might be attributed to its lower number of effective tillers m^{-2} , lower no. of leaves and lower amount of dry matter production m^{-2} . It was also evident from earlier reports of BRRI (1992) that closer spacing gives more yield than wider spacing.

It was found that, higher planting density performed better than lower planting density. Paired row planting density performed better than single row planting density. It was also in agreement with those of Ali (2005) who stated that paired row arrangement with higher plant population produced higher grain yield.

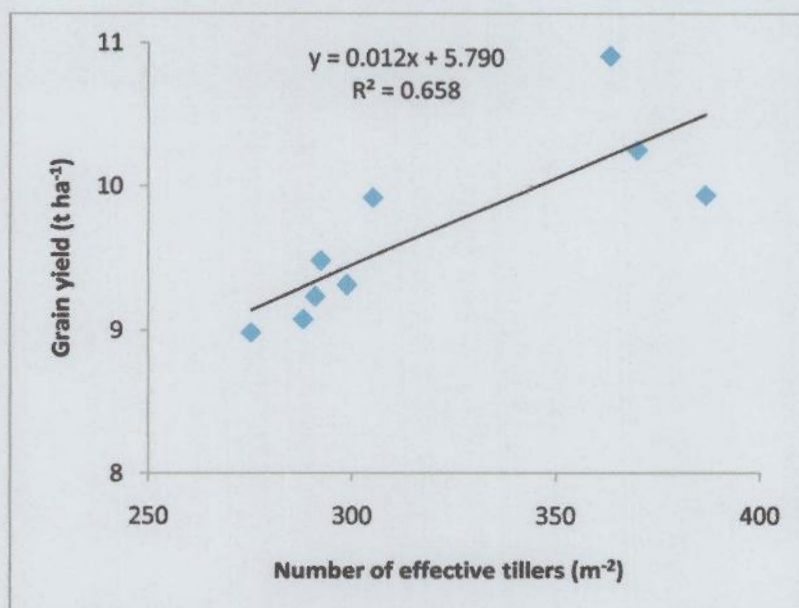


Figure1. Functional relationship between grain yield (t ha⁻¹) and number of effective tillers (m⁻²) of BRRI dhan47

Grain yield showed a positive and linear relationship with number of effective tillers m⁻² (Figure 1). The value ($R^2=0.658$) suggests that over 60% of the variation in grain yield could be explained by the variation in number of effective tillers m⁻².

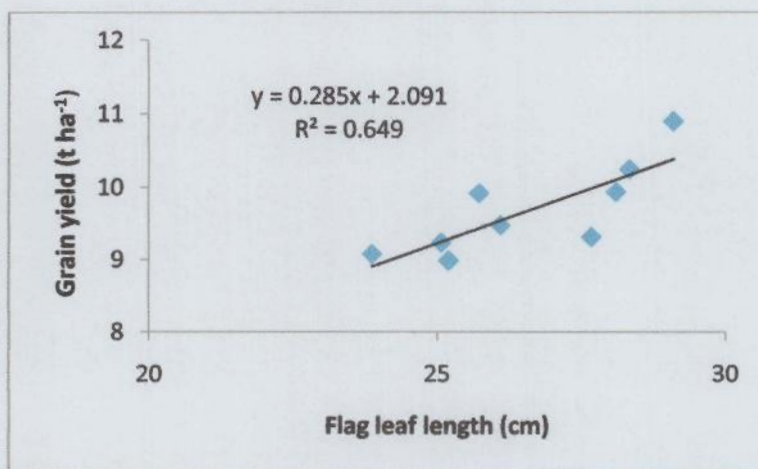


Figure 2. Functional relationship between grain yield (t ha⁻¹) and flag leaf length (cm) of BRRI dhan47

Grain yield (t ha⁻¹) when plotted against flag leaf length (cm) produced a straight line (Figure 2). This suggests that grain yield (t ha⁻¹) is dependent on flag leaf length (cm) and more than 60% ($R^2=0.649$) of the variation in grain yield is defined by variation in flag leaf length (cm).

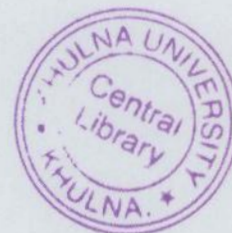
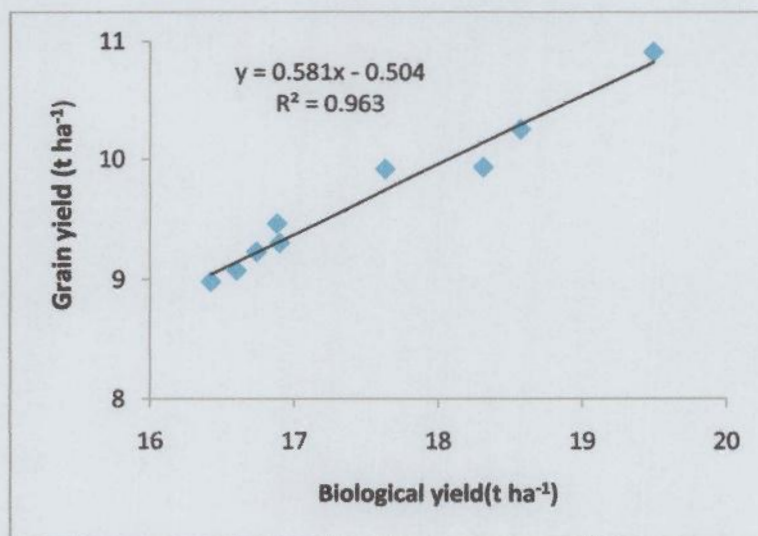


Figure 3. Functional relationship between grain yield (t ha^{-1}) and biological yield (t ha^{-1}) of BRRI dhan47

Grain yield (t ha^{-1}) when plotted against biological yield (t ha^{-1}) produced a straight line (Figure 3). This suggests that grain yield (t ha^{-1}) is dependent on biological yield (t ha^{-1}) and more than 90% ($R^2=0.963$) of the variation in grain yield is defined by variation in biological yield (t ha^{-1}).

4.2.9 Straw yield

Straw yield of BRRI dhan47 was greatly influenced by different planting densities (Table 7). The results revealed that the highest straw yield (8.58 t ha^{-1}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ which was statistically similar to D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (8.38 t ha^{-1}), D_1 $\{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ (8.32 t ha^{-1}) and D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (7.72 t ha^{-1}), respectively. The lowest straw yield (7.41 t ha^{-1}) was recorded from the planting density D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ which was statistically similar to D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (7.43 t ha^{-1}), D_3 $\{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (7.51 t ha^{-1}), D_6 $\{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ (7.53 t ha^{-1}) and D_2 $\{20 \text{ cm} \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$ (7.59 t ha^{-1}), respectively.

In this study it was found that higher planting density performed better than lower planting density and planting densities that have 50 hills m^{-2} shown better results than 32 hills m^{-2} and 24 hills m^{-2} . It was also observed that paired row planting performed better than single row planting. This was happened due to higher number of effective tillers m^{-2} , higher number of leaves m^{-2} and higher amount of dry matter production m^{-2} . This result was supported by Rahman (2005) and Islam *et al.* (1994). They reported that the straw yield increase with closer spacing.

4.2.10 Biological yield

Biological yield of BRRI dhan47 was significantly influenced by different planting density (Table 7 and Figure 3). The result revealed that the highest biological yield (19.49 t ha^{-1}) was recorded from the planting density D_7 {(30 cm + 10 cm) x 10 cm (50 hills m^{-2})} which was statistically similar to the planting density D_1 {20 cm x 10 cm (50 hills m^{-2})} (18.57 t ha^{-1}) and D_4 {(25 cm + 15 cm) x 10 cm (50 hills m^{-2})} (18.31 t ha^{-1}), respectively. The lowest biological yield (16.42 t ha^{-1}) was recorded from the planting density D_9 {(30 cm + 10 cm) x 20 cm (24 hills m^{-2})} which was statistically similar to D_6 {(25 cm + 15 cm) x 20 cm (24 hills m^{-2})} (16.60 t ha^{-1}), D_3 {20 cm x 20 cm (24 hills m^{-2})} (16.74 t ha^{-1}), D_8 {(30 cm + 10 cm) x 15 cm (32 hills m^{-2})} (16.88 t ha^{-1}), D_2 {20 cm x 15 cm (32 hills m^{-2})} (16.90 t ha^{-1}) and D_5 {(25 cm + 15 cm) x 15 cm (32 hills m^{-2})} (17.63 t ha^{-1}), respectively.

In this study, it was found that higher planting density performed better than lower planting density and planting densities that have 50 hills m^{-2} shown better result than 32 hills m^{-2} and 24 hills m^{-2} . This happened due to higher number of effective tillers m^{-2} , higher number of leaves m^{-2} and higher amount of dry matter production m^{-2} . Paired row planting performed better than single row planting.

This result was supported by Haque (2002) and Hasan (2002). They reported that the biological yield increase with closer spacing.

4.2.11 Harvest index

The harvest index of BRRI dhan47 was not significantly influenced by different planting densities (Table 7). However numerically the highest harvest index (56.26%) was recorded from the planting density D₅ {(25 cm + 15 cm) x 15 cm (32 hills m⁻²)} followed by the planting density D₈ {(30 cm + 10 cm) x 15 cm (32 hills m⁻²)} (56.11%). The lowest harvest index (54.20%) was recorded from the planting density D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} preceded by the planting density D₆ {(25 cm + 15 cm) x 20 cm (24 hills m⁻²)} (54.71%) and D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (54.71%).

In this study, it was found that planting density 32 hills m⁻² shown good result than 50 hills m⁻² and 24 hills m⁻² and paired row planting performed better than single row planting. This result was supported by Thakar *et al.* (2006) and Hossain (2005). They observed that the decrease harvest index was produced from increase in plant population.

Table 7. Effect of planting density on yield and yield attributes of BRRI dhan47

Planting densities	Number of effective tillers (m ⁻²)	Flag leaf length (cm)	Panicle length (cm)	Number of spikelets panicle ⁻¹	Number of filled spikelets panicle ⁻¹	Number of unfilled spikelets panicle ⁻¹	1000 grain weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
D ₁	370.00 a	28.33ab	23.74abc	116.10cd	101.30c	14.87	27.66	10.25 ab	8.32 abc	18.57 ab	55.21
D ₂	298.70bc	27.67abc	23.93 ab	130.50abc	117.90ab	12.60	27.94	9.31 cd	7.59 bc	16.90 cd	55.10
D ₃	290.90bc	25.07bc	24.65 a	144.60a	129.90a	14.67	27.96	9.23 cd	7.51 bc	16.74 d	55.15
D ₄	386.70 a	28.10 ab	22.44 c	113.50 d	99.30 c	14.20	27.85	9.93 bc	8.38 ab	18.31 abc	54.20
D ₅	305.10 b	25.73abc	24.10 ab	131.50abc	118.00ab	13.47	28.25	9.92 bc	7.72 abc	17.63 bcd	56.26
D ₆	288.00bc	23.87 c	24.30 a	138.40a	124.30a	14.13	28.37	9.08 d	7.53 bc	16.60 d	54.71
D ₇	363.30 a	29.10 a	22.93 bc	119.30bcd	106.10bc	13.27	27.92	10.91 a	8.58 a	19.49 a	55.97
D ₈	292.30bc	26.10abc	23.53abc	120.30bcd	108.70bc	11.67	28.19	9.47 cd	7.41 c	16.88 d	56.11
D ₉	275.20 c	25.20abc	24.01 ab	133.10ab	123.10a	10.07	28.52	8.98d	7.43 c	16.42 d	54.71
Significance level	0.01	0.01	0.01	0.01	0.01	NS	NS	0.01	0.01	0.01	NS
CV (%)	3.28	5.77	2.49	4.99	5.09	41.81	1.37	3.34	5.14	3.57	2.05

D₁ = 20 cm x 10 cm (50 hills m⁻²), D₂ = 20 cm x 15 cm (32 hills m⁻²), D₃ = 20 cm x 20 cm (24 hills m⁻²), D₄ = (25 cm + 15 cm) x 10 cm (50 hills m⁻²), D₅ = (25 cm + 15 cm) x 15 cm (32 hills m⁻²), D₆ = (25 cm + 15 cm) x 20 cm (24 hills m⁻²), D₇ = (30 cm + 10 cm) x 10 cm (50 hills m⁻²), D₈ = (30 cm + 10 cm) x 15 cm (32 hills m⁻²) and D₉ = (30 cm + 10 cm) x 20 cm (24 hills m⁻²)

**CHAPTER V
SUMMARY &
CONCLUSION**

SUMMARY AND CONCLUSION

A field experiment was carried out at Chalk Asankhali Mousa of Dumuria upazila under Khulna district of Bangladesh. The experiment was conducted during the boro season of 2011-'12. The experimental field was a typical farmer's field. The experiment received nine treatments as planting pattern. Three treatments were imposed as single row pattern and other six treatments were imposed as paired row pattern. Population densities were $D_1\{20\text{ cm} \times 10\text{ cm} (50\text{ hills m}^{-2})\}$, $D_2\{20\text{ cm} \times 15\text{ cm} (32\text{ hills m}^{-2})\}$, $D_3\{20\text{ cm} \times 20\text{ cm} (24\text{ hills m}^{-2})\}$, $D_4\{(25\text{ cm} + 15\text{ cm}) \times 10\text{ cm} (50\text{ hills m}^{-2})\}$, $D_5\{(25\text{ cm} + 15\text{ cm}) \times 15\text{ cm} (32\text{ hills m}^{-2})\}$, $D_6\{(25\text{ cm} + 15\text{ cm}) \times 20\text{ cm} (24\text{ hills m}^{-2})\}$, $D_7\{(30\text{ cm} + 10\text{ cm}) \times 10\text{ cm} (50\text{ hills m}^{-2})\}$, $D_8\{(30\text{ cm} + 10\text{ cm}) \times 15\text{ cm} (32\text{ hills m}^{-2})\}$ and $D_9\{(30\text{ cm} + 10\text{ cm}) \times 20\text{ cm} (24\text{ hills m}^{-2})\}$. The rice cultivar BRRI dhan47 differed considerably in terms of crop growth characteristics as well as yield and yield contributing characters.

5.1 Summary

The experiment was laid out in a randomized complete block design with 3 replications. The data on crop growth parameters like plant height, number of tillers, number of leaves, dry matter accumulation, crop growth rate and relative growth rate were recorded at 15 days interval starting from 30 DAT and continued 45 DAT, 60 DAT, 75 DAT and at harvest. Yield parameters like number effective tillers, panicle length, number of spikelets panicle⁻¹, number of filled spikelets panicle⁻¹, number of unfilled spikelets panicle⁻¹, 1000 grain weight, grain yield, straw yield, biological yield and harvest index were recorded at harvest. Grain yield (t ha⁻¹) and straw yield (t ha⁻¹) were recorded from whole plot (4m x 2.5m) basis. The grain and straw weight of each plot was recorded carefully after proper drying in the sun. Then 200 g of grain and straw was taken from each plot then oven dried at 70°C for 48 hours. The oven dried grain and straw weight were recorded again and adjusted to 14% moisture level.

The collected data were statistically analyzed following the analysis of variance technique and the significance of the mean difference were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984) using a statistical computer package program MSTAT-C.

Plant height was significantly affected by planting densities at all the sampling dates. It was observed that lower planting density increase plant height and higher planting density decrease plant height. The best result was found from the paired row planting pattern D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (102.8 cm). The lowest plant height was found from the single row planting pattern D₁ {20 cm x 10 cm (50 hills m⁻²)} (99.07 cm).

Higher planting density produced higher number of tillers m⁻² and lower planting density produced lower number of tillers m⁻². Number of tillers m⁻² found better in single row than paired row pattern. At harvest in paired row pattern D₄ {(25 cm + 15 cm) x 10 cm (50 hills m⁻²)} (386 m⁻²) shown the best result and paired row pattern D₉ {(30 cm + 10 cm) x 20 cm (24 hills m⁻²)} (275.2 m⁻²) performed the worst.

Number of leaves in all the treatments increased almost exponentially up to 60 DAT. From 75 DAT, a decreasing trend in leaf number was noticed. It was observed that higher planting density produced higher number of leaves m⁻². Number of leaves m⁻² found better in paired row planting density than single rows planting density.

Dry matter production (g m⁻²) at different days after transplanting was influenced by planting density. Results revealed that dry matter increased with increasing planting density. Paired row planting pattern D₇ {(30 cm + 10 cm) x 10 cm (50 hills m⁻²)} performed the best and D₉ {(30 cm + 10 cm) x 20 cm (50 hills m⁻²)} performed the worst.

Crop growth rate in all the treatments increased almost exponentially up to 60 DAT after that crop growth rate started to decrease gradually up to harvest. It was observed that

higher planting density increases crop growth rate. It was also found that paired row planting performed better than single row planting.

Relative growth rate was higher at 30-45 DAT after that it started to decrease gradually up to harvest. Higher relative growth rate was observed in lower planting density and lower relative growth rate was observed in higher planting density.

The highest number of effective tillers (386.7 m^{-2}) was recorded from the paired row planting density $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The lowest number of effective tillers (275.2 m^{-2}) was recorded from the paired row planting density $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. In the present study it was observed that higher planting density that includes 50 hills m^{-2} performed better than 32 hills m^{-2} and 24 hills m^{-2} for producing effective tillers. Paired row planting density performed better than single row planting density.

The longest flag leaf length (29.10 cm) was produced from the paired row planting density $D_7 \{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The shortest flag leaf length (23.87 cm) was produced from the paired row planting density $D_6 \{(25 \text{ cm} + 15 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. In the present study it was observed higher planting density performed better than lower planting density.

The longest panicle length (24.65 cm) was produced from the single row planting density $D_3 \{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. The shortest panicle length (22.44 cm) was produced from the paired row planting density $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. Higher population densities produced shorter panicles. Single row planting performed better than double row and 24 hills m^{-2} also shown better result than 32 and 50 hills m^{-2} .

Spikelet number panicle⁻¹ decreased with increase in planting density. The highest number of spikelets panicle⁻¹ (144.6) was found from the single row planting density $D_3 \{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ and the lowest number of spikelets panicle⁻¹ (113.5)

was found from the paired row planting density $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$.

Number of filled spikelets panicle⁻¹ decreased with increasing planting density. In spikelet number panicle⁻¹, single row performed better than paired row and 24 hills m⁻² also shown better result than 32 and 50 hills m⁻². Highest number filled spikelets panicle⁻¹ (129.9) was found from the single row planting density $D_3 \{20 \text{ cm} \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ and the lowest number filled spikelets panicle⁻¹ (99.33) was found from the paired row planting density $D_4 \{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$.

The highest number of unfilled spikelets panicle⁻¹ (14.87) was recorded from the single row planting density $D_1 \{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The lowest number of unfilled spikelets panicle⁻¹ (10.07) was recorded from the paired row planting density $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. In the present study it was observed that the single row performed better than paired row. Planting pattern that includes 50 hills m⁻² also performed better than 32 and 24 hills m⁻².

Numerically the highest weight of 1000 grain (28.52 g) was recorded from the paired row planting density $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$ and the lowest (27.66 g) was recorded from the single row planting density $D_1 \{20 \text{ cm} \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. In the present study, it was observed that the paired row performed better than single row. Planting pattern that includes 24 hills m⁻² also performed better than 50 hills m⁻² and 32 hills m⁻².

The highest grain yield (10.91 t ha⁻¹) was recorded from the paired row planting density $D_7 \{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The lowest grain yield (8.983 t ha⁻¹) was recorded from the paired row planting density $D_9 \{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. It was found that higher planting density performed better than lower planting density and paired row planting density performed better than single row planting density.

The highest straw yield (8.583 t ha^{-1}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The lowest straw yield (7.407 t ha^{-1}) was recorded from the planting density D_8 $\{(30 \text{ cm} + 10 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$. In this study it was found that higher planting density performed better than lower planting density and paired row planting density performed better than single row planting density.

The highest biological yield (19.49 t ha^{-1}) was recorded from the planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. The lowest biological yield (16.42 t ha^{-1}) was recorded from the planting density D_9 $\{(30 \text{ cm} + 10 \text{ cm}) \times 20 \text{ cm} (24 \text{ hills m}^{-2})\}$. In this study it was found that 50 hills m^{-2} shown better result than 32 hills m^{-2} and 24 hills m^{-2} and paired row performed better than single row.

The highest harvest index (56.26%) was recorded from the planting density D_5 $\{(25 \text{ cm} + 15 \text{ cm}) \times 15 \text{ cm} (32 \text{ hills m}^{-2})\}$. The lowest harvest index (54.20%) was recorded from the planting density D_4 $\{(25 \text{ cm} + 15 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$. In this study it was found that 32 hills m^{-2} show better result than 50 hills m^{-2} and 24 hills m^{-2} and paired row planting density performed better than single row planting density.

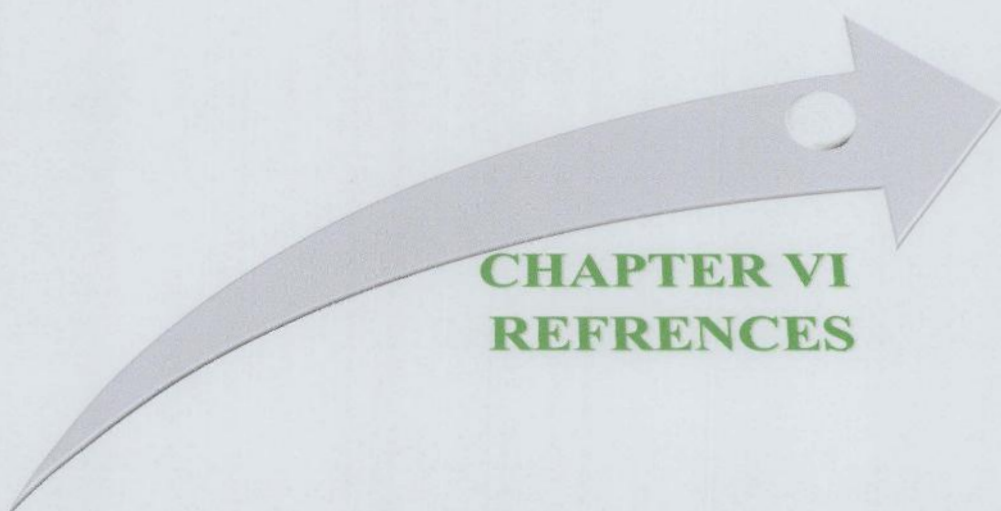
5.2 Conclusion

From the findings of the present study it might be reasonably concluded that

- ☐ Paired row planting density D_7 $\{(30 \text{ cm} + 10 \text{ cm}) \times 10 \text{ cm} (50 \text{ hills m}^{-2})\}$ found the best planting pattern for BRRI dhan47 in terms of grain yield, straw yield and biological yield
- ☐ Higher planting density (50 hills m^{-2}) produce higher yield than lower planting density (24 & 32 hills m^{-2}) in BRRI dhan47
- ☐ Higher planting density with paired row planting pattern produce higher grain yield in BRRI dhan47

5.3 Recommendation

- ☐ This research is needed to repeat in different locations of the country.



CHAPTER VI
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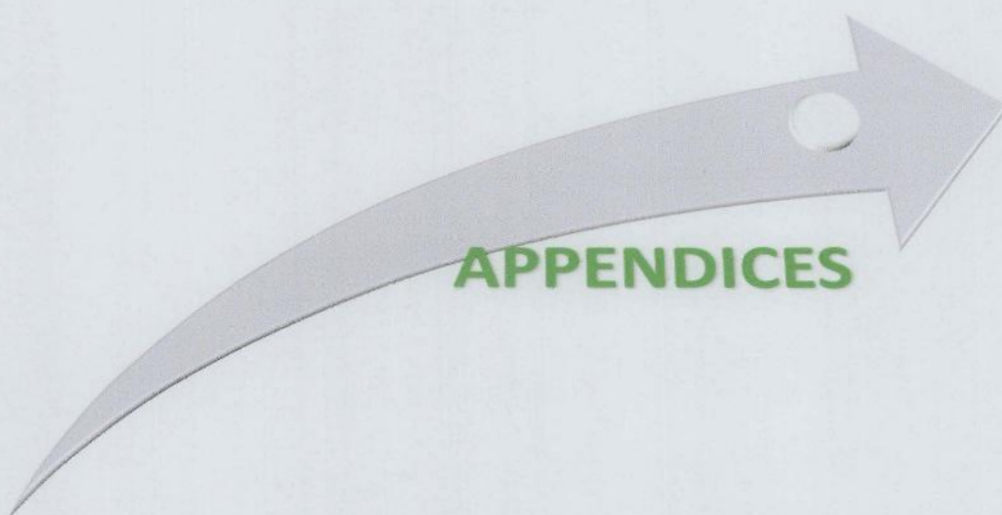
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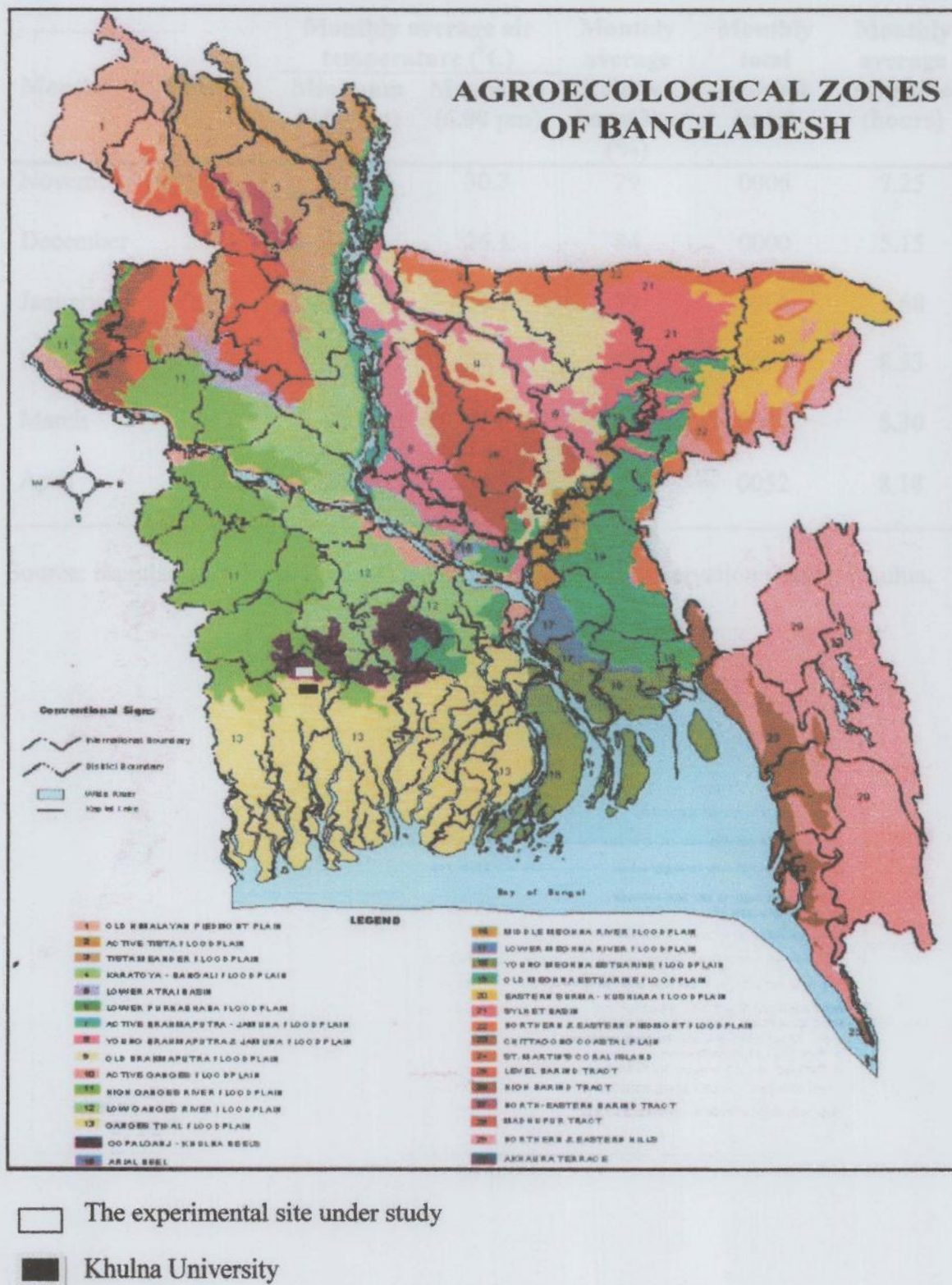
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APPENDICES

APPENDICES

Appendix I: Map showing the experimental site under study



Source: Fertilizer Recommendation Guide-2005, BARC.

Appendix III: Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results	Status
pH	7.1	Neutral
Salinity (EC)	2.0 dS m ⁻¹	Non saline
Organic matter	3.06 (%)	Medium
Exchangeable K	0.52 meq/100 g soil	Very high
Total N	0.177 (%)	Low
Available P	7.88 (µg/g Soil)	Low
Available S	92.89 (µg/g Soil)	Very high
Available Zn	0.64 (µg/g Soil)	low

Source: Soil Resources Development Institute (SRDI), Daulatpur, Khulna

Appendix IV: Classification of soil organic matter on the basis of amount present in the soil

Name of classes	Amount of organic matter (%)
Very low	< 1.0
Low	1.0 – 1.7
Medium	1.7 – 3.4
High	3.4 – 5.5
Very high	5.5 <

Source: Bhumi O Mirtika Sampad Babohar Nirdasheka, Dumuria upazila, Khulna. April, 2008, SRDI.

Appendix V: Classification of soil salinity on the basis of amount present in the soil

Name of classes	Electrical conductivity (dS m⁻¹)
Non-saline	< 2
Very low	2 - 4
Low	4 - 8
Medium	8 - 12
High	12 - 15
Very high	15 <

Source: Bhumi O Mirtika Sampad Babohar Nirdasheka, Dumuria upazila, Khulna. April, 2008, SRDI.

Appendix VI: Morphological characteristics of the soil of the experimental site

Constituents	Characteristics
Location	69,Chalk Asankhali mousa, Dumuria, Khulna
Soil tract	Gopalganj Khulna Beels
Land type	Medium high land
General soil type	Peat soil
Soil group	Harta
Soil series	Harta
Agro-ecological zone	Gopalganj Khulna Beels (AEZ 14)
Soil texture	Silty loam
Topography	Fairly level
Soil consistencey	Consistent
Soil color	Dark grey
Drainage condition	Very poorly drained



Source: Bhumi O Mirtika Sampad Babohar Nirdasheka, Dumuria upazila, Khulna. April, 2008. SRDI.