STUDY OF NERICA-1 AND TWO AMAN VARIETIES UNDER DIFFERENT LEVEL OF FERTILIZERS

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CERTIFICATE

This is to certify that the thesis entitled, "**STUDY OF NERICA-1 AND TWO AMAN VARIETIES UNDER DIFFERENT LEVEL OF FERTILIZERS"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of *bonafide* research work carried out by **MD. RAIHAN ULLAH,** Registration No. **05-01551** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dated:
Place: Dhaka, Bangladesh

DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University during July to December 2010 to evaluate the performance of introduced rice variety NERICA-1 along with HYVs in *aman* season under different levels of NPK fertilizers. The experiment was laid out in a split-plot design with three replications. Rice varieties differed significantly where BR11 produced higher grain yield (3.74 t ha^{-1}) and straw yield (5.39 t ha^{-1}) than BRRI dhan46 (3.16 t ha^{-1} and 4.98 t ha^{-1}, respectively) and NERICA-1 (2.33 t ha^{-1} and 4.33 t ha^{-1}, respectively). Fertilizer dose also significantly influenced all the growth and yield attributes except 1000-grains weight. Higher fertilizer dose (140-90-90 kg ha^{-1} N, P_2O_5 and K_2O) increased the yield in all the varieties. The highest grain yield (3.83 t ha^{-1}) and straw yield (5.28 t ha^{-1}) were obtained from higher fertilizer dose which was statistically at par with recommended fertilizer dose (120-80-80 kg ha^{-1} N, P_2O_5 and K_2O). Interaction results showed that significantly higher grain yield (4.72 t ha^{-1}) and straw yield (5.86 t ha^{-1}) were given by BR11 along with higher fertilizer dose (140-90-90 kg ha^{-1} N, P_2O_5 and K_2O) which was statistically at par with the same variety along with recommended fertilizer dose (120-80-80 kg ha^{-1} N, P_2O_5 and K_2O). NERICA-1 produced comparatively lower grain yield, straw yield and harvest index which could not improve with any one of the fertilizer dose.

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
WARDA	=	West Africa Rice Development Association
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
cv.	=	Cultivar
DAT	=	Days after transplanting
DAS	=	Days after sowing
^{0} C	=	Degree Centigrade
DF	=	Degree of freedom
DMRT	=	Duncan's Multiple Range test
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IFAD	=	International Fund for Agricultural Development
IRRI	=	International Rice Research Institute
kg	=	kilogram
LV	=	Local variety
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MV	=	Modern variety
mm	=	Millimeter
MP	=	Muriate of Potash
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
t ha^{-1}	=	Tons per hectare
TSP	=	Triple super phosphate
UNDP	=	United Nations Development Program
USG	=	Urea supergranules
Zn	=	Zinc

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is a semi aquatic cereal among the oldest and most important food crops of the world (Mikkelsen *et al.*, 1995). Rice cultivation is favored by the hot, humid climate and the large number of deltas across Asia's vast tropical and subtropical areas. As a main source of nourishment for more than two billion people in Asia and many millions in Africa and Latin America, it is by far one of the most important commercial food crops. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent of calories from protein (Anon., 2005).

Rice is one of the most important cereal crops of the world. There are 111 rice growing countries in the world that occupies about 146.5 million hectares more than 90% is in Asia. It is the staple food for more than two billion people in Asia and many millions in Africa and Latin America. About 95% of the world rice is consumed in Asia. Rice, the staple food crop of Bangladesh, is grown on over 10.80 million hectares of land producing 29.32 million metric tons with an average yield is only 2.71 t/ha (BBS, 2009) and it is historically associated with culture, rites and rituals of Bangladeshi people. It is the staple food of about 140.1 million people of Bangladesh and as staple dietary item per capita rice consumption is about 166 kg/year (BBS, 2007). It also contributes around 11% of total agricultural GDP and employs about 43.6% of total labor forces (BBS, 2009). Rice covers about 82% of the total cropped area in Bangladesh (BBS,

2009) and supplies 76% of the total calories and 66% of the protein in a typical Bangladeshi diet (Bhuiyan *et al.*, 2002). Bangladesh with its flat topography, abundant water and humid tropical climate constitutes an excellent habitat for the rice plant (BRRI, 1997a). Rice is grown in the country under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *aus*, *aman* and *boro*. Among these three seasons, the monsoon rice, transplanted *aman* covers the largest area (51.56% of total rice area) and average yield of *aman* rice is 2.08 t ha^{-1} (BBS, 2007). The population of Bangladesh is still growing by two million every year and may increase by another 30 millions over the next 20 years and expected to increase, by the year 2050, around 200 million. Half of this huge population will be urban dwellers (BBS, 2009). Thus, Bangladesh will require huge amount of rice production when the land area is gradually decreasing because of population growth, industrialization and other infrastructure development. The alarming growth of people in Bangladesh and the reduction of agricultural land, it is highly demanding to develop short duration variety of crop to increase cropping intensity to feed the increased population.

Technological change led by varietal improvement in Bangladesh has significantly contributed to the growth of rice production during the last three decades. In fact, due to the introduction of high-yielding seed and fertilizer irrigation technology and rapid expansion of the area under irrigated dry season rice, rice production has been doubled since independence in 1971 without further increase in growing area. Horizontal expansion of rice area is not possible in Bangladesh due to limited land resources and high population density. The only avenue left is to increase production of rice with increased cropping intensity by vertical means i.e. short duration variety with optimum management practices and reducing crop damaged by natural hazards like flood, drought etc.

Bangladesh is a flood prone country. Every year flood causes damage of crops. In order to ensure the timely sowing of rabi crops in November there is a need to identify *aman* rice genotypes of considerably shorter duration than the commonly cultivated varieties. BR11 and BRRI dhan46 are most commonly cultivated in *aman* season. These crop varieties require about 120 – 150 days for harvesting. Most of these crops are subjected to flood hazards at the later stage of the life cycle. NERICA-1 a short duration rice variety (90 days) which can be cultivated in all rice seasons was developed by West Africa Rice Development Association (WARDA). NERICA-1 rice has been developed through conventional crossbreeding between the African rice *Oryza glaberrima* and the Asian rice *Oryza sativa* (Jones *et al*., 1997; Jones, 1998), is being hailed as a “miracle crop” that can bring Africa its long-promised green revolution in rice. They claim that NERICA1 can boost yields and make Africa self-sufficient in rice production. NERICA-1 possesses early growth during the vegetative phase and this is a potentially useful trait for weed suppression. This variety is drought resistant (Manneh *et al*., 2007). Strong stems that can support heavy heads of grain. Tolerance to acidic soils but responsive to limited organic and inorganic fertilizers. NERICA-1 variety has high yield potential and short growth cycle of about 90 days. NERICA1 typically matures in 90–100 days, compared to typical improved upland existing variety which matures in 120–140 days.

Fertilizer management is a practice in *aman* that increase the yield. The application of fertilizer in proper amounts must be done to boost up agricultural production to an economically desirable level (Panaullah *et al.*, 1998). Due to continuous exploitation of land soil fertility decreased. As soil fertility and productivity changes over time and this change is towards negative direction because of intensive cropping with modern varieties, improper and imbalance use of fertilizers and manures and also declining soil organic matter to a considerable extent. Again crops grown in different cropping patterns and environment responded differently to fertilizer nutrients. A crop production system with high yield targets can not be sustained unless balanced nutrient inputs are supplied to soil against nutrient removal by crops (Bhuiyan *et al.*, 1991). Mineral fertilizer inputs are the crucial factors to the overall nutrient balance in intensive cropping system (Islam and Haq, 1998). Imbalanced fertilizer use is both costly in terms of nutrient loss from soil mining, decline in food supply and loss of soil fertility and land productivity and the consequent decline in food production. Bangladesh adopted a strategy for balanced fertilization to promote soil building to support sustainable land use system and ensure stable supply of food grains from existing agricultural lands. Bangladesh is gradually moving away from the traditional and rather static agriculture dependent on native soil fertility to a dynamic judicious fertilizer dependent agriculture. In a judicious fertilizer-dependent agriculture, balanced fertilization strategy has to be a cornerstone of all activities.

The new introduced variety NERICA1 can be tested in our condition to improve these cropping systems. On the other hand, this NERICA1 is to be evaluated with different level of fertilizers for its response towards potentiality. In view of this the present study was designed to evaluate NERICA1 in Bangladesh condition with following objectives –

i) To study the performance of NERICA1 over local HYVs in *aman* season.

ii) To evaluate the fertilizer dose as optimum for maximum yield of *aman* varieties.

iii) To study the interaction effect of variety and fertilizer dose on the yield performance of *aman* rice.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

2.1. Effect of variety

Variety has profound effect on different plant characters. The genetic make-up of a variety and environment mainly influence the varietal performance of a crop. Different researcher reported the effect of rice varieties on the yield contributing components and grain yield. Some available information and literature related to the effect of variety on the yield of rice are discussed below.

2.1.1. Effect on growth characters

2.1.1.1. Plant height

Ashrafuzz*aman et al.* (2009) evaluated the growth performance of six rice varieties, *viz.* BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati in an experiment under rainfed conditions. The rice varieties differed significantly ($P<0.05$) with respect to plant height and internodes length.

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

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

BINA (1993) evaluated the performance of four rice varieties – IRATOM24, BR14, BINA13 and BINA19. It was found that varieties differed significantly in respect of plant height.

BRRI (1991) observed that plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in *boro* season. Hossain and Alam (1991) found that the plant height in modern rice varieties, *viz.* BR3, BR11, BR14 and Pajam in *boro* season were 90.4 cm, 94.5 cm, 81.3 cm and 100.7 cm, respectively.

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

Shamsuddin *et al.* (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

2.1.1.2. Tillering pattern

Islam *et al.* (2009) conducted an experiment with four level of N fertilizer and three rice cultivars BINA dhan5, Tainan3 and BINA dhan6. They found that plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area hill^{-1} (cm^2), DM (dry matter) of root, stem and leaves hill^{-1}, and TDM (total dry matter) varied significantly. BINA dhan5 and BINA dhan6 showed similar result.

Duy *et al.* (2004) found that the growth of tillers of 12 rice cultivars and lines in the practice of nitrogen-free basal dressing with sparse planting density (BNo) both the primary and secondary tillers m^{-2} were smaller than the conventional cultivation (CONT) in 1999, 2000 and 2001. A large number of tillers in conventional cultivation, especially the secondary tillers, were unproductive and most of those in BNo were productive.

Inthapanva *et al.* (2000) reported that there is significant difference both in genotype and genotype-by-fertilizer interaction in total tiller number of rice varieties.

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnatak Rice Hybrid 1 (KRH1) and Karnataka rice Hybrid2 (KRH2) along with HYV IR20 as the check variety found that KRH2 out yielded IR20, the tiller number was higher than that of KRH2.

Islam (1995) in an experiment with four rice cultivars *viz.* BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Hossain and Alam (1991) also found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli rice varieties in *boro* season.

Idris and Matin (1990) stated that number of total tillers hill^{-1} was identical among the six rice varieties studied.

2.1.1.3. Total dry matter production

Amin *et al.* (2006) conducted a field experiment to compare the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful chikon) with that of a modern variety (*viz.* KK-4) and reported that traditional rice varieties accumulated higher amount of vegetative dry matter than the modern variety.

Ntanos and Koutroubas (2002) conducted a field study to assess the dry matter and N accumulation and translocation in direct water-seeded rice and examine their association with grain yield. Five rice cultivars, Olympiada and L-202 (Indica type) and Ispaniki A, Melas and Dion (Japonica type), with contrasting characteristics were grown in a silty loam soil (Aquic Xerofluvents) in 1999 and 2000. Cultivar dry matter translocation efficiencies ranged from 8.5 to 39.3% and N translocation efficiencies from 44.7 to 66.7%. Differences among Indica and Japonica cultivars in translocation efficiencies were found, but these differences depended mainly on the agronomic characteristics of each cultivar. Dry matter and N translocation were greater for short and late maturing cultivars compared to the tall and early maturing or mid-season cultivars, respectively. Greater amounts of dry matter and N content at anthesis resulted in a greater dry matter and N translocation to grain. Grain yield was positively and significantly correlated with dry matter and N translocation efficiency.

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

2.1.2. Effect on yield contributing characters

2.1.2.1. Effective tillers hill^{-1}

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB and found that WAB881-10-37-18-8-2-HI gave higher tiller number.

Devaraju *et al.* (1998) also reported that the increased yield of KRH2 was mainly attributed due to the higher number of productive tillers plant^{-1}.

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}.

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

Islam *et al.* (2010a) conducted an experiment with three rice variety BRRI dhan46, BR22 and Nizersail from 2006-2007 in *aman* season and found that BRRI dhan46 was significantly higher than other test varieties irrespective of planting dates due to heavier individual grain weight and higher grains/panicle and panicle length among the test varieties.

Alam *et al.* (2009) examined the relative performance of inbred and hybrid rice varieties at different levels of Phosphorus (P). Three varieties of inbred and hybrid rice (BRRI dhan29, Aloron and Hira2) and five levels of P (0, 24, 48, 72 and 96 kg P_2O_5 ha^{-1}) were used as treatment. They reported that the number of tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, spikelet sterility, 1000-grain weight, grain yield, straw yield, biological yield and harvest index varied significantly due to the variety.

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

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

Guilani *et al.* (2003) studied crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran, during 1997. Grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) and filled grains panicle^{-1} (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07g) and number of panicles m^{-2} than other tested varieties.

Ahmed *et al.* (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23 and BR25) and a local improved variety, Nizershail. The fertilizer dose was 60 – 60 – 40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was highest in Nizershail followed by BR25 and lowest in BR11 and BR23.

BRRI (1994) studied the performance of BR14, BR5, Pajam and Tulsimala and reported that Tulsimala produced the highest number of filled grains $panicle^{-1}$ and BR14 produced the lowest number of filled grains $penicle^{-1}$.

BINA (1993) evaluated the performance of four rice varieties IRATOM24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets $panicle^{-1}$. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains $panicle^{-1}$ compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

BRRI (1991) also reported that the filled grains $penicle^{-1}$ of different modern rice varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant *aman* season.

Hossain and Alam (1991) reported that the growth characters like plant height, total tillers $hill^{-1}$ and the number of grains $panicle^{-1}$ differed significantly among BR3, BR11, BR14 and Pajam varieties of rice in *boro* season.

Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-1009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000-grain weight were higher for C-14-8 than those of any other three rice varieties.

Rafey *et al.* (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grains differed among the cultivars studied.

Shamsuddin *et al.* (1988) also observed that panicle number hill^{-1} and 1000-grain weight differed significantly among the rice varieties.

Kamal *et al.* (1988) evaluated BR3, IR20 and Pajam2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9 respectively, for the rice varieties.

Costa and Hoque (1986) studied during Kharif-II season, 1985 at Tangail FRS site, Palima, Bangladesh with five different rice varieties of T. *aman* BR 4, BR10, BR11, Nizershail and Indrasail. Significant differences were observed in panicle length and number of unfilled grains panicle^{-1} among the rice varieties.

2.1.3. Effect on grain yield and straw yield

Ashrafuzz*aman et al.* (2009) evaluated the grain quality of six aromatic rice varieties BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati grown under rainfed conditions. The rice varieties differed significantly ($P<0.05$) with respect to thousand grain weight and grain and straw yields. Varieties differed in morphological and yield and yield contributing traits.

IFAD (2008) reported that the BRRI dhan46 yielded an additional 20 percent of paddy 4.5 tons per hectare compared with 3.6 tons per hectare for Pajam and there is another advantage of BRRI dhan46 is that compared to other high yielding *aman* varieties, it matures earlier – in about 124 days compared to 140 days for a traditional variety.

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

Duy *et al.* (2004) reported that the yield of 12 rice cultivars and lines in the practice of nitrogen-free basal dressing with sparse planting density (BNo) were lower than the conventional cultivation (CONT) in 1999, 2000 and 2001. The difference between BNo and CONT in grain yield varied with the cultivar and the year.

Molla (2001) reported that Pro-Agro6201 rice variety (hybrid) had a significant higher yield than IET 4786 (HYV) due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Patel (2000) studied that the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al.* (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *boro* season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR 54883, PMS 8A/ IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. They also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during the *boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

Rajendra *et al*. (1998) carried out an experiment with hybrid rice cv. Pusa 843 and Pusa HR3 and got the yield of 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively.

BRRI (1997b) reported that three modern upland rice varieties *viz.* BR20, BR21, BR24 was suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5, 3.0 and 3.5 t ha^{-1}, with BR20, BR21 and BR24, respectively.

Nematzadeh *et al.* (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND 160-2-1 and RNR 1446 in all possible combinations and released in 1996 under the name Nemat, it gives an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23, and BR25 varieties including two local checks Challish and Nizershail produced yields of 4.38, 3.18, 3.12, 2.70 and 5.0 t ha^{-1}, respectively.

Chowdhury *et al.* (1995) studied seven varieties of rice, of which three were native (Maloti, Nizershail and Chandrashil) and four were improved (BR3, BR11, Pajam and Mala). Straw and grain yields were recorded and found that both the grain and straw yields were higher in improved than native varieties.

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

Miah *et al.* (1994) conducted an experiment on yield stability of nine rice genotypes in transplanted ecosystems of Bangladesh across three locations over three years. The RCB design was followed with three replications in nine trials (3 locations x 3 years = 9 environments). Variation due to variety, environment and variety x environment interaction were found significant. Yield of most entries including BRRI varieties were unstable. Among them IR7156120-3-2-1-1 was found to be high yielding entry.

Ali *et al.* (1993) in field experiments at Gazipur in 1989-1990 when rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizershail (strongly photosensitive) were sown at various intervals from July to September and transplanted from August to October Among the cv. BR22 gave the highest grain yield from most of the sowing dates in both years.

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e.; grain yield and straw yield.

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-seputih. They observed that IR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih.

Chandra *et al.* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A x IR35366-62-1-2-2-3R.

Hossain and Alam (1991) studied farmers production technology in haor area and found that the grain yield of modern varieties of *boro* rice were 2.12, 2.18, 3.17, 2.27 and 3.05 t ha^{-1}, with BR14, BR11, BR9, IR8 and BR3 respectively.

In evaluation of performance of four HYV and local varieties-BR4, BR16, Rajasail and Kajalsail in *aman* season, BR4 and BR16 were found to produce more grain yield among four varieties (BRRI, 1985).

BRRI (1979) reported that Haloi gave the highest yield (2.64 t ha^{-1}) which was not different from Nizershail (2.64 t ha^{-1}) and Latisail (2.74 t ha^{-1}).

2.2. Fertility status

2.2.1. Present soil fertility status in Bangladesh

Soil fertility refers to the capability of soils to supply elements essential for plant growth without a toxic concentration of any element. It is the inherent capacity of soil to supply 14 of the 17 essential nutrient elements to the growing crop. It is the quality of soil that enables it to provide compounds or elements in adequate amounts and in proper balance for the growth of specified plants when other growth factors like light, moisture, temperature and the physical conditions of the soils are favorable. So, fertility is the potential nutrient status of a soil to produce crops. Presence of soil organic matter is the most important indicator or pre-requisite to be fertile or productive soil.

In the recent years, intensive crop cultivation using high yield varieties of crop with imbalanced fertilization has led to mining out scarce native soil nutrients to support plant growth and production, the dominant soil ecological processes that severely affected the fertility status and production capacity of the major soils in Bangladesh. Available data indicated that the fertility of most of our soils has deteriorated over the years (Ali *et al.*, 1997), which is responsible for national yield stagnation and in some cases, even declining crop yields (Cassman *et al.*, 1995). The use of chemical fertilizers mainly NPKS has been increasing steadily but they are not applied in balanced proportion.

Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice. It is said that soil of Bangladesh is the most fertile in the world. However, after 4 decades of modern agricultural practice, Organic Matter (OM) status of Bangladesh soil has become one of the lowest in the world. At present, the average OM content of Bangladesh soils is less than 1%, ranging between 0.05 and 0.9% in most cases. Soils of peat lands and some low-lying areas usually contain OM higher than 2% on an average. Organic matter supply in soil is one of the major constraints in agriculture of the country. Yet, the country has been producing good crops and cereal production in 2000 exceeded 27 million ton, with a surplus of 9 million ton. For producing this amount of crop, each year the soil looses 2 million tons nutrition. The organic matter content of Bangladesh soils in continuously cropped areas from 1967 to 1995 has been depleted by 5 to 36 percent (Ali *et al*., 1997).

Organic matter (OM) is the life of the soil. To keep soil productive for future a certain amount of OM (2% to 5%) is a must. Other wise the soil will become barren and no result will be found only using the chemical fertilizer.

2.2.2. Fertilizer used for rice production in Bangladesh

Information on nutrient balance for a particular crop production system is essential for developing nutrient management strategies for sustainable production. The continuous and unbalanced use of the chemical fertilizers under intensive cropping systems has been considered to be the main cause for declining crop yield and environmental degradation. All essential elements must be present in optimum amounts and in forms usable by plants.

Rice is the staple food for the people of Bangladesh and will continue to remain so in future. The country needs substantial increase in rice production to provide her teeming millions with food and other basic needs of life. There are not many options but for improving the living standard of her common people, raising the level of rice production from the limited land resources and diverse climatic conditions is essential. Variations in management practices (irrigation and fertilizer application, crop management practices etc), use of new high yielding varieties (HYV) and modern technologies play vital role for increasing rice production of this country (Basak, 2010).

Urea, TSP and MP are chemical fertilizers most commonly applied by rice farmers. Urea (nitrogen) is a major component of proteins, hormones, chlorophyll, vitamins and enzymes, essential for rice. Rice plants require a large amount of nitrogen at the early and mid-tillering stage to maximize the number of panicles (De-Datta, 1988). The recommended doses of other nutrients are also necessary for potential rice yield. Elimination of any one of these elements, and plants will display abnormalities in plant growth, deficiency symptoms, or may not reproduce normally.

Continuing rice production in a sustainable way, one of the important inputs required is the supply of balanced fertilizers consisting of N-P-K. Besides, it is also necessary for maintaining the soil fertility for a long period. Moreover, balanced fertilizers application is also essential for achieving higher level yield.

2.3. Effect of Fertilizer

Fertilizer is considered to be one of the main inputs for increasing crop yields and farm profit for any country but balanced fertilization is the key to efficient fertilizer use for sustainable high yields. Imbalanced application of chemical fertilizers is one of the main barriers for sustainable development of agriculture production, farm efficiency and land use and also production system, which is more complicated and more expensive. Besides, the demand of fertilizers would become significant in near future (Basak, 2010). The optimal rate of fertilizer application to a crop is that rate which produces the maximum economic returns with minimum cost, and this can be derived from a nutrient response curve (Dobermann and Fairhurst, 2000).

For rice production, 16 elements are essential- carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, zinc, iron, cropper, molybdenum, boron, manganese and chlorine. Among them, nitrogen, phosphorus, zinc and potassium are nutrient elements most commonly applied in rice fields and sulfur is occasionally applied to some soil. It is observed that the high yielding varieties are responding to higher levels of nitrogen, phosphorus and potassium than what is recommended today (Channabasavanna *et al.,* 1996). Some available information and literature related to the combined effect of NPK on the yield of rice are discussed below.

2.3.1. Effect on growth characters

2.3.1.1. Plant height

Hasanuzz*aman et al.* (2010) conducted an experiment to observe the comparative performance of different organic manures with inorganic fertilizers on the growth rate, tillering and dry matter accumulation of rice. Plant height, number of tillers hill^{-1}, total dry weight of plants, crop growth rate and relative growth rate were significantly influenced by different fertilizer dose. Except plant height and total tiller per hill all the parameters were found to be the highest with the poultry manure @ 4 t ha^{-1} + N-40, P-6, K-36, S-10 kg h^{-1} i.e. 50% NPK.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. They found that increased fertilizer dose of NPK increased plant height.

Saha *et al.* (2004) conducted a two years (2002-2003) field experiment on rice varieties during *boro* season and found that plant height significantly increased with the increased level of different NPK fertilizer model.

Singh *et al.* (2003) reported that crop growth rate, such as plant height, dry mater production averaged across treatments, was highest at 45-60 days after transplanting of rice and significantly influenced by NPK fertilizers.

2.3.1.2. Tillering pattern

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600 kg/ha). The results were that 600 kg/ha NPK (15:15:15) fertilizer rate significantly ($P < 0.05$) increased plant height, number of leaves and tillers per plant in both years. The 400 kg/ha rate increased the number of panicles per plant, length of central panicle per plant and the overall grain yields, straw yield over other rates by 4-32% and 2-21% in 2005 and 2006, respectively.

Aptosol (1989) reported that organic and inorganic fertilizers increased the number of effective tillers/hill of rice varieties.

Ahmad and Hussain (1974) reported that increase in NPK fertilizer rates significantly increased tiller number per plant.

2.3.1.3. Total dry matter production

Hasanuzz*aman et al.* (2010) reported that total dry weight of plant increased with the increase of different levels of fertilizer and they found poultry manure @ 4 t ha-1 + N-40,P-6,K-36,S-10 kg h^{-1} i.e. 50% NPK gave the higher dry matter production.

Singh *et al.* (2003) reported that crop growth rate and relative growth rate such as total dry matter production was significantly influenced by NPK. The tiller number and total dry matter production were closely correlated with yield depending on the rice cultivar (Tanaka, 1968) which could be greatly enhanced by applying proper nutrient. Prasad (1981) observed the increase of TDM due to increased N application.

2.3.2. Effect on yield contributing characters

2.3.2.1. Effective tillers hill^{-1}

Ndaeyo *et al.* (2008) found that number of effective tillers per plant was significantly ($P < 0.05$) influenced by NPK (15:15:15) fertilizer rates. The number of effective tillers per plant across the rice cultivars increased with increased rate of NPK which ranged from 5.12 - 7.42 and 5.12 - 7.19 in 2005 and 2006, respectively. The dose of 600 kg/ha produced 4-31 % and 2-29 % more tillers than other fertilizer rates in both the years, respectively.

Venkateswarlu and Singh (1980) observed higher grain yield with 120 kg N + 60 kg P_2O_5 + 45 kg K_2O ha^{-1} followed by 80 kg N + 40 kg P_2O_5 + 30 kg K_2O ha^{-1}. Yield attributes like number of effective tillers m^{-2}, panicle weight, grains $panicle^{-1}$ and test weight were increased with increase in the fertilizer level.

2.3.2.2. Panicle length, total grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, filled grain percentage, 1000-grain weight

Ndaeyo *et al.* (2008) reported that number of spikelet per plant was significantly ($P < 0.05$) influenced by increase in NPK fertilizer rates. The number of panicles per plant across the rice cultivars showed that it ranged from 15.26 - 17.04 in the 600 kg/ha plots in 2005 and 15.27 - 16.79 in 2006.

Islam *et al.* (2008) found that panicle length, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage were influenced significantly due to the application of different rates of NPK nutrients.

Saha *et al.* (2004) conducted an experiment in 2002-2003 to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results were that the application of different packages estimated by different fertilizer models significantly influenced panicle length, panicle numbers, spikelet number per panicle, total grains $panicle^{-1}$, number of filled grain and unfilled grain per panicle. The combination of NPK gave height result with 120-13-70-20 kg/ha NPKS.

Haq *et al.* (2002) conducted an experiment on rice and reported that the number of panicles increased with increase in the nitrogen rates and that the number of panicles per plant increased with increase in NPK rates.

Halder *et al.* (2000) reported that the number of panicles per plant of rice increased with increase in NPK rates.

Asif *et al.* (2000) reported that NPK levels significantly increase the panicle length, number of primary and secondary branches panicle^{-1} of rice when NPK fertilizer was applied @ 180-90-90 kg ha^{-1}; this might be attributed to the adequate supply of NPK.

Chandrashekarappa (1985) reported that application of 100 kg N, 100 kg P_2O_5 and 50 kg K_2O ha^{-1} gave the highest grain yield of rice. This was at par with 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. The increase in yield was due to increased dry matter production, plant height, leaf area index, leaf area duration, number of tillers hill^{-1} and to some extent panicle length and 1000 grain weight.

Sikdar and Gupta (1979) observed that spikelet sterility of rice was higher at 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} as compared to 50 kg N + 25 kg P_2O_5 + 25 kg K_2O ha^{-1}. The spikelets panicle^{-1}, grain yield and to some extent 1000 grain weight were higher with higher dose of fertilizers.

2.3.3. Effect on grain yield and straw yield

Islam *et al.* (2010b) conducted an experiment with eight treatments such as T_1: NPK (control), T_2: NPK + S, T_3: NPK + S + Mg, T_4: NPK + S + Mg + Zn, T_5: NPK + S + Mg + Zn + B, T_6: NPK + S + Mg + Zn + B + Mo, T_7: NPK + Poultry manure (PM) and T_8: NPK + Cowdung (CD). All plot received 80 kg N ha^{-1}, 20 kg P ha^{-1} and 30 kg K ha^{-1}. Grain yields of T. *aman* rice varied from 3410 kg to 3937 kg ha^{-1}, with the highest yield recorded in the treatment T_7: N P K + (PM) & lowest in T_1: NPK (control).

Ali *et al.* (2010) conducted an experiment in 2003-2004 and found that integrated plant nutrition system that is 116-33-5-22-0.40-5000 kg/ha N-P-K-S-Zn-Cow dung for *boro* and 87-16-15-7-0.15 kg/ha N-P-K-S-Zn for T. *aman* gave higher yield. The grain yield of *boro* and T. *aman* rice increased by 18% and 14% respectively than the absolute control and the total grain yield of rice was increased by about 16%.

Mollah *et al.* (2008) conducted an experiment at Nandigram Multilocation Testing (MLT) Site, Bogra (AEZ-25.) during 2003- 04, 2004-2005 and 2005-06 to determine the optimum fertilizer dose for Mustard - *boro* - T. *aman* rice cropping pattern for enhancing total production and profit. Six different doses of fertilizer were estimated from soil test value, BARC Fertilizer Recommendation Guide' 97 and Farmers practice. From the average of three years results it was found that the highest grain yield and gross margin were obtained from soil test base (STB) fertilizer dose that is 122-25-111-19 kg/ha NPK for *boro* rice and 82-15-70-11 kg NPK for T. *aman* rice.

Islam *et al.* (2008) conducted an experiment in 2001-2002, 2002-2003 and 2003-2004 to determine the response and the optimum rate of nutrients (NPK) for Chili- Fallow-T. *aman* cropping pattern. They found that grain yield was influenced significantly due to the application of different rates of nutrients and 60-19-36 kg/ha NPK maximized the yield of T. *aman* rice varieties in respect of yield and economics.

Howlader *et al.* (2007) conducted an experiment at farmers' field of Farming System Research and Development (FSRD) site, Lebukhali under Patuakhali district during 1999-2000, 2000-2001 and 2001-2002 to determine the response and to find out the optimum rate of nutrients (NPK) for Mungbean-T. *aus*-T. *aman* cropping pattern under AEZ-13. Average of three years study revealed that a considerable response of T. *aus* and T. *aman* rice to N, P and K was observed. The results indicated that fertilizer nutrient dose that maximized yield of T. *aus* and T. *aman* rice were 78-24-15 kg/ha and 48-13-13 kg/ha NPK, respectively while 70-19-14 kg/ha NPK was profitable for T. *aus* rice and 45-11-13 kg/ha NPK for T. *aman* rice in respect of yield and economics.

Oikeh *et al*. (2006a) reported that combination of 60 kg N, 13 kg P and 25 kg K per ha (low to moderate input) has proved sufficient to double grain yield to 4 tones per hectare as compared to zero fertilizer application for NERICA1. Doubling the level of N and P at the same level of K increased grain yield by

25% over a moderate NPK level. They recommended 120 kg N, 26 kg P and 25 kg K per ha appropriate for high input farmers which generates 145% more grain yield compared to no NPK fertilizer application.

Oikeh *et al*. (2006b) recommended the use of 60 kg N, 13 kg P and 25 kg K per ha for smallholder farmers with basal application of P and K at sowing and top dressing with one-third urea at the beginning of tillering, and the remaining two-thirds at about panicle initiation for NERICA1.

Tsuboi (2006) recommends for soils that are sufficient in K, the use of 55:23:0 NPK kg ha^{-1} in the form of 50 kg ha^{-1} di-ammonium phosphate [DAP, 18:46:0 ($NP_2O_5K_2O$)] at 15 to 20 days after germination (DAG, i.e. allowing 5 days between sowing and emergence), and 50 ha^{-1} of urea (47% N) each at 15 to 25 DAS and 55 to 65 DAG for NERICA1. For soils that are low in K, the use of 62:26: 26 NPK in the form of 150 kg ha^{-1} of NPK 17: 17: 17 and 15 to 20 DAS with additional top dressing with 30 kg ha^{-1} urea at 15 to 20 DAG and 50 kg ha^{-1} at 55 to 65 DAG are recommended for NERICA1.

Yadav and Tripathi (2006) conducted an experiment during the year 2002-2003 in India to find out the best fertility levels for different hybrid rice varieties. Three hybrid rice varieties (Pant Shankar Dhan -1, Pro-Agro 6201 and Pro-Agro 6444) and one inbred variety (NDR-359) were tested at four levels of fertility i.e. control 80: 40: 40, 160: 80:80 and 240:120:120 kg NPK/ ha. Paddy varieties (Pro-Agro 6201 and Pro-Agro 6444) being statistically at par gave significantly higher production with application of 160:80:80 kg NPK/ ha.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. They found that increased fertilizer dose of NPK increased grain and straw yield.

Sudha and Chandini (2002) found that when the recommended dose of NPK (70:35:35 kg/ha) was applied, the grain and straw yield was 4.269 and 4.652 t ha^{-1} but when the fertilizer dose was increased by 25% and 50% the grain yield and straw yield increased. For 25% increase of fertilizer the grain and straw yield was 4.363 and 4.877 t ha^{-1} and for 50% increase of fertilizer the grain and straw yield was 4.90 and 5.390 t ha^{-1}, respectively.

Haq *et al.* (2002) conducted an experiment with twelve treatments combination of N, P, K, S, Zn and Diazinon. They found all the treatments significantly increase the grain and straw yield of BRRI dhan30 rice over control. 90 kg N + 50 kg P_2O_5 + 40 kg K_2O + 10 kg S + 4 kg Zn ha^{-1} + diazinon gave the highest grain and straw yield.

Badruddin *et al.* (2000) found that the yield of *aus* (spring) rice (BR21),T. *aman* (summer) rice (BR11), wheat (Kanchan), and jute (Falguni Tosa) varieties increased with the application of recommended dose of N, P, K, S fertilizer.

Ahmed and Rahman (1991) also reported that the application of organic manure (poultry manure, cowdung) and chemical fertilizers increased straw yield of rice.

After reviewing the scientific works of different scientists it appeared that cultivation of right variety with optimum fertilizer dose was a key point of management that could improve the crop yield.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1. Experimental period

The experiment was conducted during the period July to December 2010 in *aman* season.

3.2. Site description

The experiment was carried out in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding the experimental site is shown in the Map of AEZ of Bangladesh in Appendix I.

3.3. Climate

The experimental area belongs to the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The average RH, maximum temperature, minimum temperature, total rainfall and sunshine hour of the experiment site varied as 69-84%, 26.4°C-32.1°C, 14.1°C-26.3°C, 12.8-373.1mm and 3-5.7, respectively (Appendix II).

3.4. Soil

The farm belongs to the general soil type of Shallow Red Brown Terrace type under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. The physicochemical properties of the soil have been given in Appendix III.

3.5. Crop / planting material

Rice variety BR11, BRRI dhan46 and NERICA1 were used as the test crop.

3.5.1. Description of rice varieties

BR11

The variety commonly grown in transplanted *aman* season. BRRI developed it in 1980. The variety is recommended for cultivation in medium high lands and medium low lands where the maximum tidal depths not exclude to 25 cm. This cultivar matures at 145-150 days of planting. It attains at a plant height of 115-125 cm and gives an average yield of 6.5 t ha^{-1}.

BRRI dhan46

BRRI dhan46 is generally grown in *aman* season in flood prone area after flooding. It is photosensitive like BR22, BR23 and Naizersail. This variety was developed through hybridization between BR11, Shornolota and RSC 14766a. This variety matures at 145-150 days of planting. It attains at a plant height of 90 cm. The variety gives an average yield of 5 t ha^{-1}.

NERICA1

NERICA1 rice has been developed by Africa Rice Center (WARDA) through conventional crossbreeding between the African rice *O. glaberrima* and the Asian rice *O. sativa,* which brings Africa in its long-promised green revolution in rice. NERICA1 possesses early growth during the vegetative phase and this is a potentially useful trait for weed suppression. This variety is drought resistant. It has strong stems that can support heavy heads of grain. NERICA1 varieties have high yield potential and short growth cycle of about 90-100 days. Average plant height is about 100 cm; potential yields 4-4.5 t ha^{-1}.

3.6. Seed collection and sprouting

Seeds of BR11 and BRRI dhan46 were collected from SAU farm and NERICA1 was collected from BADC. Healthy seeds were selected following standard method. Seeds of BR11 and BRRI dhan46 were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.7. Raising of seedlings

A common procedure was followed in raising seedlings of BR11 and BRRI dhan46 in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed. NERICA1 was used as direct seeded crop.

3.8. Preparation of experimental land

The experimental field was first opened on 25 July, 2010 with the help of a power tiller later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 1st August, 2010 according to design. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.9. Fertilizer management

At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental plots were fertilized with full dose of TSP (triple super phosphate), MOP (Muriate of potash) and 1\3 rd of the urea as basal dose at time of final land preparation as per treatment and incorporated well into the soil. Rest amount of urea was applied in two equal splits at 20 and 55 days after transplanting/sowing (DAT/DAS) as per treatment.

3.10. Experimental treatments

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

Factor A: Variety – 3

V_1= BR11

V_2= BRRI dhan46

V_3= NERICA1

Factor B: Fertilizer – 5 levels

		N		P_2O_5		K_2O (kg/ha)
Low fertilizer dose	F_1 =	60	–	30	–	30
Moderate fertilizer dose	F_2 =	90	–	45	–	30
Low recommended fertilizer dose	F_3 =	120	–	60	–	30
Recommended fertilizer dose	F_4 =	120	–	80	–	80
Higher fertilizer dose	F_5 =	140	–	90	–	90

3.11. Experimental design

The experiment was laid out in a split-plot design with three replications assigning fertilizer levels in the main plots and variety in the sub-plots. There were 15 treatment combinations. The total number of unit plots was 45. The size of unit plot was 4m x 2.5 m. The distances between sub-plots, main plots and replications were 0.50m, 0.75m and 1.50 m, respectively.

3.12. Uprooting and transplanting of seedlings

Twenty five days old seedlings for BR11 and 35 days old seedlings for BRRI dhan46 were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted as per experimental treatment on the well puddled plots and seeds of NERICA1 were immersed in water in a bucket for 24 hrs and then direct sowing was done on 4^{th} August, 2010.

3.13. Intercultural operations

3.13.1. Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source. A minor gap filling was done with the same source of seeds where germination of Nerica-1 was not good with in one week.

3.13.2. Weeding

During plant growth period three hand weedings were done. The first weeding was done at 15 days after transplanting and sowing (DAT/DAS) followed by second and third weeding done at 15 days interval after first and second weeding, respectively.

3.13.3. Application of irrigation water

Irrigation was done by alternate wetting and drying from transplanting/sowing to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-5 cm) was kept on the plots. Water was removed from the plots during ripening stage.

3.13.4. Method of water application

The experimental plots were irrigated through irrigation channels.

3.13.5. Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying Sumithion 60 EC twice on 28 August and 30 September, 2010. Crop was protected from birds during the grain filling period.

3.14. General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage. No bacterial or fungal diseases were observed. The flowering was not uniform. NERICA1 gave early flower followed by BRRI dhan46 and BR11. NERICA1 reached maturity at 91 DAS where BR11 and BRRI dhan46 took 122 and 110 DAT, respectively for harvest. The ripening stage of varieties have been given in plate 1-3.

3.15. Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. The harvesting was done on 3 m^2 areas (leaving the border areas) from which data were collected and harvested separately, bundled, properly tagged and then brought to the threshing floor. Threshing was done by traditional method. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields were recorded and converted to t ha^{-1}.

3.16. Recording of data

A. Crop growth characters

Plant height (cm) at 20 days interval

Tillers $hill^{-1}$ (No.) at 20 days interval

Dry matter weight $hill^{-1}$ (g) at 30 days interval

B. Yield contributing characters

Panicle length (cm)
Effective tillers $hill^{-1}$ (No.)
Fertile spikelets (filled grains) $panicle^{-1}$ (No.)
Sterile spikelets (unfilled grains) $panicle^{-1}$ (No.)
Weight of 1000- grain (g)

C. Yield

Grain yield (t ha^{-1})
Straw yield (t ha^{-1})
Biological yield (t ha^{-1})
Harvest index (%)

3.17. Experimental measurements

Experimental data collection began at 20 days after transplanting and sowing, and continued till harvest. The necessary data on agronomic characters were collected from ten selected hills from each plot in field and at harvest.

i) Plant height

Plant height was measured at 20 days interval and continued up to 80 days and then at harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of panicle after heading.

ii) Tillers $hill^{-1}$

Number of tillers $hill^{-1}$ was counted at 20 days interval up to 80 days and then at harvest from pre selected hills and finally averaged as their number $hill^{-1}$. Only those tillers having three or more leaves were considered for counting.

iii) Dry matter weight of plant

Five hills plot^{-1} uprooted from 2nd line were oven dried until a constant level from which the weights of whole plant dry matter were recorded at 30 days interval up to harvest.

iv) Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was done on an average of 20 panicles.

v) Effective tillers hill^{-1}

The panicles which had at least one grain were considered as effective tiller.

vi) Fertile spikelets (filled grains) panicle^{-1}

Spikelet was considered to be fertile if any kernel was present there. The number of total fertile spikelets present on each panicle was recorded.

vii) Sterile spikelets (unfilled grains) panicle^{-1}

Sterile spikelet means the absence of any kernel inside in and such spikelets present on each panicle were counted.

viii) Total spikelets panicle^{-1}

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

ix) Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight was expressed in gram.

x) Grain yield

Grain yield was determined from the central 3 m^{-2} area of the plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

xi) Straw yield

Straw yield was determined from the central 3 m^{-2} area of each plot. After threshing, the sub-sample was oven dried to a constant weight and finally converted to t ha^{-1}.

xii) Biological yield

The biological yield was calculated with the following formula-

Biological yield= Grain yield + Straw yield

xiii) Harvest index (%)

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

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

3.18. Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using MSTAT-C program. The mean differences among the treatments were compared by multiple comparison tests using Duncan's Multiple Range test (DMRT) at 5% level of significance. The ANOVA Table of plant characters have been given in Appendix IV – VIII.

Chapter 4

Results and Discussion

CHAPTER 4

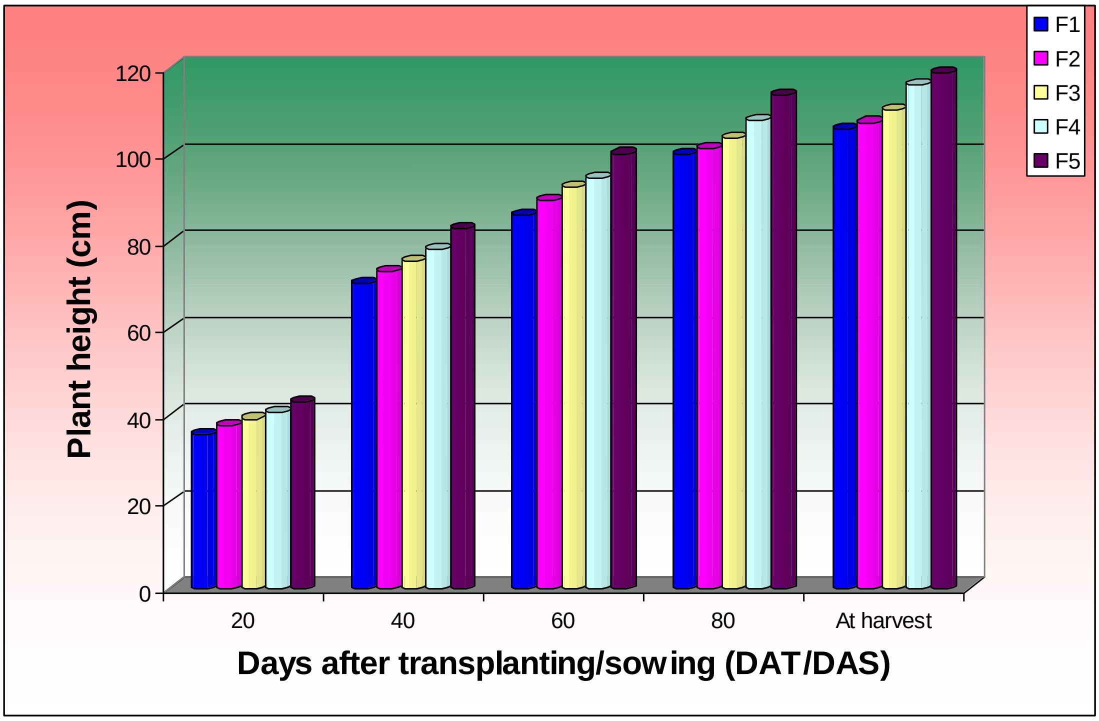
RESULTS AND DISCUSSION

4.1. Crop growth characters

4.1.1. Plant height

4.1.1.1. Effect of fertilizer

Figure 2 revealed that the plant height was increased gradually with the increased fertilizers at all studied durations. The maximum fertilizer dose (F_5) gave significantly the highest plant heights of 42.87 cm, 82.89 cm, 100.1 cm, 113.7 cm and 118.8 cm at 20, 40, 60, 80 DAT/ DAS and at harvest, respectively. Minimum fertilizer dose (F_1) produced significantly the lowest plant heights of 35.38 cm, 70.29 cm, 86.00 cm, 99.96 cm and 105.80 cm at 20, 40, 60, 80 DAT/DAS and at harvest, respectively which did not improve with increased fertilizer dose (F_2). Low recommended and recommended fertilizer dose had similar plant height at different days. It might be due to continuous availability of nutrient that enhanced the growth of the crop than the lower dose of fertilizer. Hasanuzzaman *et al*. (2010) reported that plant height was significantly influenced by different fertilizer dose. These results were in agreement with Amin *et al*. (2004) and Saha *et al*. (2004) who reported that increased fertilizer dose of NPK increases plant height of rice.



F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

Figure 1. Effect of fertilizer dose on plant height of *aman* rice at different days (SE =0.86, 0.50, 1.60, 0.75 and 0.72 at 20, 40, 60, 80 DAT/DAS and harvest, respectively).

4.1.1.2. Effect of variety

The plant height of *aman* rice was significantly influenced by different varieties at 20, 40, 60 and 80 days after transplanting/sowing (DAT/DAS) and at harvest (Figure 1 and Appendix IV). The result revealed that at 20 DAT/DAS, the BRRI dhan46 produced significantly tallest plant (46.79 cm) than BR11 (36.09 cm) and NERICA1 (34.31 cm) which were shortest but at 40 DAT/DAS BR11 produced the tallest plant (83.37 cm) where BRRI dhan46 produced 80.46 cm plant and NERICA1 gave the shortest plant (63.76 cm) and the same trend of plant height was obtained at 60 and 80 DAT/DAS and at harvest. At harvest BR11 produced the tallest plant (127.3 cm) and NERICA1 produced shortest (96.56 cm). In the early stage of growth, the increase of plant height was very slow. The rapid increase of plant height was observed from 20 to 80 DAT/DAS and then increase of plant height was ceased at harvest. Probably the genetic make up of varieties was responsible for the variation in plant height. This confirms the reports of Ashrafuzzaman *et al*. (2009), Bisne *et al*. (2006), BINA (1993), BRRI (1991) and Shamsuddin *et al*. (1988).

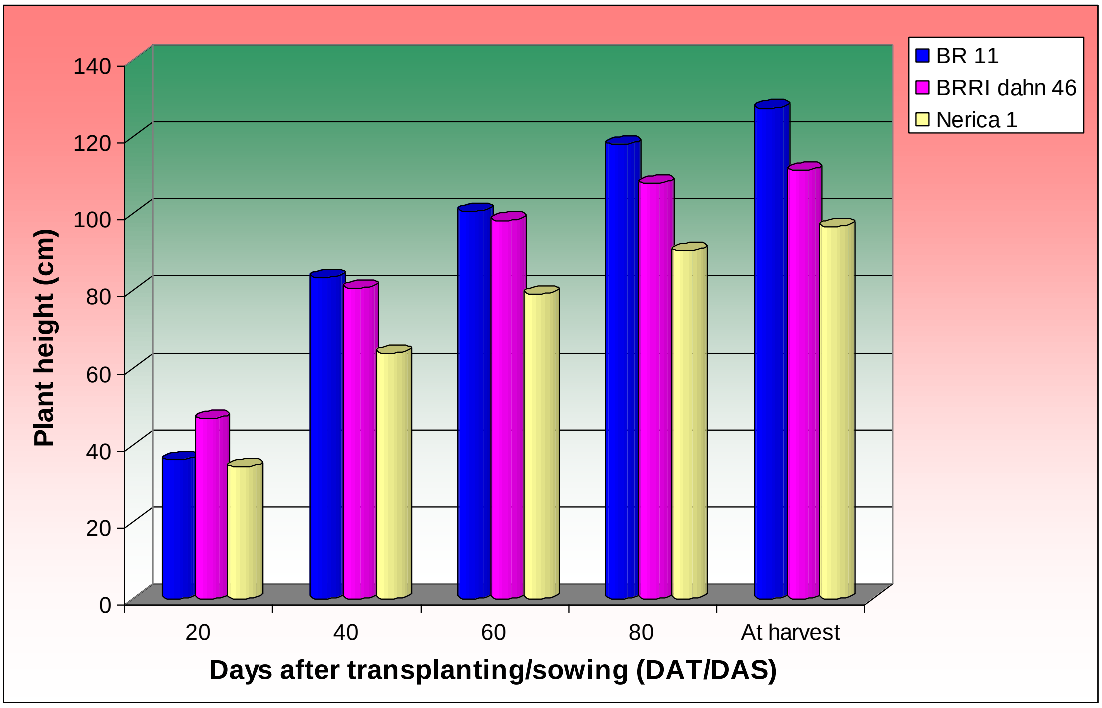


Figure 2. Effect of variety on plant height of *aman* rice at different days (SE = 0.86, 0.50, 1.60, 0.75 and 0.72 at 20, 40, 60, 80 DAT/ DAS and harvest, respectively).

4.1.1.3. Interaction effect of fertilizer dose and variety

The increased fertilizer dose could not maintain increased plant height due to the varietal effect at all studied duration (Table 1 and Appendix IV). BR11 (V_1) and BRRI dhan46 (V_2) gave intermediate plant heights combination with lower fertilizer dose. At 20 and 60 DAT/DAS the highest plant height (52.47 cm and 104.0 cm, respectively) were observed in BRRI dhan46 combinations with higher fertilizer dose (V_2F_5). Treatment V_1F_5 (BR11 combination with higher fertilizer dose) produced tallest plants 89.47cm, 103.9 cm, 120.7 cm and 130.7 cm at 40, 60, 80 DAT/ DAS and at harvest, respectively. NERICA1 produced the shortest plant heights than other two varieties at all growth stages with lower fertilizer dose. It was observed that all the varieties and NERICA-1 showed gradual increased plant height with increased fertilizer dose. Irrespective of fertilizer doses and varieties, the plant height varied from 31.27 cm to 130.7 cm. The increase in plant height attributed probably to the cell elongation and cell multiplication as optimized with variety and optimum fertilizer. Singh *et al.* (2003) who reported that plant height of rice was significantly influenced by NPK fertilizer dose.

Table 1. Interaction effect of fertilizer dose and variety on plant height at different crop growth duration of *aman* rice

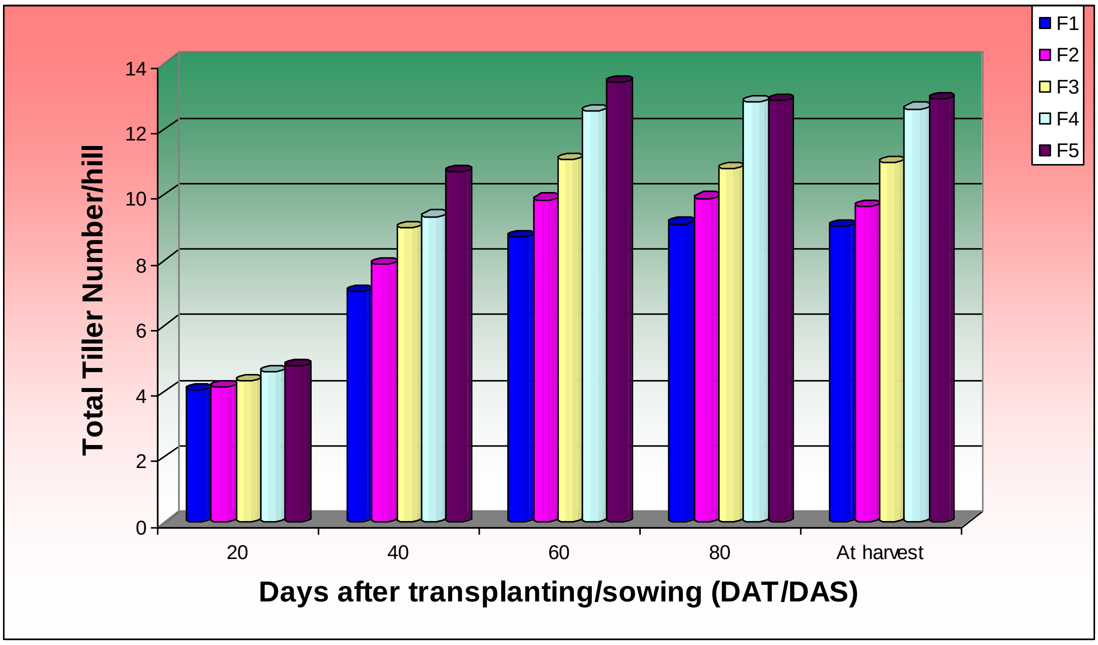
Treatments	Plant height (cm) at different days after transplanting/sowing				
	20	**40**	**60**	**80**	**At harvest**
$V_1 F_1$	32.80	78.27	96.33	115.2	123.8
$V_1 F_2$	34.87	81.07	99.13	116.1	125.6
$V_1 F_3$	36.20	82.73	101.7	117.7	126.5
$V_1 F_4$	37.53	85.33	101.9	119.5	129.8
$V_1 F_5$	39.07	89.47	103.9	120.7	130.7
$V_2 F_1$	42.07	75.53	92.33	102.1	104.2
$V_2 F_2$	44.87	79.47	94.33	103.0	105.1
$V_2 F_3$	46.40	80.93	98.80	105.7	109.4
$V_2 F_4$	48.13	82.47	101.5	111.9	116.9
$V_2 F_5$	52.47	84.80	104.0	116.5	120.1
$V_3 F_1$	31.27	57.07	71.33	82.60	89.53
$V_3 F_2$	32.93	58.27	74.67	85.13	91.13
$V_3 F_3$	34.47	62.53	77.20	87.73	94.93
$V_3 F_4$	35.80	66.53	80.13	92.07	101.7
$V_3 F_5$	37.07	74.40	92.33	103.9	105.5
SE	**0.86**	**0.50**	**1.60**	**0.75**	**0.72**
CV (%)	**3.80**	**1.09**	**3.00**	**1.24**	**1.12**

V_1=BR11, V_2=BRRI dhan46, V_3=Nerica1, F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

4.1.2. Total tiller hill^{-1}

4.1.2.1. Effect of fertilizer

Maximum fertilizer dose (F_5) influenced plant to produce greater number of tiller hill^{-1} at all growth duration (Figure 4), the values were 4.77, 10.69, 13.42, 12.87 and 12.93 at 20, 40, 60, 80 DAT/ DAS and at harvest and significantly differed which was statistically similar with F_4 (4.6, 9.33, 12.56, 12.82 and 12.62). Lower fertilizer dose (F_1) gave minimum tillers as 4.0, 7.04, 8.71, 9.11 and 9.02 closer to F_2 (4.13, 7.87, 9.84, 9.89 and 9.64) at different days of sampling. Ndaeyo *et al.* (2008) stated that increase the rare of NPK increase the total tiller number hill^{-1}. Ahmad and Hussain (1974) reported that increase in NPK fertilizer rates significantly increased tiller number plant^{-1}.



F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

Figure 3. Effect of fertilizer dose on total tiller number hill^{-1} at different crop growth duration of aman rice (SE = 0.08, 0.35, 0.52, 0.37 and 0.30 at 20, 40, 60, 80 DAT/DAS and harvest, respectively).

4.1.2.2. Effect of variety

The number of total tillers $hill^{-1}$ was significantly influenced by variety at all crop growth durations (Figure 3 and Appendix V). BR11 (V_1) showed significantly maximum tillers $hill^{-1}$ as 7.93, 11.73, 12.91, 13.59 & 13.99 at 20, 40, 60, 80 DAT/DAS & at harvest, respectively. BRRI dhan46 (V_2) had intermediate values as 4.17, 9.58, 11.99, 12.21 & 11.80 with the time. NERICA-1 was always low producer of tiller recorded as 1.00, 5.04, 8.46, 7.49 and 7.35 at all the growth durations. Irrespective of varieties, the tillers decreased at the later stage was due to greater competition for light and nutrients as observed by Ishhizuka and Tanaka (1963). This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on number of total tillers $hill^{-1}$ was also reported by Islam *et al*. (2009), Duy *et al*. (2004), Hossain and Alam (1991).

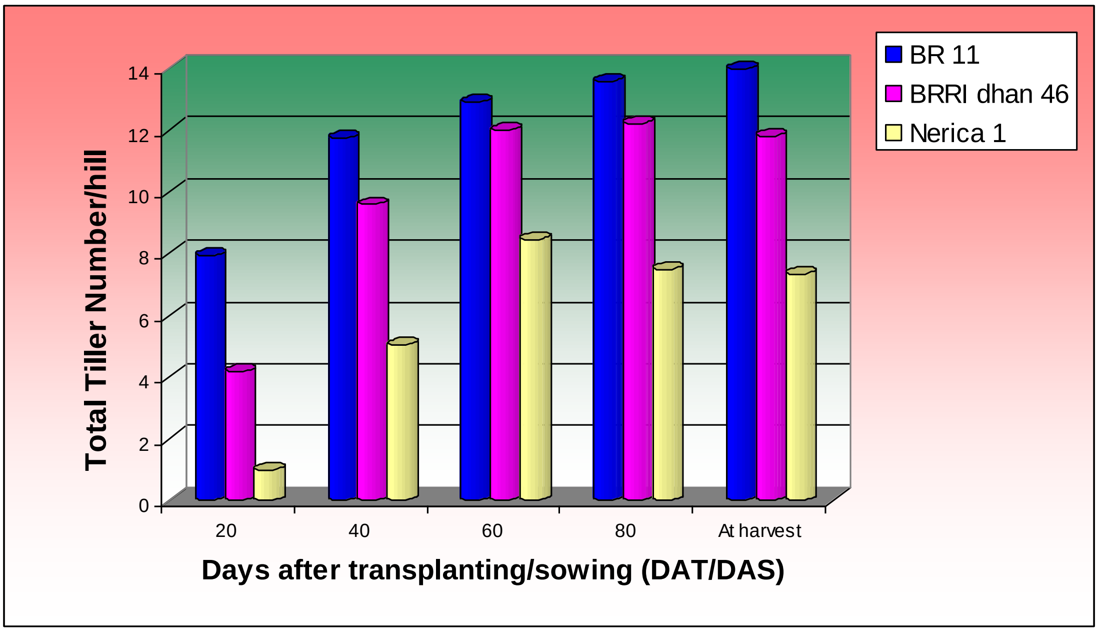


Figure 4. Effect of variety on total tiller number hill^{-1} at different crop growth duration of *aman* rice (SE = 0.08, 0.35, 0.52, 0.37 and 0.30 at 20, 40, 60, 80 DAT/DAS and harvest, respectively).

4.1.2.3. Interaction effect of fertilizer dose and variety

It was reveled from table 2 that variety BR11 gave significantly greater tillers hill^{-1} with higher fertilizer dose (F_5) at all growth duration and the values were 8.20, 13.87, 15.73, 16.47 and 17.60. The same variety with recommended fertilizer dose (F_4) gave closer number of tillers (8.13, 12.40, 13.80, 16.80 and 16.60) in different days. Even with the lower recommended fertilizer dose (F_3) the production of tillers was almost similar which could not remarkably change with higher dose of fertilizer (F_5) by BRRI dhan46. NERICA1 was lower tiller producer with lower fertilizer dose (F_1) as 1.00, 4.33, 6.46, 6.40 and 6.47 at 20, 40, 60, 80 DAT/DAS and at harvest, respectively and could not improve the tiller production remarkably with higher fertilizer dose (F_2, F_3, F_5). Inthapanva *et al.* (2000) reported that there was both genotype and genotype-by-fertilizer interaction in total tiller number of rice.

Table 2. Interaction effect of fertilizer dose and variety on total tiller number hill^{-1} at different crop growth duration of aman rice

Treatments	Total tiller number at different days after transplanting/sowing				
	20	40	60	80	At Harvest
V_1 F_1	7.73	9.80	10.47	10.33	10.53
V_1 F_2	7.67	10.27	11.60	11.80	11.67
V_1 F_3	7.93	12.33	12.93	12.53	13.47
V_1 F_4	8.13	12.40	13.80	16.80	16.60
V_1 F_5	8.20	13.87	15.73	16.47	17.60
V_2 F_1	3.33	7.00	9.20	10.60	10.07
V_2 F_2	3.73	8.60	10.13	11.07	10.73
V_2 F_3	4.00	9.53	11.80	12.40	12.33
V_2 F_4	4.67	10.60	13.20	13.33	12.93
V_2 F_5	5.13	12.20	15.60	13.67	12.93
V_3 F_1	1.00	4.33	6.47	6.40	6.47
V_3 F_2	1.00	4.73	7.80	6.80	6.53
V_3 F_3	1.00	5.13	8.47	7.47	7.13
V_3 F_4	1.00	5.00	10.67	8.33	8.33
V_3 F_5	1.00	6.00	8.933	8.47	8.27
SE	**0.08**	**0.35**	**0.52**	**0.37**	**0.30**
CV (%)	**3.01**	**6.98**	**8.11**	**5.79**	**4.75**

V_1=BR11, V_2=BRRI dhan46, V_3=Nerica1, F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

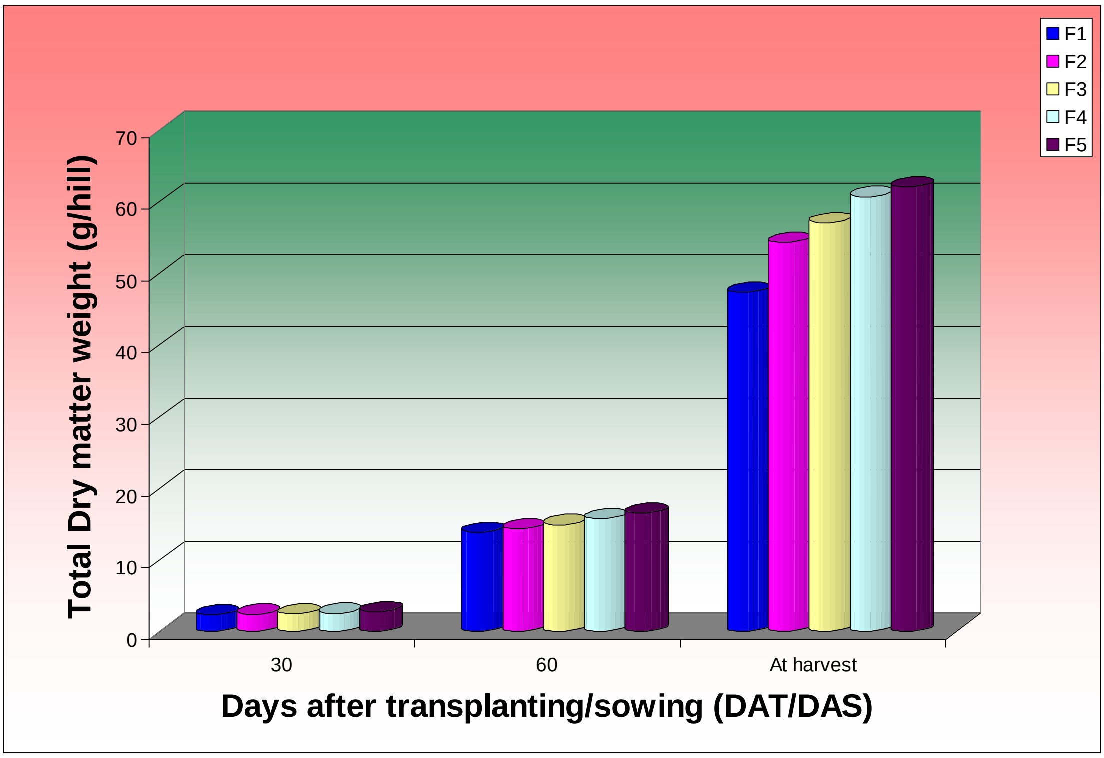
4.1.3. Total dry matter hill^{-1}

Total dry matter (TDM) is an important plant parameter that governs crop growth, development and yield. Irrespective of treatment difference, the production of TDM was very slow at early growth (30 DAT/DAS) and started increase at 60 DAT/DAS and reached the peak at harvest. The production was varied between 3.42 g and 74.07 g.

4.1.3.1. Effect of fertilizer

At 20 DAT/DAS, higher fertilizer dose (F_5) produced significantly greater TDM hill^{-1} (2.74 g) followed by recommended fertilizer dose (F_4) 2.56 g (Figure 6 and Appendix VI). Again the production was very similar for F_4, F_3 and F_2. Significantly lower dry matter (2.32 g) was found from F_1 followed by F_2 (2.40 g) and F_3 (2.45 g). At 60 DAT/DAS the maximum TDM hill^{-1} (16.49 g) was measured from higher fertilizer dose (F_5). Second amount (15.73 g) was given by recommended fertilizer dose (F_4) but significantly lowest value (13.84 g) was given by lower fertilizer dose (F_1) followed by F_2 (14.29 g). At harvest, higher fertilizer dose (F_5) and recommended fertilizer dose (F_4) gave similar production of TDM (61.96 g and 60.61 g). F_2 and F_3 produced intermediate value. F_1 showed significantly minimum production (47.29 g).This might be due to the fact that higher fertilizer dose of NPK receiving plants got continuous supply of NPK and plants could better utilize it and growth parameters were positively responded to it. This confirms the reports of

Hasanuzzaman *et al*. (2010) and Singh *et al.* (2003) who reported that total dry weight of plant increased with the increased level of NPK fertilizer.



F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

Figure 5. Effect of fertilizer dose on total dry matter hill^{-1} at different crop growth duration of aman rice (SE = 0.06, 0.22 and 1.08 at 30, 60 DAT/DAS and at harvest, respectively).

4.1.3.2. Effect of variety

BR11 remained on the top of the position of three tested varieties for their production of TDM hill^{-1} (Figure 5). Significantly maximum TDM were 3.70 g, 20.52 g and 74.07 g on 30, 60 DAT/DAS and at harvest, respectively. BRRI dhan46 was the second producer of TDM at all sampling. NERICA1 produced significantly minimum TDM, 0.35 g, 9.39 g and 38.02 g at 30, 60 DAT/DAS and at harvest, respectively. BR11 gave 9.57 %, 118% and 95% more TDM than NERICA1 at different days. Ntanos *et al*. (2002) reported that grain yield was positively and significantly correlated with dry matter and N translocation efficiency. Amin *et al*. (2006) and Son *et al*. (1998) reported that total dry matter production of rice differed due to varietal variation.

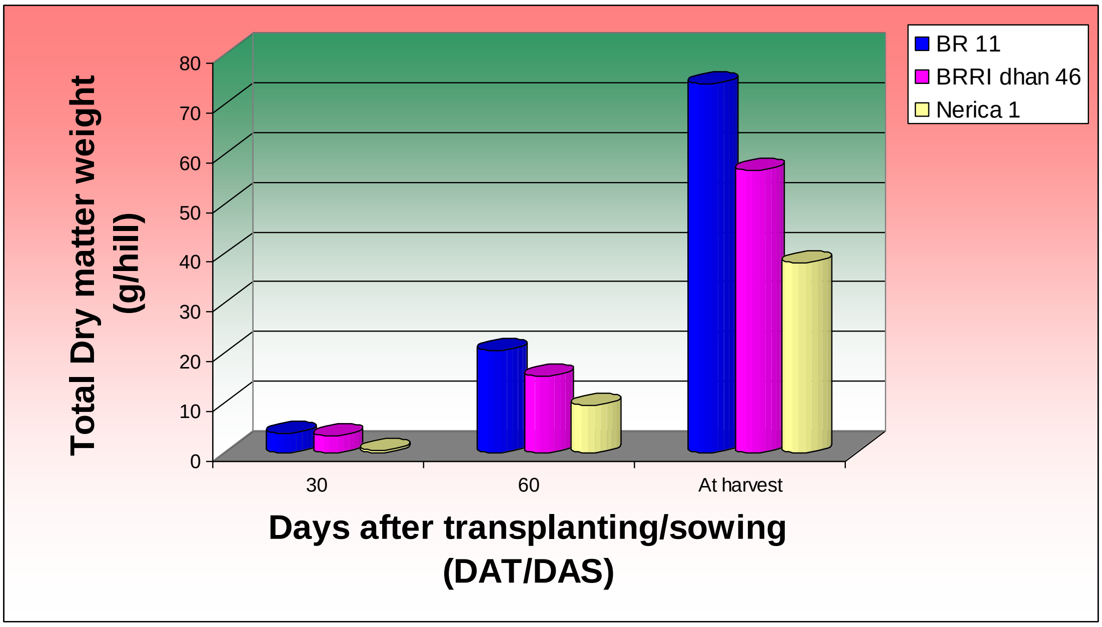


Figure 6. Effect of variety on total dry matter hill^{-1} at different crop growth duration of aman rice (SE = 0.06, 0.22 and 1.08 at 30, 60 DAT/DAS and harvest, respectively).

4.1.3.3. Interaction effect of fertilizer dose and variety

Irrespective of treatment difference, there was an increased trend of total dry matter hill^{-1} production with increased fertilizer dose. Interaction between variety and fertilizer dose was found to have significant influence on the production of total dry matter hill^{-1} (Table 3 and Appendix VI). BR11 along with higher fertilizer dose (V_1F_5) produced maximum dry matter 4.08 g, 22.27 g and 79.48 g at 30, 60 DAT/DAS and at harvest, respectively. At harvest this variety with next fertilizer dose (V_1F_4) produced similar quantity of dry matter (78.77 g). This variety also gave second highest amount of dry matter with lower fertilizer dose at different days of sampling. NERICA1 with different dose of fertilizer produced minimum weight of dry matter at each sampling. It suggested that NERICA1 was not suitable for cultivating in *aman* season of Bangladesh. The variation between the production of total dry matter hill^{-1} for BR11 × higher dose of fertilizer (V_1F_5) and NERICA1 × higher dose of fertilizer (V_3F_5) were 90%, 54% and 46% at 30, 60 DAT/DAS and at harvest, respectively.

Table 3. Interaction effect of fertilizer dose and variety on total dry matter production hill^{-1} of *aman* rice at different days

Treatments	**Total dry weight hill^{-1} (g) at different days**		
	30 DAT/DAS	**60 DAT/DAS**	**At harvest**
$V_1 F_1$	3.41	18.85	62.69
$V_1 F_2$	3.57	19.50	74.16
$V_1 F_3$	3.67	20.43	75.27
$V_1 F_4$	3.81	21.56	78.77
$V_1 F_5$	4.08	22.27	79.48
$V_2 F_1$	3.24	14.12	46.45
$V_2 F_2$	3.31	14.48	54.49
$V_2 F_3$	3.33	14.95	57.01
$V_2 F_4$	3.50	15.66	61.28
$V_2 F_5$	3.74	17.02	63.57
$V_3 F_1$	0.32	8.56	32.72
$V_3 F_2$	0.33	8.90	34.08
$V_3 F_3$	0.35	9.35	38.70
$V_3 F_4$	0.38	9.97	41.77
$V_3 F_5$	0.40	10.18	42.83
SE	**0.06**	**0.22**	**1.08**
CV (%)	**4.39**	**2.52**	**4.05**

V_1=BR11, V_2=BRRI dhan46, V_3=Nerica1, F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

4.2. Yield contributing characters

4.2.1. Effective tillers hill^{-1}

Total tillers determine the amount of dry matter production unit area^{-1} while productive tillers unit area^{-1} determined the final yield of rice.

4.2.1.1. Effect of fertilizer

Irrespective of fertilizer dose the production of effective tiller hill^{-1} gradually increased with increased fertilizer dose. Different NPK fertilizer level significantly influenced the number of effective tillers hill^{-1} (Table 4 and Appendix VII). The maximum number of effective tillers hill^{-1} (10.81) was obtained from the recommended fertilizer dose which was statistically similar with higher fertilizer dose (10.67). The second highest effective tiller hill^{-1} was recorded as 9.38 and 8.49 for F_3 and F_2, respectively. Lower fertilizer dose produced minimum number of effective tillers hill^{-1} (7.82). This confirms the report of Ndaeyo *et al.* (2008) and Venkateswarlu and Singh (1980) who reported that the number of effective tillers per plant across the rice cultivars increased with increased rate of NPK.

4.2.1.2. Effect of variety

It was evident from table 4 and appendix VII that variety had significant influence on numbers of effective tiller hill^{-1}. BR11 produced significantly higher number (11.01) than BRRI dhan46 (9.6) and then NERICA1 (7.69) which was 13% and 43% greater than BRRI dhan46 and NERICA1, respectively. This confirms the report of Sawant *et al.* (1986), who reported that variable effect of variety on the number of effective tillers hill^{-1} of rice.

4.2.1.3. Interaction effect of fertilizer dose and variety

The effect of interaction between variety and fertilizer was found to be significant in respect of number of productive tillers hill^{-1} (Table 4 and Appendix VII). Combination of BR11 with recommended fertilizer dose (V_1F_4) produced the highest (12.77) number of productive tillers hill^{-1} which was statistically similar to same variety (12.13) with higher fertilizer dose (V_1F_5). NERICA1 with lower fertilizer dose (V_3F_1) gave minimum number of effective tiller hill^{-1} (6.13) followed by same variety with moderate fertilizer dose (V_3F_2).

4.2.2. Panicle length

4.2.2.1. Effect of fertilizer

The panicle length varied significantly due to different NPK fertilizer dose (Table 4 and Appendix VII). Longer (26.20 cm) panicle was produced due to the application of higher lever of NPK fertilizer dose (F_5) which was statistically similar (25.69 cm) due to application of recommended NPK fertilizer dose. F_3 and F_2 produced moderate panicle length. The shortest (23.31 cm) panicle length was found with lower fertilizer dose (F_1). A similar finding was reported by Saha *et al.* (2004). Islam *et al.* (2008) and Asif *et al* (2000) whom reported that panicle length of rice was influenced significantly due to application of different rates of NPK nutrients.

4.2.2.2. Effect of variety

The panicle length varied significantly due to variety shown in table 4 and appendix VII. It was observed that BRRI dhan46 produced longer (25.92 cm) panicle than BR11 (25.00 cm) and NERICA1 (23.49 cm). This confirms the report of Alam *et al.* (2009), Ahmed *et al*. (1997) and Idris and Matin (1990) who reported that panicle length of rice was differed due to variety.

4.2.2.3. Interaction effect of fertilizer dose and variety

Panicle length was statistically influenced by the interaction of variety and different NPK fertilizer dose (Table 4 and Appendix VII). The longer panicle length (27.20 cm) was found in BRRI dhan46 combinations with higher fertilizer dose (V_2F_5) which was statistically similar with same variety combination with recommended NPK fertilizer dose (V_2F_4) (26.80 cm) and BR11 with higher fertilizer dose (26.73 cm). The shortest panicle length was found in NERICA1 (22.09 cm) in combination with lower fertilizer dose (V_3F_1) followed by same variety with moderate fertilizer dose (V_3F_2).

4.2.3. Total grains panicle^{-1}

The total number of grains panicle^{-1} is an important factor which contributes towards grain yield.

4.2.3.1. Effect of fertilizer

Different fertilizer dose affected number of total grains panicle^{-1} significantly (Table 4 and Appendix VII). Results showed that higher total number of grains panicle^{-1} (141.3) was obtained with recommended NPK fertilizer dose (F_4) which was statistically similar (136.1) with higher NPK fertilizer dose (F_5). Lower number of total grains panicle^{-1} (116.3) was found in lower NPK fertilizer dose (F_1) at par with F_2 that produced 119.0 total grain panicle^{-1}. This result confirms the findings of Saha *et al.* (2004) who reported that total grains panicle^{-1} of rice significantly differed due to different fertilizer dose.

4.2.3.2. Effect of variety

Table 4 and Appendix VII shows that cultivars affected significantly the number of total grains panicle^{-1}. It was revealed that BR11 gave significantly higher number (142.3) grains panicle^{-1} than BRRI dhan46 (127.3) and NERICA1 (115.5) which was 10% and 19% higher than BRRI dhan46 and NERICA1, respectively. This result confirms the findings of Hossain and Alam (1991) who said that total grains panicle^{-1} of rice significantly differed due to variety.

Table 4. Effect of fertilizer dose and variety and their interaction on yield contributing characters of *aman* rice

Treatments	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Total grains panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Filled grains panicle^{-1} (%)	1000 grain weight (g)
Fertilizer							
F_1	7.822	23.31	116.3	88.06	28.29	75.25	25.50
F_2	8.489	24.11	119.0	93.11	25.91	78.01	25.74
F_3	9.378	24.73	129.1	104.7	24.37	80.96	25.78
F_4	10.81	25.69	141.3	119.9	21.39	84.64	25.84
F_5	10.67	26.20	136.1	115.4	20.78	84.48	25.91
SE	**0.36**	**0.27**	**3.78**	**3.82**	**0.48**	**0.67**	**0.20**
CV (%)	**6.59**	**1.88**	**5.10**	**6.34**	**3.43**	**1.44**	**1.33**
Variety							
V_1	11.01	25.00	142.3	119.8	22.55	83.92	23.10
V_2	9.600	25.92	127.3	102.9	24.40	80.51	25.11
V_3	7.693	23.49	115.5	90.04	25.50	77.57	29.06
SE	**0.36**	**0.27**	**3.78**	**3.82**	**0.48**	**0.67**	**0.20**
CV (%)	**6.59**	**1.88**	**5.10**	**6.34**	**3.43**	**1.44**	**1.33**
Interaction effect of fertilizer dose and variety							
$V_1 F_1$	9.10	23.57	131.1	104.8	26.35	79.87	22.63
$V_1 F_2$	10.27	24.23	131.2	107.0	24.17	81.57	23.00
$V_1 F_3$	10.77	24.53	138.9	116.2	22.78	83.60	23.00
$V_1 F_4$	12.77	25.95	157.6	137.7	19.95	87.34	23.50
$V_1 F_5$	12.13	26.73	152.7	133.2	19.50	87.23	23.37
$V_2 F_1$	8.23	24.27	115.8	87.50	28.27	75.55	24.87
$V_2 F_2$	8.50	25.32	116.7	89.67	27.07	76.75	25.20
$V_2 F_3$	9.70	26.02	130.5	105.8	24.67	81.03	25.30
$V_2 F_4$	10.80	26.80	138.9	117.7	21.20	84.75	25.00
$V_2 F_5$	10.77	27.20	134.4	113.6	20.78	84.46	25.17
$V_3 F_1$	6.13	22.09	102.2	71.92	30.27	70.34	29.00
$V_3 F_2$	6.70	22.78	109.1	82.63	26.50	75.70	29.03
$V_3 F_3$	7.67	23.64	117.8	92.18	25.65	78.23	29.03
$V_3 F_4$	8.87	24.30	127.2	104.2	23.03	81.84	29.03
$V_3 F_5$	9.10	24.66	121.4	99.30	22.07	81.74	29.20
SE	**0.36**	**0.27**	**3.78**	**3.82**	**0.48**	**0.67**	**0.20**
CV (%)	**6.59**	**1.88**	**5.10**	**6.34**	**3.43**	**1.44**	**1.33**

V_1=BR11, V_2=BRRI dhan46, V_3=Nerica1, F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

4.2.3.3. Interaction effect of fertilizer dose and variety

Interaction effect of variety and different level of NPK fertilizer was found significant on total grains panicle^{-1} (Table 4 and Appendix VII). It was observed that the highest total grains panicle^{-1} (157.6) was found from the combination of BR11 with recommended dose of NPK fertilizer (V_1F_4) which was statistically similar with the combination of same variety with higher level of NPK fertilizer (V_1F_5) (152.7). NERICA1 with lower fertilizer dose (V_3F_1) gave lower grains panicle^{-1} (102.2) and followed by same variety with moderate fertilizer dose (V_3F_2).

4.2.4. Filled grains panicle^{-1}

4.2.4.1. Effect of fertilizer

From the table 4 and Appendix VII it was observed that there was a statistical variation in number of filled grains panicle^{-1} due to different level of NPK fertilizer application. Results showed that higher number of filled grains panicle^{-1} (119.9) was obtained with recommended NPK fertilizer dose (F_4) which was statistically similar (115.4) with higher NPK fertilizer dose (F_5). Lower recommended NPK fertilizer dose (F_1) and moderate fertilizer dose (F_2) produced minimum filled grains, 88.06 and 93.11. Higher fertilizer dose (F_5) and low recommended fertilizer dose (F_3) gave similar number of grains panicle^{-1} which was second highest. Islam *et al.* (2008) and Saha *et al.* (2004)

reported that number of filled grains per panicle of rice was influenced significantly due to application of different rates of NPK nutrients.

4.2.4.2. Effect of variety

Table 4 and Appendix VII showed that cultivars produced significantly higher number of filled grains panicle^{-1}. It was revealed that BR11 gave significantly higher number (119.8) of grains panicle^{-1} than BRRI dhan46 (102.9) and NERICA1 (90.04) and it was 14% and 25% greater than BRRI dhan46 and NERICA1, respectively. Alam *et al.* (2009) and BRRI (1994) found that number of filled grains panicle^{-1} significantly differed due to variety.

4.2.4.3. Interaction effect of fertilizer dose and variety

Interaction effect of variety and different level of NPK fertilizer was found significant for filled grains panicle^{-1} (Table 4 and Appendix VII). From the results it was observed that highest (137.7) filled grains panicle^{-1} was found from the combination of BR11 with recommended dose of NPK fertilizer (V_1F_4) which was statistically similar with the combination of BR11 with higher level of NPK fertilizer (V_1F_5) (133.2). The lowest (71.92) filled grains panicle^{-}1 was recorded from NERICA1 with lower fertilizer dose (V_3F_1) followed by the same variety with moderate fertilizer dose (V_3F_2).

4.2.5. Unfilled grains panicle^{-1}

4.2.5.1. Effect of fertilizer

Irrespective of fertilizer dose, the increased amount of fertilizer probably influenced grain filling. Different levels of NPK fertilizer showed significant variation on the number of unfilled grains panicle^{-1} (Table 4 and Appendix VII). The lowest number of unfilled grains panicle^{-1} (20.78) was obtained from the higher level of fertilizer dose (F_5) which was statistically similar with recommended NPK fertilizer dose (F_4) (21.39). The highest number of unfilled grain (28.29) was obtained from the lower fertilizer dose (F_1). This confirmed the report of Saha *et al.* (2004) and Islam *et al.* (2008) who reported that number of unfilled grain panicle^{-1} was influenced significantly due to the application of different rates of NPK nutrients.

4.2.5.2. Effect of variety

Results showed that variety had significant effect on the number of unfilled grains panicle^{-1} (Table 4 and Appendix VII). BR11 produced minimum number (22.55) of unfilled grains panicle^{-1} than BRRI dhan46 (24.40) and NERICA1 (25.50). This variation might be due to genetic characteristics. Alam *et al.* (2009), BINA (1993) and Chowdury *et al.* (1993) reported differences in number of unfilled grains panicle^{-1} due to varietal differences.

4.2.5.3. Interaction effect of fertilizer dose and variety

Interaction of variety and different fertilizer did not significant response on unfilled grains panicle^{-1} (Table 4 and Appendix VII). It was observed that maximum unfilled grains panicle^{-1} (30.27) was collected from NERICA1 with lower fertilizer dose (V_3F_1). Minimum (19.50) was in BR11 with higher fertilizer dose (V_1F_5) followed by same variety with recommended fertilizer (V_1F_4) and BRRI dhan46 with higher fertilizer dose (V_2F_5).

4.2.6. Filled grains panicle^{-1} (%)

4.2.6.1. Effect of fertilizer

It was observed that increased fertilizer dose improved grain filling. There was a statistical variation in filled grains percentage panicle^{-1} due to different level of NPK fertilizer application (Table 4 and Appendix VII). Results showed that higher number of filled grains percentage panicle^{-1} was obtained with recommended NPK fertilizer dose (F_4) (84.64 %) which was statistically similar with higher NPK fertilizer dose (F_5) (84.48 %). Lower filled grain percentage was found in lower NPK fertilizer dose (F_1) (75.25 %). Similar result was also found by Islam *et al.* (2008).

4.2.6.2. Effect of variety

The varietal effect on percentage of filled grains panicle^{-1} was found significant (Table 4 and Appendix VII). It was appeared that BR11 gave significantly highest (83.92 %) filled grain percentage than BRRI dhan46 (80.51 %) and

NERICA1 (77.57 %) and it was 4% and 7% greater. The result is an agreement with the findings of Guilani *et al.* (2003).

4.2.6.3. Interaction effect of fertilizer dose and variety

Percentage of filled grains panicle significantly responded for interaction effect of variety and different level of NPK fertilizer (Table 4 and Appendix VII). It was observed that highest filled grain percentage (87.34 %) was found from the combination of BR11 with recommended dose of NPK fertilizer (V_1F_4) which was statistically similar with the combination of BR11 with higher level of NPK fertilizer (V_1F_5) (87.23 %). The lowest (70.34 %) filled grains panicle^{-1} was recorded in NERICA1 with lower fertilizer dose (V_3F_1).

4.2.7. 1000-grain weight

4.2.7.1. Effect of fertilizer

There was no significant variation in 1000-seed weight due to different NPK fertilizer level (Table 4 and Appendix VII). The weight of 1000-seed was 25.91 g, 25.84 g, 25.78 g, 25.74 g and 25.50 g for higher fertilizer dose (F_5), recommended fertilizer dose (F_4), low recommended dose (F_3), moderate fertilized dose (F_2) and low fertilizer dose (F_1), respectively. This result was an agreement with the findings of Chandrashekarappa (1985) and Sikdar and Gupta (1979) who reported that with the increase of fertilizer dose, 1000-grain weight increased to some extent.

4.2.7.2. Effect of variety

Variety had significant effect on 1000-grain weight (Table 4 and Appendix VII). The highest weight of 1000-grains (29.06 g) was obtained from the NERICA1. BRRI dhan46 had moderate grain size (25.11 g) and BR11 had smaller grain size (23.10 g). The variation of 1000-grains weight among varieties might be due to genetic constituents. Similar results were found by Alam *et al.* (2009) and Bhowmick and Nayak (2000). This result was an agreement with the findings of Rafey *et al*. (1989) and Shamsuddin *et al.* (1988) who stated that weight of 1000-grain differed due to the varietal differences.

4.2.7.3. Interaction effect of fertilizer dose and variety

Interaction of variety and different fertilize level showed significant variation on 1000-grain weight (Table 4 and Appendix VII). It ranged between 22.63 g to 29.20 g. the heaviest (29.20 g) 1000-grain weight was obtained from NERICA1 combination with higher level of fertilizer dose (V_3F_5) at par with V_3F_4, V_3F_3, V_3F_2 and V_3F_1. The lowest (22.63 g) seed weight was obtained from BR11 combination with lower level of fertilizer dose (V_1F_1) and similar with (V_1F_2) and (V_1F_3).

4.3. Yields

4.3.1. Grain yield

4.3.1.1. Effect of fertilizer

Different fertilizer dose had significant effect on grain yield (Table 5 and Appendix VIII). Higher NPK fertilizer dose (F_5) produced significantly the highest grain yield (3.83 t ha^{-1}) which was statistically similar with recommended fertilizer dose (F_4) (3.68 t ha^{-1}). Reduction rate of fertilizer gradually decrease the grain yield i.e. F_3 (2.97 t ha^{-1}), F_2 (2.62 t ha^{-1}) and F_1 (2.29 t ha^{-1}) and it was 29%, 31% and 40% lower than grain yield of higher fertilizer rate (F_5). With the application of higher fertilizer dose present experiment produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave higher grain yield. Badruddin *et al.* (2000) found that the yield of T. aman (summer) rice (BR11) varieties increased with the application of recommended dose of N, P, K, S fertilizer. Similar results were found by Islam *et al.* (2008) and Mollah *et al.* (2008). Sudha and Chandini (2002) found increased grain yield of rice with increased fertilizer rate.

4.3.1.2. Effect of variety

Grain yield is a function of various yield components such as number of productive tillers, filled grains $panicle^{-1}$ and 1000-grain weight (Hassan *et al*., 2003). In present experiment variety had significant effect on grain yield

(Table 5 and Appendix VIII). It was evident that BR11 produced higher (3.74 t ha^{-1}) grain yield which was contributed from higher number of effective tiller $hill^{-1}$, higher number of grains $panicle^{-1}$ and higher number of filled grains $panicle^{-1}$. BRRI dhan46 produced second highest grain yield (3.16 t ha^{-1}) and NERICA1 (2.33 t ha^{-1}) the lowest. BR11 out yielded BRRI dhan46 and NERICA1 by 18% and 60% respectively. Similar results on grain yied of rice were found by Ashrafuzzaman *et al.* (2009), Duy *et al*. (2004) and Molla (2001). Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) who recorded variable grain yields among tested varieties. The probable reason for variation on yield was due to the heredity of the variety.

4.3.1.3. Interaction effect of fertilizer dose and variety

Grain yield was significantly influenced by the interaction of variety and fertilizer dose (Table 5 and Appendix VIII). The highest (4.72 t ha^{-1}) grain yield was observed from the combination of BR11 with higher fertilizer dose (V_1F_5) which was statistically similar with the combination of the same variety with recommended fertilizer dose (V_1F_4) (4.54 t ha^{-1}). The lowest (1.97 t ha^{-1}) yield was found from the combination of NERICA1 with low fertilizer dose (V_3F_1) which was statistically similar (2.08 t ha^{-1}) with the combination of the same variety with moderate fertilizer dose (V_3F_2). NERICA1 could not produce higher yield with further higher fertilizer dose.

Table 5. **Effect of fertilizer dose and variety and their interaction on grain yield, straw yield, biological yield and harvest index of aman rice**

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Fertilizer				
F_1	2.29	4.51	6.79	33.51
F_2	2.62	4.65	7.28	35.78
F_3	2.97	4.82	7.79	37.88
F_4	3.68	5.24	8.92	40.78
F_5	3.83	5.28	9.12	41.60
SE	**0.07**	**0.07**	**0.10**	**0.64**
CV (%)	**3.83**	**2.31**	**2.16**	**2.93**
Variety				
V_1	3.74	5.39	9.13	40.53
V_2	3.16	4.98	8.14	38.37
V_3	2.33	4.33	6.66	34.83
SE	**0.07**	**0.07**	**0.10**	**0.64**
CV (%)	**3.83**	**2.31**	**2.16**	**2.93**
Interaction effect of fertilizer dose and variety				
V_1 F_1	2.64	4.89	7.53	35.05
V_1 F_2	3.23	5.09	8.32	38.84
V_1 F_3	3.57	5.32	8.89	40.14
V_1 F_4	4.54	5.79	10.33	43.97
V_1 F_5	4.72	5.86	10.58	44.64
V_2 F_1	2.25	4.47	6.72	33.39
V_2 F_2	2.56	4.57	7.13	35.88
V_2 F_3	3.04	4.93	7.97	38.17
V_2 F_4	3.92	5.42	9.34	41.96
V_2 F_5	4.05	5.50	9.55	42.44
V_3 F_1	1.97	4.16	6.13	32.09
V_3 F_2	2.08	4.30	6.39	32.62
V_3 F_3	2.30	4.21	6.50	35.32
V_3 F_4	2.58	4.50	7.08	36.41
V_3 F_5	2.72	4.49	7.22	37.74
SE	**0.07**	**0.07**	**0.10**	**0.64**
CV (%)	**3.83**	**2.31**	**2.16**	**2.93**

V_1=BR11, V_2=BRRI dhan46, V_3=Nerica1, F_1=Low fertilizer dose, F_2= Moderate fertilizer dose, F_3= Low recommended fertilizer dose, F_4= Recommended fertilizer dose, F_5= Higher fertilizer dose

4.3.2. Straw yield

4.3.2.1. Effect of fertilizer

From the Table 5 and Appendix VIII, it was found that straw yield was significantly affected due to the different fertilizer dose. The mean straw yield due to application of NPK fertilizer revealed that the straw yield was the highest (5.28 t ha^{-1}) with higher fertilizer dose which was similar with the application of recommended fertilizer dose (5.24 t ha^{-1}). Yadav and Tripathi (2006), Amin *et al.* (2004) and Sudha and Chandini (2002) found increased straw yield with increased fertilizer dose.

4.3.2.2. Effect of variety

The yield of straw was observed to differ significantly due to varieties (Table 5 and Appendix VIII). It was evident from the experimental results that BR11 produced the highest (5.39 t ha^{-1}) straw yield compared to BRRI dhan46 (4.98 t ha^{-1}) and NERICA1 (4.33 t ha^{-1}). The variety BR11 was tall produced higher straw yield compared to dwarf variety BRRI dhan46 and NERICA1. The result was in agreement with the findings of Panda and Leeuwrik (1971) who reported that the straw yield could be relate to plant height. Ashrafuzzaman *et al.* (2009) found that straw yield differed due to variety.

4.3.2.3. Interaction effect of fertilizer dose and variety

It was evident from the Table 5 and Appendix VIII that interaction of variety and fertilizer dose had significant effect on straw yield. The highest straw yield (5.86 t ha^{-1}) was found from the combination of BR11 with higher fertilizer dose (V_1F_5) which was statistically similar (5.79 t ha^{-1}) with the same variety with recommended fertilizer dose (V_1F_4). The lowest (4.16 t ha^{-1}) straw yield was observed from the combination of NERICA1 with lower fertilizer dose (V_3F_1) which was similar with same variety with low recommended fertilizer dose (V_3F_3) and the moderate fertilizer dose (V_3F_2).

4.3.3. Biological Yield

4.3.3.1. Effect of fertilizer

From the Table 5 and Appendix VIII, it was found that biological yield was significantly affected due to the different fertilizer dose. The mean biological yield due to application of NPK fertilizer revealed that the biological yield was the highest (9.12 t ha^{-1}) with higher fertilizer dose (F_5) which was similar with the application of recommended fertilizer dose (F_4) (8.92 t ha^{-1}). Biological yield was lower (6.79 t ha^{-1}) with lower fertilizer dose (F_1).

4.3.3.2. Effect of Variety

Varieties differed significantly among themselves regarding biological yield (Table 5 and Appendix VIII). It was evident from the experimental results that

BR11 produced the highest (9.13 t ha^{-1}) biological yield than BRRI dhan46 (8.14 t ha^{-1}) and NERICA1 (6.66 t ha^{-1}). Higher grain and straw yield attributed to higher biological yield. This view was supported by Singh and Ganger (1989). Alam *et al.* (2009) reported that biological yield varied significantly due to variety.

4.3.3.3. Interaction effect of fertilizer dose and variety

Interaction effect of variety and fertilizer had significant effect on biological yield (Table 5 and Appendix VIII). Maximum (10.58 t ha^{-1}) biological yield was found from the combination of BR11 with higher fertilizer dose (V_1F_5) which was statistically similar with the combination of same variety with recommended fertilizer dose (V_1F_4) (10.33 t ha^{-1}). Minimum yield (6.13 t ha^{-1}) was obtained from the combination of NERICA1 with lower fertilizer dose (V_3F_1) and same variety with moderate fertilizer dose (V_3F_2).

4.4. Harvest index

4.4.1. Effect of fertilizer

NPK fertilizer had significant effect on harvest index (Table 5 and Appendix VIII). Higher dose of NPK fertilizer (F_5) produced the maximum (41.60 %) harvest index which was statistically similar to recommended NPK fertilizer dose (F_4) (40.78 %). On the other hand, the minimum (33.51%) harvest index was obtained from lower dose of NPK fertilizer (F_1).

4.4.2. Effect of variety

It was found from Table 5 and Appendix VIII that variety had significant effect on harvest index. From the results it was evident that BR11 produced the highest (40.53%) harvest index than BRRI dhan46 (38.37%) and NERICA1 (34.83 %). Low HI in BRRI dhan46 and NERICA1 were caused by poor grain yield. The result was in agreement with the findings of Alam *et al.* (2009) who reported that harvest index differed significantly due to variety.

4.4.3. Interaction effect of fertilizer dose and variety

The effect of interaction of variety and different fertilizer dose was found significant on harvest index (Table 5 and Appendix VIII). Maximum (44.64 %) harvest index was found from the combination of BR11 with higher level of NPK fertilizer dose (V_1F_5) which was statistically similar with combination of the same variety with recommended fertilizer dose (V_1F_4) (43.97). Minimum (32.09 %) harvest index was found from the combination of NERICA1 with lower level of NPK fertilizer dose (V_3F_1) followed by the same variety with lower fertilizer dose (V_3F_2) and BRRI dhan46 also with lower fertilizer dose (V_2F_1).

Chapter 5

Summary and conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December, 2010 to study the performance of introduced rice variety NERICA1 in Bangladesh condition under different fertilizer dose. Two sets of treatments included in the experiment are as follows: Varieties (V_1 = BR11, V_2 = BRRI dhan46, V_3 = NERICA1) and five combined fertilizer doses (low fertilizer dose, F_1= 60 kg N ha^{-1} + 30 kg P_2O_5 ha^{-1}+ 30 kg K_2O ha^{-1} , moderate fertilizer dose, F_2= 90 kg N ha^{-1} + 45 kg P_2O_5 ha^{-1}+ 30 kg K_2O ha^{-1}, low recommended fertilizer dose, F_3= 120 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1}+ 30 kg K_2O ha^{-1}, recommended fertilizer dose, F_4= 120 kg N ha^{-1} + 80 kg P_2O_5 ha^{-1}+ 80 kg K_2O ha^{-1} , higher fertilizer dose, F_5= 140 kg N ha^{-1} + 90 kg P_2O_5 ha^{-1}+ 90 kg K_2O ha^{-1}). The experiment was laid out in a split-plot design with three replications. There were 45 unit plots, each plot measuring 4.0 m × 2.5 m.

A common procedure was followed in raising of seedlings in the seed bed. Seedlings of 25 days old for V_1 (BR11) and 35 days old for V_2 (BRRI dhan46) were uprooted from the nursery beds carefully. Seedlings of V_1 (BR11) and V_2 (BRRI dhan46) were transplanted and seeds of V_3 (NERICA1) was directly sown on 4th August, 2010 in the well-puddled experimental plots. Spacings were given 20 cm × 15 cm. Full dose of TSP (triple super phosphate), MP (Muriate of potash) and 1\3 rd of the Urea (as per treatment) was applied as basal dose at the time of final land preparation as per treatment and incorporated well into the soil. Besides, cowdung at the rate of 10 t ha^{-1} was applied before final ploughing. Urea was applied in two equal splits at 20 and 55 days after transplanting (DAT) and sowing for all varieties.

The first weeding was done at 15 days after transplanting and sowing followed by second and third weeding were done at 15 days interval after first and second weeding. Irrigation was done by alternate wetting and drying from transplanting to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3cm) was kept on the plots. Water was removed from the plots during ripening stage. The crop of each plot was harvested separately on different dates at full maturity when 90% of the grains became golden yellow in color. Ten sample hills were collected from each plot for collection of data on plant characters and yield components. The grain and straw weights for each plot were recorded after proper sun drying and then converted into t ha^{-1}. The grain yield was adjusted at 12% moisture level. The data were analyzed using MSTAT-C program. The mean differences among the treatments were compared by Duncan's Multiple Range test (DMRT).

Different NPK fertilizer dose significantly affected all growth characters. Higher fertilizer rate improved all the parameters where recommended dose gave similar results. Among the yield contributing parameters effective tillers $hill^{-1}$ and filled grains $panicle^{-1}$ affected significantly. Grain yield, straw yield, biological yield as well as harvest index significantly increased with the increase of NPK fertilizer dose. The maximum total dry matter hill^{-1} at harvest (61.96 g), highest panicle length (26.20 cm), maximum grain yield (3.83 t ha^{-1}), straw yield (5.28 t ha^{-1}), biological yield (9.12 t ha^{-1}) and harvest index (41.60 %) were recorded at higher fertilizer dose.

Results of the experiment showed that variety had significant difference to produce plant height, total tillers hill^{-1}, total dry matter production, effective tiller hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, filled grain (%), 1000-grain weight, grain yield, biological yield and harvest index of a crop. The rapid increase of plant height and dry weight were observed from 20 days to 80 days of growth duration which was higher in the BR11 and BRRI dhan46 compared to the NERICA1. At harvest BR11 gave maximum total dry matter hill^{-1} (74.07 g), highest effective tillers hill^{-1} (11.01) and highest number of filled grains panicle^{-1} (119.8). As a result BR11 contributed to higher grain yield (3.74 t ha^{-1}), biological yield (9.13 t ha^{-1}) and harvest index (40.53%) than BRRI dhan46 and NERICA1. BRRI dhan46 gave total dry matter hill^{-1} (56.56 g) at harvest, effective tillers hill^{-1} (9.6), longer panicle length (25.92 cm) and moderate number of filled grains panicle^{-1} (102.9) which was of intermediate value. It gave intermediate value of grain yield 3.14 t ha^{-1}, biological yield 8.14 t ha^{-1} and harvest index 38.37%. On the other hand NERICA1 gave lowest total dry matter hill^{-1} (38.02 g), lower effective tillers hill^{-1} (7.69), shortest panicle length (23.49 cm), higher number of unfilled grains panicle^{-1} (25.50), lower number of filled grains panicle^{-1} (90.04), lower grain yield (2.33 t ha^{-1}), lower straw yield (4.33 t ha^{-1}) as a result lower biological yield (6.66 t ha^{-1}) and lower harvest index (34.83 %).

Interaction effect of fertilizer dose and variety also significantly affected growth as well as yield and yield contributing characters. Maximum total dry weight $hill^{-1}$ (79.48 g) at harvest, effective tillers $hill^{-1}$ (12.13), filled grain $panicle^{-1}$ (133.2), grain yield (4.72 t ha^{-1}), straw yield (5.86 t ha^{-1}), biological yield (10.58 t ha^{-1}) and harvest index (44.64%) were obtained from the variety BR11 along with higher fertilizer dose (V_1F_5) which was at par with the same variety along with recommended fertilizer dose (V_1F_4) and the lowest total dry weight $hill^{-1}$ (32.72 g) at harvest, effective tillers $hill^{-1}$ (6.13), filled grains $panicle^{-1}$ (71.92), grain yield (1.97 t ha^{-1}), straw yield (4.16 t ha^{-1}), biological yield (6.13 t ha^{-1}) and harvest index (32.09%) were obtained from variety NERICA1 combination with lower fertilizer dose (V_3F_1).

Based on the results of the present study it could be concluded that though NERICA1 is a short duration (90 days) crop but its yield potentiality under different fertilizer dose is comparatively lower than the existing popular aman varieties BR11 and BRRI dhan46. However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones to judge the possibility of cultivating NERICA1 in aman season as a short duration crop.

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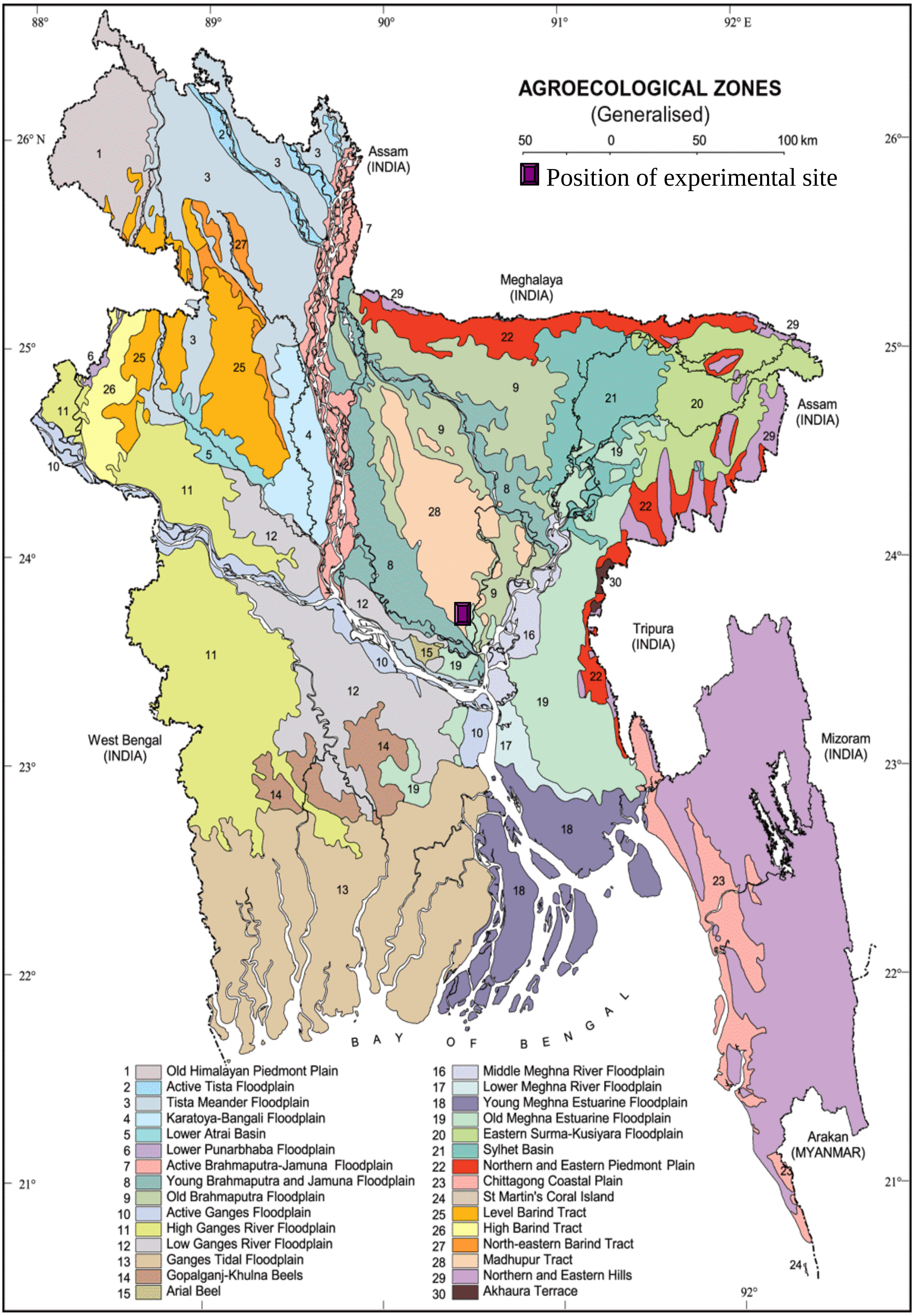
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average RH, air temperature, total rainfall and sunshine hours of Dhaka during June to December, 2010

Month	Average RH (%)	Average Temperature (ºC)		Total Rainfall (mm)	Average daily Sunshine hours
		Max.	Min.		
June	81	32.1	26.1	340.4	4.7
July	84	31.4	26.2	373.1	3.3
August	80	31.6	26.3	316.5	4.9
September	80	31.6	25.9	300.4	3.0
October	78	31.6	23.8	172.3	5.2
November	77	29.6	19.2	34.4	5.7
December	69	26.4	14.1	12.8	5.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix III. Physicochemical properties of the initial soil of the experimental site

Characteristics	Value
Partical size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. Mean square values for plant height of *aman* rice at different days

Sources of variation	DF	Mean square values at different days after transplanting/sowing				
		20	40	60	80	At Harvest
Replication	2	8.52	3.01	19.54	3.34	2.11
Fertilizer	4	72.80**	189.62**	236.03**	277.43**	281.75**
Error (a)	8	1.57	1.44	5.39	1.08	1.50
Variety	2	683.23**	994.52**	2071.00**	2918.26**	3539.02**
Fertilizer × variety	8	2.78	16.08**	27.32**	31.84**	17.39**
Error (b)	20	2.21	0.74	7.72	1.71	1.58

**Significant at 1% level

Appendix V. Mean square values for total tiller number hill^{-1} of *aman* rice at different days

Sources of variation	DF	Mean square values at different days after transplanting/sowing				
		20	**40**	**60**	**80**	**At Harvest**
Replication	2	0.12	0.42	1.04	0.77	0.08
Fertilizer	4	0.90**	17.65**	33.29**	26.10**	27.25**
Error (a)	8	0.01	0.17	0.23	1.12	0.31
Variety	2	180.70**	175.20**	82.38**	153.23**	171.17**
Fertilizer × variety	8	0.42**	1.79**	2.75**	3.51**	4.29**
Error (b)	20	0.02	0.38	0.81	0.41	0.28

**Significant at 1% level

Appendix VI. Mean square values for total dry matter weight hill^{-1} of *aman* rice at different days

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting/Sowing		
		30 DAT/DAS	60 DAT/DAS	At harvest
Replication	2	0.03	0.57	4.93
Fertilizer	4	0.23**	10.31**	185.58**
Error (a)	8	0.01	0.18	3.05
Variety	2	51.81**	465.01**	10545.45**
Fertilizer × variety	8	0.04**	0.52**	25.76**
Error (b)	20	0.01	0.14	3.57

**Significant at 1% level

Appendix VII. Mean square values for effective tiller hill^{-1}, panicle length, total grain panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, filled grains panicle^{-1}(%), 1000-grain weight of *aman* rice

Sources of variation	DF	Mean square values at different days after transplanting/sowing						
		Effective tiller hill^{-1}	Panicle length	Total grain panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Percent filled grains panicle^{-1}	1000 grain weight
Replication	2	2.65	5.40	99.16	51.26	17.94	7.14	0.02
Fertilizer	4	15.55**	12.23**	1032.89**	1696.45**	88.32**	150.21**	0.22
Error (a)	8	0.43	0.30	72.77	68.21	1.19	2.02	0.06
Variety	2	41.48**	22.51**	2701.18**	3333.68**	33.39**	151.52**	137.94**
Fertilizer × variety	8	0.20**	0.18**	23.05**	25.98**	0.93	3.26*	0.12
Error (b)	20	0.39	0.22	42.80	43.68	0.69	1.34	0.13

*Significant at 5% level

**Significant at 1% level

Appendix VIII. Mean square values for grain yield, straw yield, biological yield and harvest index of aman rice

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting/sowing			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.002	0.033	0.041	0.51
Fertilizer	4	4.002**	1.087**	9.252**	102.98**
Error (a)	8	0.005	0.017	0.030	0.66
Variety	2	7.552**	4.251**	23.132**	123.96**
Fertilizer × variety	8	0.288**	0.103**	0.706**	3.17*
Error (b)	20	0.014	0.013	0.030	1.23

*Significant at 5% level

**Significant at 1% level

LIST OF PLATES

Plate 1. Ripening stage of BR11

Plate 2. Ripening stage of BRRI dhan46

Plate 3. Ripening stage of NERICA1