GROWTH AND YIELD PERFORMANCE OF AROMATIC RICE IN RESPONSE TO VARIETY AND NITROGEN LEVEL

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*This is to certify that thesis entitled, "**GROWTH AND YIELD PERFORMANCE OF AROMATIC RICE IN RESPONSE TO VARIETY AND NITROGEN LEVEL** " submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRICULTURAL BOTANY**, embodies the result of a piece of bona-fide research work carried out by **PROKASH KUMAR DAS**, Registration no. **14-05855** 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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ABSTRACT

The experiment was conducted at the experimental field of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from July 2019 to December 2019 in *Aman* season to observe the growth and yield performance of aromatic rice in response to variety and level of nitrogen. The experiment comprised of two factors *viz*. factor A: Varietis; V_1 =Badshavog, V_2 =Katarivog and V_3 =BRRI dhan34; factor B: Levels of nitrogen; N_0 =0 kg, N_1=40 kg, N_2=80 kg and N_3 =120 kg N ha^{-1}. V_3 (BRRI dhan34) exhibited its superiority over Katarivog in terms of grain yield, the former out-yielded V_2 (Katarivog) by 28.63% higher yield. V_3 (BRRI dhan34) also showed the highest number of tillers $hill^{-1}$ at harvest (17.16), the maximum leaf area index at harvest (5.49), the maximum CGR (5.19 g running m^{-1} day^{-1}), the highest number of panicles $hill^{-1}$ (14.10), the longest panicle (25.03 cm), the highest number of grains $panicle^{-1}$ (145.45), the highest weight of 1000-grains (15.50 g), the maximum straw yield (5.93 t ha^{-1}), the highest biological yield (7.92 t ha^{-1}) and the highest harvest index (35.18%) than other tested variety (Katarivog).Significant differences existed among different levels of nitrogen with respect to growth, yield and yield attributing parameters of rice.Treatment N_3(120 kg N ha^{-1}) showed a yield advantage of 0.25 t ha^{-1}, 0.70 t ha^{-1}, 1.48 t ha^{-1} over N_2 (80 kg N ha^{-1}), N_1 (40 kg N ha^{-1}) and N_0 (0 kg N ha^{-1}), respectively, which was possibly aided by taller plant at harvest (123.13 cm), higher number of tillers $hill^{-1}$ at harvest (17.16), higher leaf area index at 90 DAT (4.44), maximum CGR at 90 DAT (4.68 g running m^{-1} day^{-1}), the highest number of panicles $hill^{-1}$ (13.33), the longest panicle (24.14 cm), the maximum number of grain $panicle^{-1}$ (144.1), the heaviest 1000-grain weight (14.38 g), the maximum straw yield (5.69 t ha^{-1}) and the highest biological yield (8.3 t ha^{-1}). Combination of V_3N_3 (BRRI dhan34 × 120 kg N ha^{-1}) performed the best in all for higher yield in aromatic rice.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
eds.	Editors
et al.	et alia (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agriculture Organization
L.	Linnaeus
LSD	Least Significant Difference
i.e	id est (that is)
MOP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops, which supplies major source of calories for above 45% of the world population. Particularly to the people of Asian countries. Rice stands the second in the world after wheat in area and population. It occupies an area of 153.76 m. ha with an annual production of 598.85 MT. with a productivity of 4895 kg ha^{-1} in the world (FAO, 2017). Asia produces and consumes 90% of world's rice. Among the rice growing countries, India ranks the 1^{st} in area following by China and Bangladesh. Rice is a major cereal crop of India occupied an area of 41.91 million ha and production of 83.13 MT. with average productivity of 8.84 t ha^{-1} (FAO, 2018).

Rice is the most important cereal crop in Bangladesh and it is our staple food. Approximate 75% of the total cultivated land covering about 11.58 million ha produces approximate 30 million tons of rice annually (BBS, 2018). The 2^{nd} largest part of the total production of rice comes of Aman rice after Boro. Agriculture in Bangladesh is characterized by intensive crop production with rice based cropping system. The average yield of rice in our country is around 4.57 t ha^{-1} which is less than the world average (7.48 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2019).

In Bangladesh three distinct classes of rice, based on the season of cultivation namely Aus, *Aman* and Boro are cultivated during the period April to July, August to December and January to May, respectively. On average, Aus, *aman* and Boro rice were recently reported to account for 7%, 38%, and 55%, respectively, of the total rice production in Bangladesh (Risingbd, 2014). Among three growing seasons Aman rice occupies the highest area coverage (34% of gross cropping area). There are 47 *aman* rice varieties cultivated in Bangladesh including aromatic, non-aromatic, hybrid and HYV rice (BRRI, 2018).

More than four thousand wild races of rice are adapted in our country. Some of these have some good qualities i.e. taste, aroma, fineness, and protein content (Kaul *et al.*, 1982). Aromatic rice is a special type of rice containing natural ingredient 2-acetyl−1-pyrroline, responsible for their fragrant taste and aroma (Hossain *et al.,* 2008; Gnanavel and Anbhazhagan, 2010) and had 15 times more 2-acetyl−1-pyrroline content than non - aromatic rice (0.14 and 0.009 ppm, respectively) (Singh *et al.,* 2000). In addition, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols and some other compounds, which are associated with the aroma development in rice (Singh *et al.,* 1999). Most of the aromatic rice varieties in Bangladesh are traditional photoperiod sensitive types and are grown during *aman* season. Demand for aromatic rice in recent years has increased largely for both internal consumption and export (Singh *et al.*, 2014). Aromatic rice varieties are rated best in quality and fetch a much higher price than non-aromatic rice.

Urea is the principal source of N, which is the essential element in determining the yield potential of rice (Mae, 1997). Nitrogen is associated with plant growth as well as higher yield of rice. Without Nitrogen it is impossible to achieve a desirable yield from rice or a number of crops. A main source of N is urea fertilizer. Generally, urea is broadcast in three equal splits- one as basal dose at the time of final land preparation, one at maximum tillering stage and the remaining one at prior to panicle initiation stage.

The efficient use of nitrogen fertilizer can increase crop yield and reduce cost of production. The yield of the rice can be increased by even 50% through the use of optimum nitrogen fertilizer. An increase in yield of rice by 70-80% may be obtained from proper application of N-fertilizer (IFC, 1982). The efficiency of nitrogen use by rice plant is very low, the recovery being only 30-50% (Dubey *et al.*, 1991). The effects of N fertilizer levels (0, 75, 150, 225 and 300 kg ha^{-1}) on japonica rice cv. 9325 grain yield and quality under water saving irrigation, the number of panicles·ha^{-1}, head rice rate, protein content and gel consistency decreased, which chalkiness value and amylase content increased. Grain yield and rice quality were significant correlated with variations of N absorption and utilization (Yuan *et al.*, 2005). An experiment at Joydebpur, Bangladesh in 1991, rice cv. BR3 (dry season) and BR11 (wet season) were given 0, 29.58 or 87 kg N ha^{-1} as prilled urea broadcast in 3 equal splits (after seedling establishment, at active tillering and 5-7 days before panicle initiation) or injected into the soil immediately after seedling establishment, or as urea super granules placed by hand at 8-10 cm depth after seedling establishment. Grain yield in both seasons was highest (4.80 and 3.80 t ha^{-1} in the dry and wet season, respectively compared with 2.70 t ha^{-1} in both seasons without applied N fertilizer) when 87 kg N ha^{-1} was applied as urea super granules, while broadcasting prilled urea gave the lowest grain yield and N use efficiency. N uptake was highest with the highest rate of urea, while application N recovery was highest with the lowest N rate applied as urea (Choudhury and Bhuiyan, 1994).

So, it is essentially required to elucidate the impact of different aromatic rice varieties with the application of different levels of nitrogen fertilizer in Bangladesh condition. Under the above circumstances, the present experiment was undertaken with the following objectives:

1. To assess the effect of variety on the growth and yield of aromatic rice in *Aman* season,

2. To find out the optimum nitrogen level for higher yield and quality in aromatic rice and

3. To evaluate the combined effect of variety and different nitrogen levels on yield components and yield of aromatic rice.

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characters of rice considerably depend on basic ingredients of agriculture. The basic ingredients include variety, environment and agronomic practices (planting density, fertilizer, irrigation, seedling types etc.). Among the above factors N application are more responsible for the growth and yield of aromatic rice. High yielding varieties (HYV) are generally more adaptive to nitrogen application and they produce higher yield with increasing nitrogen levels up to a certain end. The available relevant reviews of literature on the related works done in the recent past have been presented and discussed in this chapter.

2.1 Effects of nitrogen fertilizer on growth, yield attributes, yield and harvest index of aromatic rice

Paul *et al.* (2021) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during December 2017 to May 2018 to study growth performance of aromatic Boro rice (cv. BRRI dhan50) in response to nitrogen and potassium fertilization. The experiment consisted of four levels of nitrogen viz., 0, 50, 100 and 150 kg ha^{-1}, and four levels of potassium viz., 0, 30, 60 and 90 kg ha^{-1}. The results revealed that nitrogen and potassium fertilization and their interaction exerted significant influence on growth performance of BRRI dhan50. Application of 100 kg N ha^{-1} produced the tallest plant (82.17 cm), the highest number of tillers $hill^{-1}$ (10.08) and chlorophyll content (52.21) at heading stage. While, application of 90 kg K ha^{-1} produced the tallest plant (81.44 cm) at physiological maturity stage, the highest number of tillers $hill^{-1}$ (9.66) and chlorophyll content (51.54) at heading stage. In case of interaction, the tallest plant (85.33 cm), the highest number of tillers $hill^{-1}$ (10.83) and chlorophyll content (58.28) were obtained from 100 kg N ha^{-1} along with 90 kg K ha^{-1} at heading stage. Therefore, application of 100 kg N ha^{-1}

along with 90 kg K ha^{-1} interaction appeared as the promising practice in aromatic rice (cv. BRRI dhan50) cultivation in terms of growth performance.

Ahmad *et al.* (2020) conducted a field experiment to examine the effect of nitrogen (N) management regimes on rice quality in different rice production systems in 2017 and 2018. The experimental treatments comprised of two production systems (transplanted rice: TPR and dry direct-seeded rice: DDSR) and six N treatments: N_1 = 0 kg N ha^{-1}, N_2 = 50 kg N·ha^{-1} as basal, N_3 = 100 kg N ha^{-1} as basal, N_4 = 150 kg N ha^{-1} as basal, N_5 = 100 kg N ha^{-1} in three splits and N_6 = 150 kg N ha^{-1} in three splits. The results revealed that the rice quality attributes, i.e., broken rice recovery, abortive kernel, bursting, and curling were increased by 8%, 14%, 8%, and 14%, respectively, under DDSR than TPR. In the case of N management, split application of N reduced the chalky kernel (44%), abortive kernel (23%), opaque kernel (31%), bursting (24%) and curling (31%), while kernel protein contents, water absorption ratio, cooked grain length, and elongation ratio were increased by 41%, 88%, 25%, and 26%, respectively, as compared to the basal application of N. In short, DDSR cultivation reduced the appearance and cooking quality traits but white head rice recovery and nutritional quality were comparable to TPR. However, N application in splits either in DDSR or in TPR potentially improved the grain quality of rice compared with the basal application.

Mo *et al.* (2019) conducted field experiments in the early season (March–July) and repeated in the late season (July–November) to conform that nitrogen application and different water regimes at booting stage improved yield and 2-acetyl-1-pyrroline (2AP) formation in fragrant rice. The treatments were applied urea (90 kg ha^{-1}), calcium super phosphate (90 kg ha^{-1}) and potassium chloride (195 kg ha^{-1}) as basal fertilizer, and urea (65 kg ha^{-1}) at tillering stage. Three N levels i.e., 0 kg N ha^{-1} (N_1), 30 kg N ha^{-1} (N_2), and 60 kg N ha^{-1} (N3) and three water levels i.e., W_1 treatment (well-watered treatment with water layer of 2–4 cm), W_2 treatment (soil water potential was − 15 ± 5 kPa), and W3 treatment (soil water potential was − 25 ± 5 kPa) at booting stage was set up for three rice varieties i.e., Nongxiang 18, Yungengyou 14 and Basmati. The grain yield, head milled rice yield, 2AP contents and the biochemical parameters related to 2AP formation were investigated. Result indicated that W and N dynamics regulated the grain yield, head milled rice yield, and 2AP contents in brown rice across three varieties. The N_2 and N_3 treatment significantly increased the 2AP contents in brown rice by 9.54% and 11.95%, and 8.88% and 32.54% in the early and the late season, respectively; improved grain yield and head milled rice yield. The 2AP content, 1-pyrroline-5-carboxylic acid (P5C) content and diamine oxidase (DAO) activity during grain filling periods was highly related to the 2AP content in brown rice. This study revealed that the 60 kg N ha^{-1} coupled with -25 ± 5 kPa treatment showed the best positive effects on yield and aroma in fragrant rice, suggested that water and nitrogen management at booting stage can improve grain yield and fragrance in fragrant rice.

Sugiyanta *et al.* (2018) carried out a study to evaluate Nitrogen use efficiency (NUE) of local and national Indonesian superior aromatic rice varieties treated with different levels of nitrogen fertilizer (N). The experiment was arranged using five levels of N as the main plot, plots, i.e., 0, 45, 90, 135 and 180 kg ha^{-1}; and two rice varieties as sub plots, a local Aceh variety "Sigupai" and a national rice variety "Inpari 23 Bantul". The results showed that the application of N 180 kg·ha^{-1} to "Sigupai" significantly increased the plant height. However, it caused a delay in the time to flower in both varieties. "Inpari 23 Bantul" applied with N 180 kg ha^{-1} produced the highest number of tillers. Application of N 90 kg ha^{-1} on "Sigupai" variety significantly reduced the number of empty grains. "Sigupai" has a higher proportion of grains $panicle^{-1}$ and yield per sampling plot than "Inpari 23 Bantul", and dosage N 90 kg ha^{-1} increased grain yield per clump and yield per sampling plot significantly. Nitrogen at 180 kg ha^{-1} increased the N content and absorption N in primordial phase of "Sigupai" variety, and increased N grain content of the "Inpari 23 Bantul" variety. Nitrogen at 90 kg ha^{-1} in "Sigupai" had a higher NUE at primordia phase than "Inpari 23 Bantul".

This study showed that local variety "Sigupai" is suitable for growing rice with low nitrogen input.

Djaman *et al*. (2016) conducted field experiments at Ndiaye and Fanaye (Senegal) during the hot and dry season 2012 and the wet season 2012 to evaluate the effect of nitrogen on rice yield and nitrogen use efficiency under phosphorus and potassium omission management. The objective of this study was to optimize nitrogen fertilizer for higher yield and nitrogen use efficiency of four aromatic rice varieties. Five rates of nitrogen (0, 60, 90, 120 and 150 kg ha^{-1}) were associated with P (26 kg P ha^{-1}); or P-K (26 kg P ha^{-1} and 50 kg K ha^{-1}). Four aromatic rice varieties Pusa Basmati, Sahel 329, Sahel 177 and Sahel 328 and a non-aromatic variety Sahel 108 were evaluated. The two season pooled data (at Ndiaye and Fanaye) showed that under N-P fertilizer, Sahel 108 the most popular variety grown in the Senegal River Valley had the highest performance followed by Sahel 329, and Sahel 328. Pusa Basmati had the poorest performance with the lowest yield. Under NPK fertilizer, the non-aromatic rice variety Sahel 108 still had the best performance followed by the aromatic variety Sahel 177 and Sahel 328 and Sahel 329; Pusa Basmati registered the poorest performance. The performance of varieties is shown through some agronomic traits of each of them. Even if Pusa Basmati had a relatively high panicle density, it had the lowest spikelet fertility, the lowest harvest index. Among the aromatic rice varieties, Sahel 177 obtained the highest harvest index and the highest spikelet fertility after the non-aromatic check Sahel 108. Therefore, the aromatic variety Sahel 177 could be the best choice of rice producers among the existing aromatic materials in the area in the Senegal River Valley. Results showed that across genotypes, rice yield varied from 3.30 to 8.60 Mg ha^{-1} under N-P fertilizer and from 3.50 to 8.80 Mg ha^{-1} under N-P-K fertilizer at Ndiaye. At Fanaye, rice yield varied from 3.7 to 8.6 Mg ha^{-1} under N-P fertilizer and from 3 to 10.3 Mg ha^{-1} under N-P-K fertilizer. The highest grain yield was obtained by Sahel 177 among the aromatic rice varieties. The optimum nitrogen dose varied with rice genotype and location. The partial factor productivity of applied nitrogen (PFPN) and the Agronomic nitrogen use efficiency (ANUE) were influenced by genotype and varied from 161 to 28 kg grain kg^{-1} N and from 105.9 to 0.9 kg grain kg^{-1} N, respectively. The highest PFPN was obtained by Sahel 108 followed by Sahel 177. K addition to N-P significantly increased ANUE from 6.4 to 20.78 kg grain kg^{-1} N. The aromatic rice variety Sahel 177 is the performing alternative to the non-aromatic rice Sahel 108 in Senegal.

Jahan *et al.* (2014) was conducted a field experiment to evaluate the effect of different nitrogen levels on the yield performance of three aromatic rice varieties in the transplanted aman (monsoon) season. The rice varieties including Morichshail, Kachra and Raniselute and five nitrogen levels i.e. 0, 30, 60, 90 and 120 kg N ha^{-1} were formed for the treatment variables. All the yield contributing characters were differed significantly due to the variety. Morichsail produced the maximum number of grains·$panicle^{-1}$ (76.35) and gave the maximum grain yield (2.69 t ha^{-1}). Different nitrogen rates also significantly affected the yield and yield attributes of aromatic rice varieties. Plant height, total tillers·$hill^{-1}$ and biological yield were increased with the nitrogen application. Panicle length, effective tillers·$hill^{-1}$, 1000-grains weight, grain yield and harvest index were significantly increased up to 60 kg N ha^{-1} application and thereafter decreased. The combination of varieties and nitrogen rates significantly affected panicle length, filled grains·$panicle^{-1}$ and grain yield of aromatic rice varieties. It was observed that interaction of the variety Morichsail with 60 kg N ha^{-1} application gave the highest panicle length, filled grain·$panicle^{-1}$ and grain yield in this experiment.

Yadav and Meena (2014) conducted a field experiment during the rainy (kharif) season to study the performance of aromatic rice (*Oryza sativa* L.) genotypes as influenced by integrated nitrogen management (INM). The treatments comprised 3 aromatic rice genotypes (‘Pusa Basmati 1’, ‘PRH 10’ and ‘HUR 105’) in main plots and 7 INM practices [100% recommended nitrogen dose (RND), 75% RND + 25% RND as farmyard manure/vermicompost (FYM/VC), 75% RND + 25% RND as FYM/VC] along with biofertilizer blue green algae (BGA)/*Azospirillum* in subplots. The genotype 'PRH 10' was recorded significantly higher dry matter (DM) (36.8 g $hill^{-1}$), panicles m^{-2} (306.9), grains $panicle^{-1}$ (133.0), 1,000-grain weight (22.40 g), grain yield (5.19 tonnes ha^{-1}), straw yield (7.55 tonnes ha^{-1}), total N uptake (103.0 kg ha^{-1}), N-use efficiency (57.6 kg/kg) and net returns (53,518 ha^{-1}) than 'Pusa Basmati 1' but were at par with 'HUR 105'. Among the INM, application of 75% RND + 25% RND as VC + BGA gave significantly highest plant height (105.80 cm), DM (39.50 g $hill^{-1}$), panicles m^{-2} (321.1), grains $panicle^{-1}$ (138.2), 1,000-grain weight (22.70 g), grain yield (5.16 tonnes ha^{-1}), straw yield (7.77 tonnes ha^{-1}), total N uptake (105.7 kg ha^{-1}), N-use efficiency (57.3 kg/kg), net returns (54,376 ha^{-1}) and benefit : cost ratio (2.0) over other treatments and remained at par with application of 75% RND + 25% RND as FYM + BGA.

Mannan *et al.* (2010) conducted the experiment was with different Basmati rice varieties at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur during 1999 and 2000 T. aman season. Four rice genotypes (Basmati PNR, Basmati 370, Basmati 375 and Basmati-D) were tested with 0, 25, 50, 75 and 100 kg N ha^{-1} to determine the optimum N level as well as to find out the genotype having high yield potential. The plant height, tiller number, number of panicles, panicle length, spikelet sterility and straw yield increased with the increase of nitrogen levels up to 75 kg N ha^{-1}. Maximum plant growth at the highest level of N caused lodging of plant which increased spikelet sterility and lower number of grains·$panicle^{-1}$ and ultimately decreased grain yield. Genotype Basmati PNR having dwarf plant characteristics performed well at higher level of nitrogen (100 kg N ha^{-1}), while other genotypes having medium plant height responded well at lower level of nitrogen (52–56 kg N ha^{-1}).

Lal *et al.* (2009) conducted field experiments during wet seasons of 2005 and 2006 at the Crop Research Station, Masodha, Faizabad, Uttar Pradesh in split plot design having three nitrogen levels (30, 60 and 90 kg N ha^{-1}) in main plots and four aromatic rice varieties (IET-17566, Badshahbhog, Kalanamak and Kanakjeer as local check) in sub plots to find out the suitable variety and optimum levels of nitrogen which were evaluated for maximum grain yield under irrigated ecosystem. It was observed that IET-17566 gave significantly higher grain yield (3.64 t ha^{-1}). The Kalanamk and Badshahbhog were at par (4.04 and 3.06 t ha^{-1}). The graded levels of nitrogen significantly increased grain yield and all the attributing characters up to 60 kg N ha^{-1} (3.37 t ha^{-1}). The maximum panicle number (390 m^{-2}) and highest panicle weight (2.30 g $panicle^{-1}$) was recorded by IET-17566. The N response at 60 and 90 kg N ha^{-1} (12.33 and 8.66 t ha^{-1}) was higher over the mean grain yield at 30 kg N·ha^{-1}.

Hossain *et al.* (2008) conducted a field experiment to evaluate the effect of different nitrogen levels on the performance of four rice varieties in transplanted aman (monsoon) season. Aromatic rice varieties included BRRI dhan38, Kalizira, Badshabhog and Tulsimala, while nitrogen was applied at 30, 60, 90 and 120 kg·ha^{-1}. Performance of different varieties was different. All the yield contributing characters differed significantly due to variety. Kalizira produced the maximum number of grains·$panicle^{-1}$ (135.90). Among the varieties, BRRI dhan 38 gave the maximum grain yield (4.00 t ha^{-1}). Different nitrogen rates also significantly affected the aromatic rice varieties. All the yield components were significantly increased up to 90 kg N ha^{-1}. Nonetheless, maximum grain yield (3.62 t ha^{-1}) was observed from 60 kg N ha^{-1}. The combination of varieties and nitrogen rates also affected the plant characters and yield components of aromatic rice, which ultimately affected the yield and it was observed that in combination the variety BRRI dhan38 was more responsive to nitrogen to produce better yield.

Islam *et al.* (2008) conducted a field experiment to find out the effect of nitrogen levels and transplanting dates on the yield and yield components of aromatic rice cv. Kalizira. The experiment was laid out in a randomized complete block design with three replications using four (0, 50, 100, and 150 kg N ha^{-1}) levels of nitrogen and three transplanting dates (10 August, 22 August and 04 September, 2007) along with the basal doses of triple super phosphate (TSP), muriate of potash (MoP) and gypsum. The study revealed that most of the yield and yield contributing characters with few exceptions were significantly influenced by nitrogen levels and transplanting dates. They had significant positive effect on total tillers·hill^{-1}, effective tillers hill^{-1}, grains·panicle^{-1} and straw yield. The maximum plant height (137 cm and 135 cm, respectively) was observed in 150 and 100 kg N ha^{-1} and 10 August transplanting date. The maximum number of effective tillers·hill^{-1} (12.2, 9.40 respectively) was also observed with same N rate and transplanting date. The highest number of grains panicle^{-1} was obtained (191) in 150 kg N ha^{-1} treatment with 10 August transplanting date and the lowest number was obtained (175) in N control. Single effect of N and transplanting date significantly affected the 1000-grain weight. The highest 1000-grain weight (12.0 g) was obtained in 150 kg N ha^{-1} with transplanting date 10 August and the lowest (10.7 g) in 0 kg N ha^{-1} with transplanting date 10 August. The highest grain yield (2.63 t ha^{-1}) was observed in 100 kg N ha^{-1} with 10 August transplanting treatment and straw yield (6.43 t ha^{-1}) was found the highest in 150 kg N ha^{-1} with same date of transplanting and the lowest grain (1.83 t ha^{-1}) and straw yields (5.14 t ha^{-1}) were found in N control treatment with transplanting date of 04 September. The highest grain length (4.68 mm), grain breadth (2.49 mm) and imbibition ratio (6.93) were observed with 100 kg ha^{-1} N rate coupled with 10 August transplanting, and for length-breadth ratio, the same rate recorded the highest result, but with different transplanting date i.e 22 August.

2.2 Effect of nitrogen fertilizer on growth attributes of rice

2.2.1 Plant height

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants in boro season. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased leaf area index and plant height. The highest plant height at harvest was recorded about 92.81 cm when rice plants were fertilized with the highest nitrogen level of 70 kg ha^{-1}. On the contrary, the lowest value of the height was recorded about 80.21 cm when rice plants received no nitrogen fertilizer.

Ahmed *et al.* (2005) observed that among 5 levels, 80 kg $N \cdot ha^{-1}$ gave the highest plant height (155.86) and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Mandavi *et al.* (2004) showed that plant height was negatively correlated with grain yield. Thus, in improved genotypes, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

Plant height varied from 182.5 cm to 206.2 cm for *Oryza rufipogon,* 60.1 cm to 74.9 cm for Minghui-63 and 186.9 cm to 199.8 cm for hybrids. The result showed that the plant height of hybrids was nearly the same as that of *Oryza rufipogon,* but was significantly greater than that of Minghui-63 (Song *et al.,* 2004).

Meena *et al*. (2003) reported that between two levels of N 100 and 200 $kg \cdot ha^{-1}$, application of 200 kg ha^{-1} significantly increased the plant height (127.9 cm) of rice and total number of $tillers \cdot hill^{-1}$ (16.3).

Ravisankar *et al*. (2003) conducted a field experiment during the 2000 and 2001 rainy seasons in Port Blair, Andaman and Nicobar Island, India to study the effect of rice cv. Mansarovar cultivated wider lowland conditions. The treatments comprised no nitrogen (T_1), 30 kg N ha^{-1} at basal, 30 and 70 days after planting (DAP) (T_2), 45 kg N ha^{-1} at 30 and 70 DAP (T_3), 32 kg $N \cdot ha^{-1}$ at basal, 30 and 70 DAP and 25 kg N ha^{-1} at panicle initiation stage (T_4). 4.5% controlled release N at 60% of the recommended dose and 6.0% controlled release N at

60% of the recommended dose. The highest plant height at harvest (106 cm) was obtained with T_3 treatment

De *et al.* (2002) concluded that plant height ranged from 80 cm to 132 cm; whereas, panicle length ranged from 22 cm to 29 cm; which was responsible for grain yield plant^{-1}.

Ebaid and Ghanem (2000) conducted a field experiment at the Rice Research and Training Centre (Etai El-Baroud Agriculture research station Farm) in Egypt during the year of 1996-97 to find out the productivity and also the plant height of Gila 177 rice (*Oryza sativa*). Nitrogen fertilizer was applied to the rice crop at the rate of 0, 96 and 144 kg N ha^{-1} in urea form and they found that increasing nitrogen level up to 144 kg ha^{-1} significantly increased plant height.

2.2.2 Number of tillers hill^{-1}

Awan *et al.* (2011) conducted an experiment to study the effect of different N levels (110, 133 and 156 kg N ha^{-1}) in combination with different row spacing (15 m, 22.5 cm and 30 cm). They noted that maximum level of N (156 kg N ha^{-1}) produced maximum effective tillers irrespective of spacing.

Mnnujan *et al.* (2010) conducted a field experiment at Gazipur in 1993 to determine the effects of nitrogen (N) fertilizer and planting density on growth and yield of long grain rice. Tiller·plant^{-1} increased linearly with the increase in N fertilizer levels.

BRRI (2008a) conducted an experiment to study of some promising lines with RRI modern rice varieties to different N levels viz. 0, 30,160, 90, 120 and 150 kg It was reported that tiller production with N @ 120 kg ha^{-1} produced significantly higher tiller than those of lower N levels.

BRRI (2006) reported that the maximum tillers hill^{-1} (10.2) was produced with 120 kg N ha^{-1} compared to 90 and 0 kg N ha ^{1} application.

Song *et al.* (2004) found that hybrids produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

A field experiment was conducted by Lang *et al.* (2003) to study the effect of: different fertilizer application rates on seedling of Jinyou 207, Guihuanian and Teyou 524 were sown in no-tillage plots situated in 3 different countries in Guangxi, China. At an early stage of growth, the seedlings were subjected to one of three N fertilizer treatments. Treatment A used a conventional application rate CAR of 157-5-172.5 kg N ha^{-1} treatments and C used CAR + 10% and CAR + 20%, respectively. They found that the increase in N fertilizer application rate the speed of seedling establishment and tillering peak.

A field experiment was conducted by Singh and Shivay (2003) at the Research Farm of the Indian Agricultural Research-Institute, New Delhi, India to study the effect of coating prilled urea with eco-friendly neem formulations in improving the efficiency of N use in hybrid rice. Two rice cultivars, hybrid rice (NDHR-3) and Pusa Basmati-1, formed the main plots with the levels of N (0, 60, 120 and 150 kg ha^{-1})

Wang *et al.* (2002) reported that the tiller number increased with increasing N levels.

Meena *et al.* (2002) studied the response of hybrid rice to N (0, 100 and 200 kg) potassium application (0, 75 and 150 kg ha^{-i}) at the research farm of the IARI, New Delhi. They observed that application of N significantly increased the effective tillers.

Lawal and Lawal (2002) carried out 3 field experiments during the rainy season of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield response of low land rice to varying N rates and placement methods. The treatment consisted of 4 N rates (0, 40, 80 and 120 kg ha^{-1}) and 2 fertilizer placement method of (deep and surface placement). They found that application of 80 kg N ha^{-1} significantly increased the number of tillers $hill^{-1}$.

Ehsanullah *et al.* (2001) carried out a field experiment to determine the effect of various methods of nitrogen application for increasing nitrogen use efficiency in Aus rice (Oryza sativa L.) using cv. Supper Basmati. They found that the application of 100 kg N ha^{-1} showed the maximum number of tillers·$hill^{-1}$ and 75 kg N·ha^{-1} showed minimum tillers $hill^{-1}$. Similarly, application of nitrogen by incorporating in between hills wrapped tissue paper produced more tillers·$hill^{-1}$ than other treatments and the differences were significant.

Yang *et al.* (2001) studied the growth and yield components of two rice cultivars Jinongda3 (JND3) and Jinongda13 (JND13). They observed that JND3 exhibited a higher tillering ability than JND13.

Kumar and Subbaiah (2001) noted that application of DAP + urea resulted in the highest number of tillers m^{-2}.

Nuruzzaman *et al.* (2000) conducted an experiment to figure out the relationship between the tillering ability and morphological characters among 14 rice varieties. They observed that tillers number varied widely among the varieties and the number of tillers $plant^{-1}$at the maximum tillering stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties, IR36produced the highest no. of tillers $plant^{-1}$ followed by Suweon 258while Dawn produced the lowest no. of tillers $plant^{-1.}$

2.2.3 Leaf area index

Miah *et al.* (2004) found that LAI was significantly higher in USG receiving plots than urea at heading and the total dry matter production was affected significantly by the forms of N fertilizer. USG applied plots gave higher TDM compared to urea irrespective of number of seedlings transplanted $hill^{-1}$. At the same time, it also noticed that the difference between treatments for TDM was narrower at early growth stages but became larger in later stages.

Das (1989) reported that the dry matter yield of rice was higher with application of USG. Of various forms and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry matter production and were the lowest with urea applied as a basal drilling (Raju *et al.,* 1987).

2.3 Effect of nitrogen fertilizer on yield attributes of rice

2.3.1 Panicle length

Hasanuzzaman *et al.* (2009) conducted an experiment to study the economic and active method of urea application in rice crop. They noted that urea super granules produced longest panicle (22.3 cm).

Islam *et al.* (2008) conducted an experiment to study the effect of N and number of seedlings hill^{-1} on the yield and yield components of T. Aman rice (BRRI Dhan 33). They noted that panicle length, number of grains·panicle^{-1} increased with the application rate of N up to 100 kg ha $^{-1}$ and then declined.

Chakma (2006) found that BINA dhan-5 produced the longest panicle (22.86 cm) followed by BRRI dhan29 (22.78 cm) and BINA dhan-6 (22.28 cm).

El-Batal *et al.* (2004) showed that increasing N rate from 50 to 80 kg ha^{-1} significantly increased panicle length.

Singh and Shivay (2003) found that increasing levels of N significantly increased the panicle length.

Meena *et al.* (2002) observed that increase in N fertilizer application rate enhanced length and weight of panicles of hybrid rice.

Sarkar *et al*. (2001) conducted a field experiment during the kharif 1995 in west Bengal, India to evaluate the performance of 3 rice cultivars (IET 12199, IET 10664 and IET 15914) treated with 5 different nitrogen fertilizer levels (0, 40, 80 and 160 kg ha^{-1}). IET 12199, treated with 80 kg N ha^{-1} gave the highest values for panicle length (25.77 cm); IET 10664 and IET 15914 also performed well.

Ghosh (2001) studied the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general, gave higher values for panicle length compared with high yielding cultivars.

Ebaid and Ghanem (2000) indicated that increasing N levels up to 144 kg N ha^{-1} significantly increased panicle length of rice.

2.3.2 Number of grains·panicle^{-1}

BRRI (2016) found that increasing level of N increased the number of spikelets·panicle^{-1} (82.2) was obtained with 120 kg ha^{-1} compared to 90 and 0 kg N ha^{-1}, respectively.

Yuan *et al.* (2016) studied the variation in the yield components of 75 high quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains panicle^{-1} in *indica* rice, and no. of panicles plant^{-1} in *japonica* rice.

A field experiment was conducted by Edwin and Krishnarajan (2005) to study the effect of irrigation and N fertilizer treatments on the yield of rice hybrid variety CoRH2 m Coimbatore, Tamil Nadu, India. They suggested that N supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest filled grains.

Subhendu *et al*. (2003) conducted an experiment to evaluate the effect of N split application (during transplanting, tillering and panicle initiation, transplanting, tillering, panicle initiation and 50% flowering and 10 days after transplanting, panicle initiation and botting) on the yield and yield components of rice cultivars BRT-5204, MTU-1010 and IR-64 in Rajendranagar, Hyderabad, Andhra Pradesh, India. They found that the application N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and tillering flowering resulted in the highest number of grains·panicle^{-1} (89.8) in MTU-1010.

Meena *et al.* (2002) noted that increase in N fertilizer application rate enhanced number of grains and filled grains of aromatic rice.

Ehsanullah *et al.* (2001) pointed out that the N level of 125 kg ha^{-1} produced maximum number of grains panicle^{-1}.

2.3.3 Number of filled grains panicle^{-1}

Parvez *et al.* (2003) reported that yield advantage for the hybrid rice was mainly due to the proportion of filled grains panicle^{-1}, heavier grain weight (35%) and increased harvest index values than the control (28%).

Shrirame and Mulley (2003) conducted an experiment on variability and correlation of different biometric and morphological plant characters with grain yield. Grain yield was significantly correlated with number of filled grains panicle^{-1}.

Ganesan (2001) experimented with 48 rice hybrids. Filled grains panicle^{-1} (0.895) had the highest significant positive direct effect on yield plant^{-1} followed by number of tillers plant^{-1} (0.688), panicle length (0.167) and plant height (0.149).

Mrityunjay (2001) conducted an experiment to study the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general; gave higher values for number of filled grains panicle^{-1}, plant height at harvest and panicle length compared with the others.

2.3.4 1000-grain weight

BRRI (2006) reported that the weight of rice 1000-grain was increased up to 90 kg·ha^{-1} and after that the weights declined.

Ibrahim *et al.* (2004) found that number of grains·panicle^{-1}, 1000-grain weight, panicle weight and grain and straw yields·ha^{-1} of rice were not significantly affected by increasing nitrogen levels from 30 to 60 kg N ha^{-1}.

Sudhendu *et al.* (2003) conducted a field experiment during aman season at Hyderabad, India. They found that the application of nitrogen (120 kg N ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and 50% flowering resulted in the highest 1000 grain weight (22.57g).

Lawal and Lawal (2002) conducted three field experiments during the rainy season of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield responses of lowland rice to varying N rates and placements methods. The treatment consisted of four N rates (0, 40, 80 and 120 kg ha^{-1}) and two fertilizer placement method (deep and surface placement). They found that the nitrogen rates up to 120 kg ha^{-1} has a positive effect on the 1000-grain weight.

Rodriguez *et al*. (2002) carried out an experiment in Araure, Portuguesa (Venezuela) during the rainy season of 1998 to evaluate the response of rice cultivars Fouaiapl and Cimarron at two different rates of nitrogen (150 and 200 kg N ha^{-1}). They found that nitrogenous fertilizer supplied @ (150 and 200 kg ha^{-1}) has a positive effect on 1000-grain weight of both cultivars.

Neerja and Sharma (2002) conducted an experiment on non-aromatic (cvs. IRB, Jaya, PR113, PR103, PR106, PR108, PR115 and PR116) and aromatic (cvs. Basmati 370, Basmati 385, Basmati 386 and Pusa Basmati No. 1) rice and found that the highest 1000 kernel weight rice, brown rice and milled rice was recorded for PR113.

Ma *et al.* (2001) experimented with ADTRH1 which was a hybrid rice. Its 1000-grain weight was 23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18.

Uddin *et al.* (2001) conducted an experiment to find out the crop performance of hybrid, inbred and local improved rice varieties and reported that variety had significant effect on all crop characters under study. Sonarbangla-1 ranked first in respect of 1000-grain weight followed by Alok 6201 and Habiganj.

Devasenamma *et al*. (2001) conducted a field experiment in Andhra Pradesh, India during the rabi season of 1996-97 to study the performance of rice hybrids (APHR 2, DRRH 1, MGR 1, TNRH 16 and NLR 33358) at various N fertilizer rates (0, 60, 120 and 180 kg N ha^{-1}). They found that the TNRH 16 exhibits the highest 1000-grain weight (20.50g) than others.

Ehsanullah *et al*. (2001) conducted a field experiment to evaluate the effect of split application of nitrogen at three different stages like sowing, tillering and panicle emergence @ 125 kg N ha^{-1}. They found that the split application of N fertilizer at different growth stages significantly affected the 1000 grain weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea super granules (USG) and broadcasting prilled urea (PU) as purees of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160 Kg ha^{-1}. They suggested that USG was more efficient than PU in producing panicle length, filled grains $panicle^{-1}$ and 1000-grain weight.

2.4 Effect of nitrogen fertilizer on yield and harvest index of rice

2.4.1 Grain and straw yield

BRRI (2019) conducted an experiment on study of N release pattern from USG and prilled urea under field condition and its effect on grain yield and N nutrition of rice with three doses of N namely 50, 100 and 150 kg N ha^{-1} from two types of urea e.g prilled (PU) and urea super granules (USG) were tested as treatment.

Kabir *et al.* (2009) conducted an experiment to find out the effect of urea super pules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield contributes of transplant aman rice. They observed that the highest grain yield (5.17 t h^{-1}), straw yield (6.13 t h^{-1}) and harvest index (46.78%) were found from full dose of USG.

BRRI (2008b) conducted an experiment on the title of response of MVs and hybrid entries to added N in a rice cropping pattern. Six N doses 0, 40, 80, 120, 160 and 120 kg N ha^{-1} were tested and resulted that grain yield of hybrid responded up to 120 kg N·ha^{-1}.

Lin *et al.* (2008) conducted an experiment to find out the effect of plant density and N fertilizer rates (120, 150, 180 and 210156 kg N ha^{-1}) on grain yield and N uptake of hybrid rice. They observed that there was a better response to N fertilization, as increasing N application from 120 to 180 kg N ha^{-1} (by 50%) raised yield by 17%. Raising the application rate to 210 kg N ha^{-1} (by 75%) boosted yield by 24.1%.

Xie *et al.* (2007a) in his experiment found that the level of nitrogen application depends on the variety for obtaining the highest grain yield. They also reported Shanyou63 variety gave the highest yield (12 t ha^{-1}) with the application of 150 kg N ha^{-1} whereas 120 kg N ha^{-1} for Xieyou46 variety (10 t ha^{-1}).

Yield experiments were conducted by Wan *et al.* (2007) in China to, study the effects of different N fertilizer application regimes (basal and panicle applications) on the yield, quality and N use efficiency of super japonica hybrid rice cv. Changyou 1. They indicated that yield was significantly influenced by the different N fertilizer application regimes. The regime with the highest yield was at the basal to panicle application ratio of 58.34:41.66 and equal split panicle applications at the fourth and second leaf age from the top.

Twenty-one advanced cultivars were evaluated in transplanted condition during 2005 wet season in a replicated trial along with three checks (Swarna, Pooja and Gayatri) for yield and yield contributing characters like plant height, days to flowering and number of ear-bearing tillers. Variety Swarna (4.864 t ha^{-1}) and CR 874-59 (4.675 t ha^{-1}) gave higher grain yield compared with others. (Patnaik and Mohanty, 2006).

Several *indica/japonica* (I/J) lines were screened and evaluated for higher grain yield in the boro season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36 (Roy, 2006).

A rice cultivar Takanari showed the highest grain yield among the genotypes across 2 years, and successfully produced over 11 t ha^{-1} of grain yield in 2000. The genotypic difference in grain yield was most closely related to that in Crop Growth Rate (CGR) during the late reproductive period (14–0 days before full heading). Rice genotypes having higher CGR during this period produced a greater number of spikelets per unit land area. Therefore, Takanari appeared to have succeeded in over 11 t ha^{-1} of grain yield by achieving both the prerequisite of biomass production during the late reproductive period and better grain filling (Takai *et al.,*2006).

A study was conducted by Mubarak and Bhattacharya (2006) under the Gangetic alluvial soil of West Bengal, India, to investigate the response of hybrid rice cultivars to various levels of N and potassium. Significantly higher values for growth and grain were obtained with the application of 150:60:80 kg NPK ha^{-1}, which was at par with 150:60:80 kg NPK ha^{-1}.

Bowen *et al*. (2005) conducted on-farm trials during the boro and aman seasons in 7 districts of Bangladesh from 2000-2004. The results showed that UDP (Deep placement of urea super granule) increased grain yield by 1120 kg·ha^{-1} and 890 kg·ha^{-1} during the boro season and aman season, respectively.

A study was conducted by Ingale *et al*. (2005) to determine the effects of seedling ages at transplanting (25, 40 and 55 days), number of seedlings·hill^{-1} (one or two) and N rates (50, 100 and 150 kg ha^{-1}) on the yields of Sahyadri rice hybrid. They found that the application of 150 and 100 kg N ha^{-1} resulted in significantly higher yields than treatment with 50 kg N ha^{-1}.

Satio *et al*. (2005) conducted an experiment to evaluate three traditional and three improved cultivars which were grown under four fertilizer treatments: no added fertilizer, N only (N; 90 kg N ha^{-1}), phosphate only (P; 50 kg P ha^{-1}), and N and P (NP) at three locations. The two improved cultivars, IR55423-01 and B6144-MR-6-0-0 out-yielded traditional cultivars in all locations and fertilizer treatments. N fertilizer application increased grain yields of the two improved cultivars from 3.1 to 4.0 t ha^{-1} while increasing those of traditional cultivars from 1.6 to 1.9 t·ha^{-1}.

A field experiment was conducted by Rakesh *et al.* (2005) at Research farm, institute of Agricultural Sciences, Banaras Hindu University, Varanasi; Uttar Pradesh, India, to determine the response of hybrid rice cv. MPH-501 to different N (40, 80, 120 and 160 kg N·ha^{-1}) and potassium levels (30, 60, and 90 kg K_2O ha^{-1}). The application of 160 kg N and 60 kg K_2O ha^{-1} significantly influenced the growth and yield attributes of hybrid rice and produced higher grain and straw yield.

Zayed *et al.* (2005) found that increasing nitrogen levels up to 165 kg N ha^{-1} significantly increased growth and yield of rice and its components.

Elbadry *et al.* (2004) in pot and lysimeter experiment showed that the increasing level of N had statistically significant difference on growth parameters and yield attributes like dry weight, number of productive tillers, grain and straw yields of rice. They also noted that after inoculation the grain yields of Giza 176 were 0.63, 0.93 and 1.22 t ha^{-1} at 0, 47.6 and 95.2 kg N ha^{-1}, respectively.

Sidhu *et al.* (2004) conducted field experiment from 1997 to 2001 in Indian Punjab, India to determine the optimum N requirement of Basmati rice in different cropping sequences i.e. fallow-Basmati rice-sunflower. N fertilizers were applied at 0, 20, 40 and 60 kg ha^{-1}. Nitrogen fertilizers substantially increased the mean grain yield of Basmati up to 40 kg N ha^{-1} in the fallow Basmati-wheat sequence while 60 kg N ha^{-1} reduced Basmati yield.

N fertilizer when applied as USG was reported to have increased grain yield by around 18% and saved around 32% N in wetland rice over prilled urea and appeared to be a good alternative N fertilizer management for rice production (Anon., 2004).

A field experiment was conducted by Upendra *et al.* (2004) at Pusa, Bihar, India to evaluate two newly developed rice hybrids (KHR2 and DRRH1) and one local control (Boro 5) growth under 10 different N-potassium (NK) fertilizer levels. Yield and related characters increased with increasing fertilizer levels up to 150 kg N·ha^{-1} and 80 kg K ha^{-1}.

Singh *et al.* (2004) conducted a field experiment during the rainy (aman) season, in New Delhi India, to study the effect of nitrogen levels (0, 60, 120 and ISO kg ha^{-1}) on the yield nitrogen use efficiency (NUE) of the rice cultivars Pusa Basmati-I (traditional high avidity aromatic rice) and Pusa rice hybrid (aromatic hybrid rice). They found that Pusa rice hybrid-10 had given the significantly higher value for the yield attributes and nutrient accumulation than the nob hybrid Pusa Basmati-I. The Maximum grain yield (5.87 t ha^{-1}) was recorded at the highest level of N nutrient (180 kg N ha^{-1}) and was 4.2, 15.5 and 39.3% higher than in the 120, 60 and 0 kg N ha^{-1} treatments, respectively.

Rahman (2003) worked out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during aman season with three levels of USG viz. one, two and three USG/4 hills providing 40, 80 and 120 kg ha^{-1} found that two USG/4 hills produced the higher grain and straw yield (5.22 and 6.09 t ha^{-1}, respectively).

Maitti *et al.* (2003) reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield.

El-Rewainy (2002) recorded that applying 40 kg N ha^{-1} caused significant increase in plant height, number of panicles m^{-2}, panicle length, and panicle weight, number of filled grains·$panicle^{-1}$ as well as grain and straw yields.

A field experiment was conducted by Devasenamrna *et al.* (2001) in Andhra Pradesh, India to study the performance of rice hybrids (APHR-2, DRRI-1, MGR-1, TNRH-16 and NLR-33358) at various N fertilizer rates (0, 60, 120 and 180 kg ha^{-1}). The highest values for yield and yield components were obtained with 180 kg N ha^{-1}.

Sudhakar *et al.* (2001) carried out an experiment to evaluate the effects of various rice cultivars and nitrogen levels on yield and economics of direct sown semidry rice during aman 1996 and 1999. They found that cultivar PMK-1 shows the maximum grain and straw yield, net return and B: C ratio with each increment of nitrogen application up to 125 kg ha^{-1}. N_0

Ahmed *et al*. (2000) revealed that USG was more efficient than PU at all respective levels of nitrogen in producing all yield components and in turs, grain and straw yields. Placement of USG @ 160 kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of nitrogen.

2.4.2 Biological yield

Peng *et al.* (2000) concluded that the increasing trend in yield of cultivars due to the improvement in harvest index (HI), while increase in total biomass was associated with yield trends for cultivars–lines.

Ramesha *et al.* (1998) found that the superior yielding ability of the hybrids over the controls resulted from increased total biomass and increased panicle weight, with almost the same level of harvest index.

Kim and Rutger (1988) noted that hybrids that gave higher grain yields also produced higher biomass. In addition, biomass yield at different growth stages showed different patterns for hybrid rice and conventional rice. Hybrid rice has more dry matter accumulation in the early and middle growth stages.

Hybrid rice accumulates more total dry matter than conventional rice (Zhende, 1988).

2.4.3 Harvest index (%)

Senapati *et al.* (2004) observed adaptability of aman paddy under Sundarban areas of West Bengal. Grain yield and number of days to maturity were evaluated in 40 *aman* rice genotypes grown during the kharif seasons of 1997, 1998, 1999 and 2000 under rainfed lowland condition of Kakdwip, West Bengal, India. They observed significant genetic variation and genotype-environment interaction for both traits. Of these, CR-626-26-2-3, CR-383-10, Dudhraj, Lilabati, Dhusari and Bogamanohar were late matured variety, which was desirable for *aman* rice cultivation in Sundarban areas. Twenty-two genotypes were highly stable for grain yield and widely adapted to Sundarban areas.

Shrirame and Mulley (2003) conducted an experiment on variability and correlation studies of different biometric and morphological plant characters of rice with grain yield. It was carried out with rice hybrids TNRH10, TNRH13 and TNRH18 and cultivar Jaya. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and number of filled grains panicle^{-1}.

Kiniry *et al.* (2001) studied different parameters describing processes of crop growth and yield production. The mean harvest index was 0.32 (32%) for all four cultivars over the two harvests in each of the 2 years. They concluded that yield differences among cultivars were due to harvest index differences.

Liao-Yaoping *et al.* (2001) conducted an experiment where rice cv. Yuexiangzhan was compared with cv. Qishanzhan and Jingxian 89 and observed that the main reason for the higher harvest index and yield of Yuexiangzhan was balanced and co-ordinate sink, source and assimilate flow.

Peng *et al.* (2000) concluded that the increasing trend in yield of cultivars released before 1980 was mainly due to the improvement in harvest index (HI), while an increase in total biomass was associated with increasing yield trends for cultivars–lines developed after 1980.

Cui *et al.* (1998) conducted a varietal trial of Japanese rice varieties (J group) along with 20 high yielding Asian rice varieties (H group). They reported significantly higher yield and harvest index in H group than that of the J group. Days to heading (DTH) showed significantly positive correlation with total dry matter weight and a significantly negative correlation with harvest index.

Sitaramaiah *et al.* (1998) evaluated six promising rice hybrids with two check varieties and found that hybrids MTUHR 2033, MTUHR 2020 and MTUHR 2037 gave higher grain yield, greater biomass production and harvest index than other varieties. They also observed that higher yielding hybrids also recorded for higher biomass yield and harvest index. It was found that the hybrids showed a superior performance because of higher number of grains panicle^{-1}, which was indicated by higher harvest index.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental period

This research work was carried out within July to December, 2019.

3.2 Location of the experimental field

The experiment was carried out in the *Aman* season in the field laboratory of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the site is 23°74/N latitude and 90°35/E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.3 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.6. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Climate of the experimental field

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979).The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.5 Plant materials and features

Rice cv. Badshavog, Katarivog and BRRI dhan34 were used as plant materials for the present study. These varieties are recommended for *Aman* season. The features of these four varieties are presented below:

Badshavog: Badshavog variety is grown in *Aman* season. It is aromatic transplanted local *aman* rice. The grain is short, thick and scented. The cultivar matures at 140 days of planting. It attains a plant height 130 cm. The cultivar gives an average yield of 1.50 t ha^{-1} (BRRI, 2003).

Katarivog: Katarivog variety is grown in *Aman* season. It is aromatic transplanted local *aman* rice. Katarivog rice was GI product in Dinajpur region. The grain is short and thick. The cultivar matures at 140 days of planting. It attains a plant height 125 cm. The cultivar gives an average yield of 2.50 t ha^{-1} (BRRI, 2003).

BRRI dhan34: BRRI dhan34 variety is grown in aromatic *aman* season. It is modern transplanted *aman* rice released by BRRI in 1997. The grain is short, thick and scented. The cultivar matures at 135 days of planting. It attains a plant height 117 cm. It is semi-photosensitive and semi-lodging tolerant. Its grain is long slender. The cultivar gives an average yield of 3.50 t ha^{-1} (BRRI, 2010).

3.6 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Varieties

V_1 – Badshavog,

V_2 – Katarivog and

V_3 – BRRI dhan34.

Factor B: Levels of nitrogen

N_0 – Control (0 kg N ha^{-1})
N_1 – 40 kg N ha^{-1},
N_2 – 80 kg N ha^{-1} and
N_3 – 120 kg N ha^{-1}.

3.7 Design and layout

The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. The size of the individual plot was 4 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Each block was divided into 4 unit-plots. Lay out of the experiment was done on 14-07-2019 with inter plot spacing of 0.50 m and inter block spacing of 1 m.

3.8 Cultivation procedure

3.8.1 Growing of crop

3.8.1.1 Plant materials collection

Healthy and vigorous seeds of aromatic *aman* rice cv. Badshavog, Katarivog and BRRI dhan34 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur.

3.8.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.8.1.3 Seed bed preparation and seedling raising

A piece of high land was selected in the Agricultural Botany Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka for raising seedlings. The land was puddled well with country plough followed by levelling with a ladder. The sprouted seeds were sown in the seedbed on 30.06.2019. Proper care was taken to raise the healthy seedlings in the nursery bed. Weeds were removed and irrigation was given in the nursery bed as and when necessary.

3.8.1.4 Final land preparation

The land was first opened with a tractor drawn disc plough on 25 July 2019. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently levelled by laddering. The field layout was made on 26 July 2019 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were levelled properly by wooden plank so that no water pocket could remain in the field.

3.8.1.5 Fertilizer application

The doses of fertilizers with their sources are given below:

Nutrient	Source	Dose (kg ha^{-1})
N (Nitrogen)	Urea (46% N)	As per treatment
P (phosphorus)	TSP (20% P_2O_5)	80
K (potassium)	MoP (50% K_2O)	60
S (Sulphur)	Gypsum (18% S)	20
Zn (Zinc)	Zinc sulphate (36% Zn)	4

Source: Adhunik Dhaner Chash, BRRI (2016)

Fertilizers such as Urea, TSP, MoP, Gypsum and Zinc sulfate were used as sources for P, K, S and Zn, respectively. The full doses of all fertilizers except urea were applied as basal dose to the individual plot on 27 July 2019 at the time of final land preparation through broadcasting method. Urea was applied in three equal splits on 20 and 40 days after transplanting (DAT) and at maximum tillering stage as per treatment.

3.8.1.6 Uprooting of seedlings

The seedbed was made wet by application of water in the morning and evening on the previous day before uprooting. The seedlings were uprooted without causing any mechanical injury to the roots and were kept in the soft mud in shade. The age of seedling on the day of uprooting was 30 days.

3.8.1.7 Transplanting

30 days old rice seedlings were transplanted on 04.08.2019 in 36 experimental plots which were puddled further with spade on the day of transplanting. Transplanting was done by using two seedlings hill^{-1} with 25 cm × 15 cm spacing between the rows and hills, respectively.

3.8.2 Intercultural operation

3.8.2.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.8.2.2 Irrigation and drainage

Flood irrigation was given to maintain a level of standing water up to 2–4 cm until maximum tillering stage and after that, a water level of 7–10 cm was maintained up to grain filling stage and then drained out after milk stage to enhance maturity.

3.8.2.3 Herbicide application

Herbicides spraying were done by a hand crop sprayer (model: AM S021, capacity: 20 Litre, Brand name: AGROS, made in Zhejiang, China, Working Pressure: 0.2–0.3 Mpa) at 5 days after transplanting. When field was water lock then herbicide was used.

3.8.2.4 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug.

3.8.2.5 General observations of the experimental field Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant in the treatment plots than that of control plots.

3.8.2.6 Harvest and post-harvest operation

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in colour. From the centre of each plot, 1 m^2 area was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills $hill^{-1}$ were selected randomly outside the sample area of each plot and cut at the ground level for collecting data on yield contributing characters.

3.9 Collection of data

3.9.1 Plant height

The height of plant was recorded in centimetre (cm) at the time harvest for all the entries on 10 randomly selected plants from the middle rows. The height was measured from ground level up to tip of the uppermost panicle.

3.9.2 Number of tillers hill^{-1}

Number of tillers ·hill^{-1} was recorded at 30, 60, 90 DAT and at harvest stage as the average of randomly selected 5 plants from the inner rows of each plot.

3.9.3 Leaf area index (LAI)

Green leaf area (LA) was measured by an automatic leaf area meter (Model: LI-3100, Li-COR, Lincoln, NE, USA) just after removal of leaves to avoid rolling and shrinkage and then transformed into leaf area index (LAI) according to Yoshida (1981).

3.9.4 Crop growth rate (CGR)

CGR represents the increase of plant material per unit time per unit land area. It was measured by the following formula.

$$\text{CGR (g running m}^{-1}\text{ day}^{-1}) = \frac{W_2 - W_1}{T_2 - T_1}$$

Where,

W_1 = total dry matter (g) at time T_1 (day),

W_2 = Total dry matter (g) at time T_2 (day)

and $T_2 - T_1$ = time interval (days) between first and second harvests.

3.9.5 Panicle length

Panicle length was measured with a meter scale from 10 selected panicles and average value was recorded.

3.9.6 1000-seeds weight

One thousand clean and dried seeds were randomly taken from the 1 m^2 harvesting area of each plot and the weight was taken in an electrical balance.

3.9.7 Number of filled grains panicle^{-1}

The total number of filled grains was collected from randomly selected 10 plants of a plot and then average number of filled grains·panicle^{-1} was recorded.

3.9.8 Number of unfilled grains panicle^{-1}

The total number of unfilled grains was collected from randomly selected 10 plants of a plot based on no grain in spikelet and then average number of unfilled grains·panicle^{-1} was recorded.

3.9.9 Number of total grains panicle^{-1}

Number of total grains panicle^{-1} was calculated by summation of filled and unfilled grains panicle^{-1}.

3.9.10 Grain yield

Grain yield was calculated from the grains harvested from central 1 m^2 area. Final grain yield was adjusted at 14% moisture. The grain yield t ha^{-1} was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.9.11 Straw yield

The straw yield t ha^{-1} was measured by the following formula:

$$\text{Straw yield (t ha}^{-1}\text{)} = \frac{\text{Straw yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.9.12 Biological yield

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

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

3.9.13 Harvest index

Harvest Index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Grain weight + Straw weight)}} \times 100$$

3.10 Statistical analysis

The recorded data were compiled and subjected to statistical analysis. Analysis of variance following a split plot design were relation with MSTAT C (Russell, 1986) and Microsoft office Excel 2010 package program. The mean differences among the weed control treatments were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth and yield performance of aromatic rice in response to variety and levels of nitrogen. The results obtained from the study have been presented, discussed and compared in this chapter through table(s) and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix IV to IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings. The analytical results have been presented in Table 1 through Table 8 and Figure 1 through Figure 12.

4.1 Plant height

4.1.1 Effect of variety

Varieties showed significant effect on plant height of aromatic rice among them (Figure 1 and Appendix IV). Varieties also showed an increasing trend in plant height with advances of age of plant after transplanting and the highest increase was found at harvesting stage. Among the varieties V_3 (BARI dhan34) showed the shortest and V_1 (Badshavog) showed the tallest plant for all sampling dates. However, the tallest plant at 30, 60, 90 DAT and harvest (17.22, 42.11, 72.89 and 124.82 cm, respectively) was reported from V_1 (Badshavog) treatment while, the shortest plant (14.83, 33.09, 68.14 and 114.70 cm, respectively) was observed in V_3 (BRRI dhan34) treatment. This result agreed with Bisne *et al.* (2006) who described that plant height varies significantly among varieties.

4.1.2 Effect of levels of nitrogen

Plant height of aromatic rice was significantly influenced by the application of different levels of nitrogen (Figure 2 and Appendix IV). The figure indicated that irrespective nitrogen doses height of the plant showed a gradual increasing trend with the advances of growth stages. The rate of increase in plant height was much higher up to 90 DAT and then the rate was slower than earlier stage of growth whereas, the tallest plant at 30, 60, 90 DAT and harvest (17.54, 44.48, 79.74 and 123.13 cm, respectively) was recorded from N_3 (120 kg N ha^{-1}) treatment. In comparison, the shortest plant at 30, 60, 90 DAT and harvest (14.59, 33.81, 61.29 and 114.62 cm, respectively) was obtained from N_0 (no nitrogen application) treatment. The results agree with those of Singh and Singh (1986) who reported that USG produced taller plants than pilled urea when applied @ 100 to 120 kg N ha^{-1}.

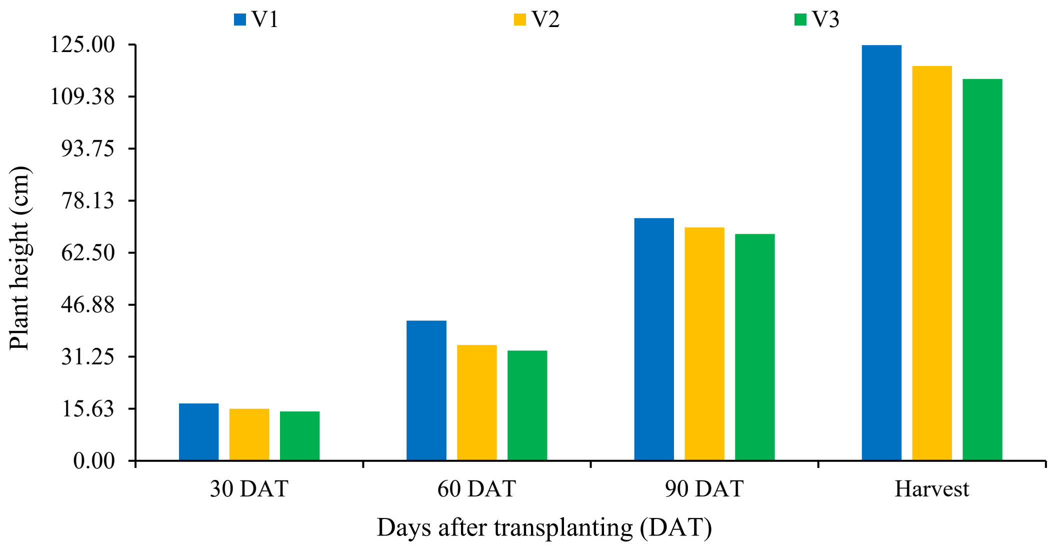

Figure 1. Effect of variety on the plant height (cm) in aromatic rice at different days after transplanting (LSD value = 0.94, 1.67, 1.97 and 2.06 at 30, 60, 90 DAT and harvest, respectively) (V_1 – Badshavog , V_2 – Katarivog and V_3 – BRRI dhan34)

4.1.3 Interaction effect of variety and nitrogen levels

Plant height of aromatic rice was significantly influenced by the interaction of different varieties and different levels of nitrogen doses (Table 1 and Appendix IV). At 30, 60, 90 and harvest, the tallest plant (20.67, 51.56, 86.22 and 128.10 cm, respectively) was recorded from V_1N_3 (Badshavog with 120 kg N ha^{-1}) treatment combination which was statistically identical with V_1N_2 (127.00 cm) at harvest. On the other hand, the shortest plant at 30, 60, 90 DAT and harvest (14.00, 29.44, 60.22 and 107.10 cm, respectively) was observed in V_3N_0 (BRRI dhan34 with no nitrogen application) treatment combination which was statistically identical with V_3N_1 (14.33 cm) ,V_2N_0 (14.44 cm) and V_3N_2 (15.22 cm) at 30 DAT.

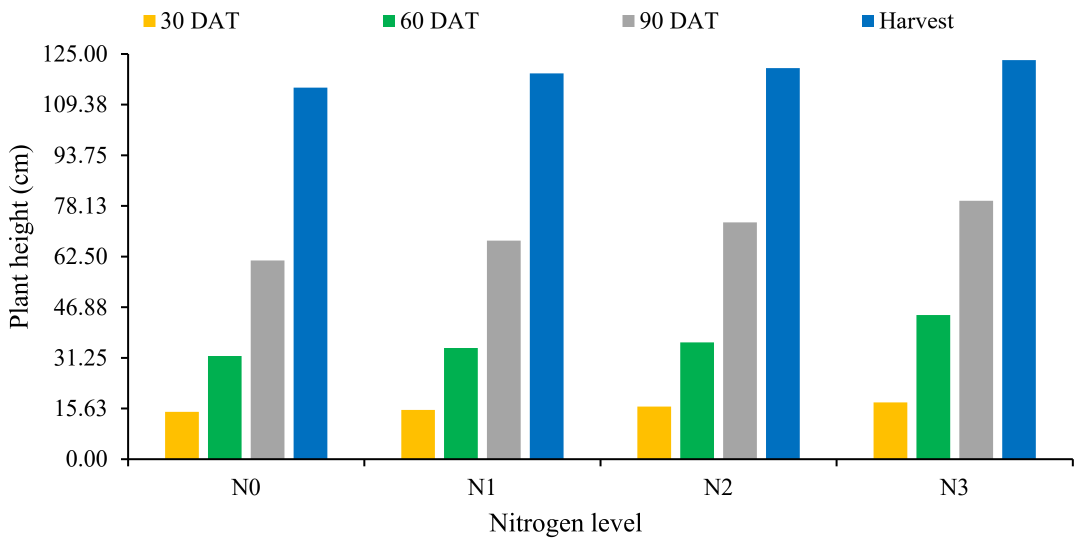

Figure 2. Effect of nitrogen levels on the plant height (cm) in aromatic rice at different days after transplanting (LSD value = 0.93, 1.38, 1.75 and 2.45 at 30, 60, 90 DAT and harvest, respectively) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.2 Number of tillers hill^{-1}

4.2.1 Effect of variety

The number of total tillers hill^{-1} was significantly influenced by variety at all different day after sowing(DAS) (Figure 3 and Appendix V). At 30, 60, 90 DAT and harvest, BRRI dhan34 (V_3) was achieved maximum (15.48, 24.15, 18.55 and 17.16, respectively) tiller then with advancement to age it declined up to maturity and Badshavog (V_3) minimum (9.53, 16.51, 13.32 and 10.14, respectively) tiller production was observed also then with advancement to age it declined up to maturity. 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 Hussain *et al*. (1989) who noticed that number of total tillers hill^{-1} differed among the varieties.

Table 1. Interaction effect of variety and nitrogen on the plant height (cm) in aromatic rice

Treatment combination	Plant height (cm) at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1N_0	15.33 d	35.11 e	62.33 h	120.36 c
V_1N_1	15.44 cd	39.22 d	67.00 f	123.80 b
V_1N_2	17.44 b	42.56 c	76.00 c	127.00 a
V_1N_3	20.67 a	51.56 a	86.22 a	128.10 a
V_2N_0	14.44 e	29.44 i	61.33 h	116.40 e
V_2N_1	15.89 cd	31.71 gh	65.11 g	118.30 d
V_2N_2	16.11 c	32.00 g	72.89 d	118.60 d
V_2N_3	16.18 c	46.00 b	81.00 b	120.90 c
V_3N_0	14.00 e	30.89 h	60.22 i	107.10 h
V_3N_1	14.33 e	32.00 g	70.11 e	114.90 f
V_3N_2	15.22 de	33.56 f	70.22 e	116.40 e
V_3N_3	15.78 cd	35.89 e	72.00 d	120.40 c
LSD (0.05)	**0.78**	**0.90**	**1.11**	**1.65**
CV (%)	**5.38**	**7.38**	**4.68**	**8.18**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.2.2 Effect of levels of nitrogen

Number of tillers $hill^{-1}$ was significantly influenced by the nitrogen levels at all the assessment dates. Number of tillers $hill^{-1}$ increased with age reaching a peak at 60 DAT and there after decline (Figure 4 and Appendix IV). As the nitrogen rate was increased from 0 kg N ha^{-1} to 120 kg N ha^{-1}, the number of tillers increased significantly and recorded at 30, 60, 90 DAT and at harvest stage, the maximum tillers (13.78, 23.21, 18.68 and 16.42, respectively) was observed with 120 kg N ha^{-1} (N_2) application and minimum tiller (10.83, 16.64, 13.94 and 12.22, respectively) with 0 kg N ha^{-1} (N_0) treatment. Application of 120 kg N ha^{-1} (N_2) produced maximum tiller $hill^{-1}$ and followed by 80 kg N ha^{-1} (N_1) and control (N_0) irrespective of growth stage. The improvement in the formation of tillers with N application in the present experiment might be due to increase of nitrogen availability which enhanced tillering. Mirzeo and Reddy (1989) and Singh and Singh (1986) also reported that nitrogen produced highest number of tillers @ 87 kg N ha^{-1}. Hamidullah *et al.* (2006) found that tiller number increased with increasing N and 120 and 160 kg N ha^{-1} produced statistically similar tiller $hill^{-1}$. On the other hand, Peng *et al.* (1996) reported that N supply controlled the tiller production of rice plant unless other factors such as spacing or light became limiting.

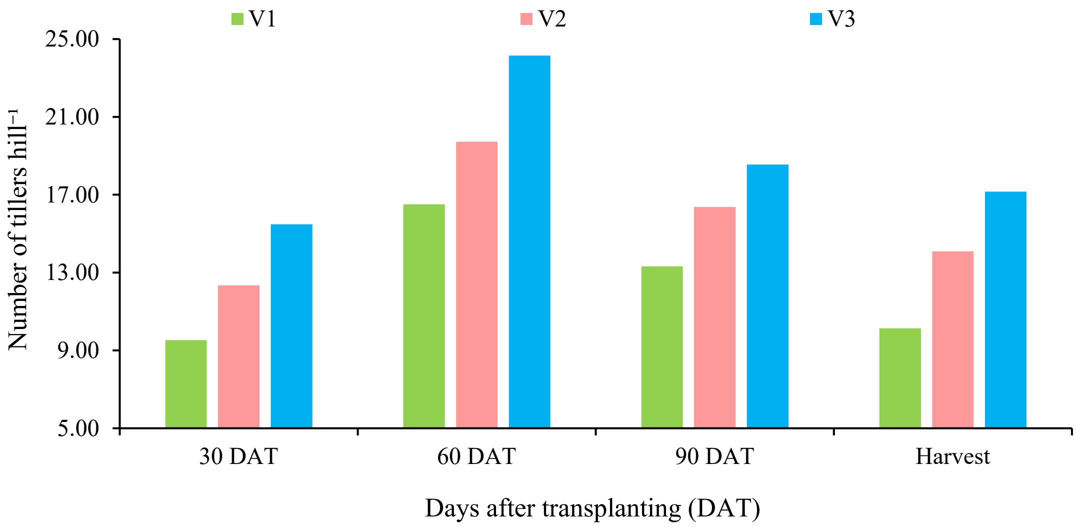

Figure 3. Effect of variety on the number of tillers $hill^{-1}$ in aromatic rice at different days after transplanting

(LSD value = 1.45, 2.03, 1.83 and 1.96 at 30, 60, 90 DAT and harvest, respectively (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34)

4.2.3 Interaction effect of variety and nitrogen levels

The interaction effect of variety and nitrogen levels showed significant influence on the tiller dynamic of the aromatic rice (Table 2 and appendix V). At 30, 60, 90 DAT and at harvest, the maximum tiller (15.13, 25.85, 19.55 and 17.78, respectively) was achieved by V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) treatment combination which was statistically identical to V_3N_2 (14.24) at 30 DAT. At 30, 60, 90 DAT and at harvest, the minimum tiller (6.29, 11.65, 9.55 and 6.56, respectively) was found with V_1N_0 (Badshavog rice with 0 kg N ha^{-1}) which was statistically similar to V_1N_1 (7.28) and V_1N_2 (7.99) at 30 DAT; V_1N_1 (10.95) at 90 DAT and V_1N_1 (7.58) and V_1N_2 (7.98) at harvest stage.

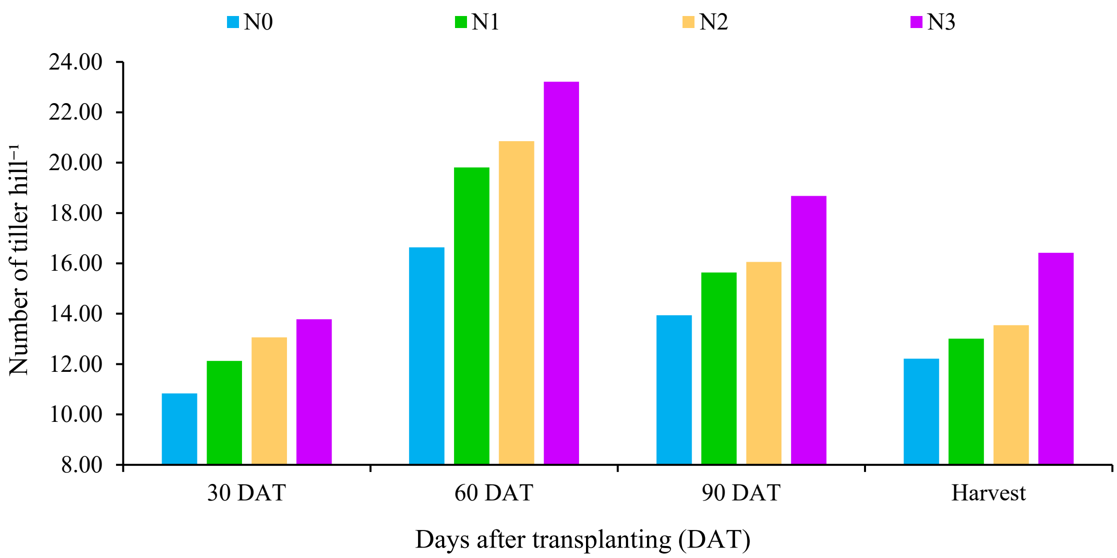

Figure 4. Effect of nitrogen levels on the number of tillers hill^{-1} in aromatic rice at different days after transplanting

(LSD value = 1.12, 1.58, 1.41 and 1.52 at 30, 60, 90 DAT and harvest, respectively) (N_0 - 0 kg N ha^{-1} (control), N_1 -40 kg N ha^{-1}, N_2 - 80 kg N ha^{-1} and N_3 -120 kg N ha^{-1})

4.3 Leaf area index (LAI)

4.3.1 Effect of variety

Leaf area index (LAI) or the surface area of green leaves produced by rice plants unit area^{-1} of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. LAI was significantly influenced by variety to variety at different day after transplanting (DAT) (Figure 5 and Appendix VI). 'BRRI dhan34' variety (V_3), maintained the superior LAI as compared to other treatment at all the growth stages of observations. The highest LAI (0.94, 4.90 and 5.49, respectively) was found at 30, 60 and 90 DAT due to the effect of BRRI dhan34 (V_3) whereas, the lowest LAI (0.48, 1.78 and 2.87, respectively) was found at 30, 60 and 90 DAT due to the effect of Badshavog (V_1).

Table 2. Interaction effect of variety and nitrogen on the number of tillers hill^{-1} in aromatic rice.

Treatment combination	No. of tillers hill^{-1} at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1N_0	6.29 f	11.65 g	9.55 f	6.56 d
V_1N_1	7.28 f	14.25 f	10.95 ef	7.58 d
V_1N_2	7.99 ef	15.11 f	11.30 e	7.98 d
V_1N_3	8.54 e	17.04 e	13.47 cd	10.44 c
V_2N_0	8.74 e	14.31 f	12.19 de	10.53 c
V_2N_1	10.02 d	17.41 de	13.92 c	11.13 c
V_2N_2	10.95 cd	18.44 d	14.35 c	11.67 c
V_2N_3	11.66 c	20.75 cd	17.02 b	15.04 b
V_3N_0	11.47 c	17.96 d	14.08 c	13.57 b
V_3N_1	13.08 b	21.76 bc	16.04 b	14.31 b
V_3N_2	14.24 a	23.02 b	16.53 b	14.98 b
V_3N_3	15.13 a	25.85 a	19.55 a	17.78 a
LSD $_{(0.05)}$	**1.12**	**1.58**	**1.41**	**1.52**
CV (%)	**9.75**	**8.34**	**4.98**	**9.27**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.3.2 Effect of levels of nitrogen

LAI was significantly influenced by nitrogen rate at different growth stages (Figure 6 and Appendix VI). The highest LAI (0.75, 3.68 and 4.44, respectively) was found at 30, 60 and 90 DAT due to the effect of 120 kg N ha^{-1} (N_3) treatment which was statistically identically to N_2 (0.75, 3.63 and 4.41, respectively) whereas, the lowest LAI (0.52, 2.95 and 3.75, respectively) was found at 30, 60 and 90 DAT due to the effect of 0 kg N ha^{-1} (N_0) treatment. Masum *et al.* (2008) reported that LAI was significantly higher in USG receiving plants than urea. Gorgy *et al*. (2009) observed higher LAI (7.09) with application of 165 kg N ha^{-1} as three equal splits and Hamidullah *et al.* (2006) found maximum LAI with 160 kg N ha^{-1}. Ali *et al.* (2005) reported that LAI was significantly higher in USG receiving plants than urea.

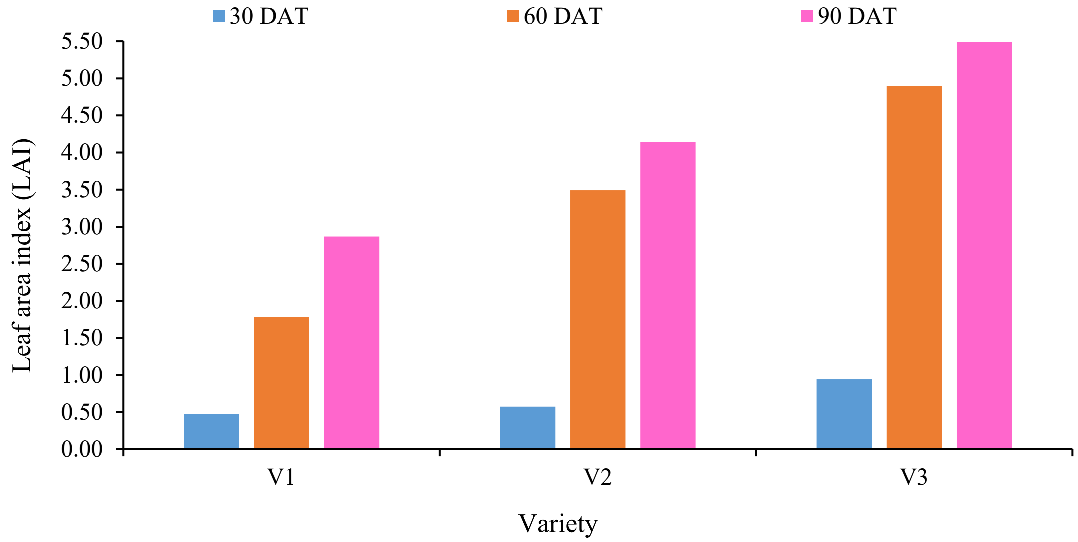

Figure 5. Effect of variety on the leaf area index (LAI) in aromatic rice at different days after transplanting (LSD value = 0.08, 0.22 and 0.24 at 30, 60 and 90 DAT, respectively)

Note: V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34

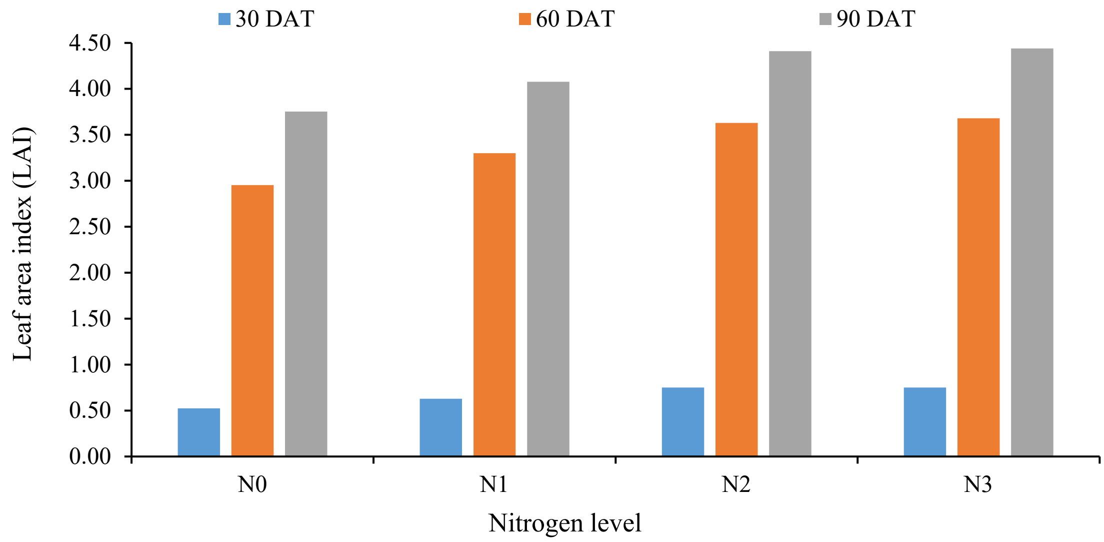

Figure 6. Effect of nitrogen levels on the leaf area index (LAI) in aromatic rice at different days after transplanting (LSD value = 0.06, 0.28 and 0.31 at 30, 60 and 90 DAT, respectively) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.3.3 Interaction effect of variety and nitrogen levels

The interaction effect of variety and nitrogen levels showed significant influence on the leaf area index (LAI) of the aromatic rice (Table 3 and appendix VI). At

30, 60 and 90 DAT, the highest LAI (1.05, 5.22 and 5.39, respectively) was observed with V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) which was statistically identical with V_3N_2 (1.05, 5.04 and 5.31, respectively). On the other hand, at 30, 60 and 90 DAT, the lowest LAI (0.38, 1.35 and 2.08, respectively) was found by V_1N_0 (Badshavog with 0 kg N ha^{-1}) treatment combination which was statistically similar with V_1N_1 (1.53 and 2.31 at 60 and 90 DAT, respectively).

4.4 Crop growth rate (CGR)

4.4.1 Effect of variety

Crop growth rate (CGR) was significantly influenced by different variety at different day after transplanting (DAT) (Figure 7 and Appendix VII). Critical appraised of the data showed that the maximum crop growth rate was recorded the variety 'BRRI dhan34' (V_3) at 30, 60 and 90 DAT. The maximum CGR (0.56, 4.21 and 5.19 g running m^{-1} day^{-1}, respectively) was recorded with BRRI dhan34 (V_3) whereas, the minimum CGR (0.26, 1.08 and 2.55 g running m^{-1} day^{-1}, respectively) was found at 30, 60 and 90 DAT due to the effect of Badshavog rice (V_1). Similar results also reported by Ashraf *et al.* (2006).

4.4.2 Effect of levels of nitrogen

Significant variation was observed in terms of crop growth rate (CGR) at different growth stages of aromatic rice influenced by different levels of nitrogen (Figure 8 and Appendix VII). At 30, 60 and 90 DAT, the maximum CGR (0.45, 3.41 and 4.68 g running m^{-1} day^{-1}, respectively) was recorded with N_3 (120 kg N ha^{-1}) which was statistically identical with N_2 (0.43 g running m^{-1} day^{-1} at 30 DAT) whereas, the minimum (0.36, 1.75 and 3.12 g running m^{-1} day^{-1}, respectively) was recorded with N_0 (0 kg N ha^{-1}). Similar results also reported by Boonchuay *et al.* (2013); Muthukumararaja and Sriramachandrasekharan (2012).

Table 3. Interaction effect of variety and nitrogen on the leaf area index (LAI) in aromatic rice

Treatment combination	Leaf area index (LAI) at		
	30 DAT	**60 DAT**	**90 DAT**
V_1N_0	0.38 g	1.35 h	2.08 h
V_1N_1	0.45 f	1.53 gh	2.31 h
V_1N_2	0.54 e	1.71 g	2.54 g
V_1N_3	0.54 e	1.73 g	2.54 g
V_2N_0	0.45 f	2.84 f	3.23 f
V_2N_1	0.54 e	3.20 e	3.55 e
V_2N_2	0.65 d	3.54 d	4.08 d
V_2N_3	0.65 d	3.59 d	4.09 d
V_3N_0	0.74 c	4.07 c	4.65 c
V_3N_1	0.89 b	4.57 b	5.07 b
V_3N_2	1.05 a	5.04 a	5.31 a
V_3N_3	1.05 a	5.22 a	5.39 a
LSD (0.05)	**0.06**	**0.28**	**0.31**
CV (%)	**10.82**	**11.24**	**9.37**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34 (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

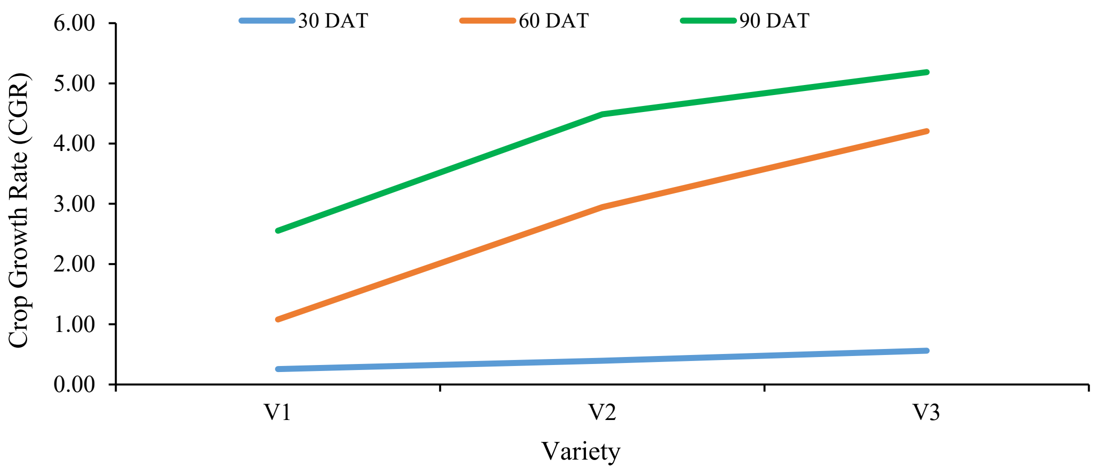

Figure 7. Effect of variety on the crop growth rate (CGR) in aromatic rice at different days after transplanting

(LSD value = 0.07. 0.29 and 0.49 at 30, 60 and 90 DAT, respectively) (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34)

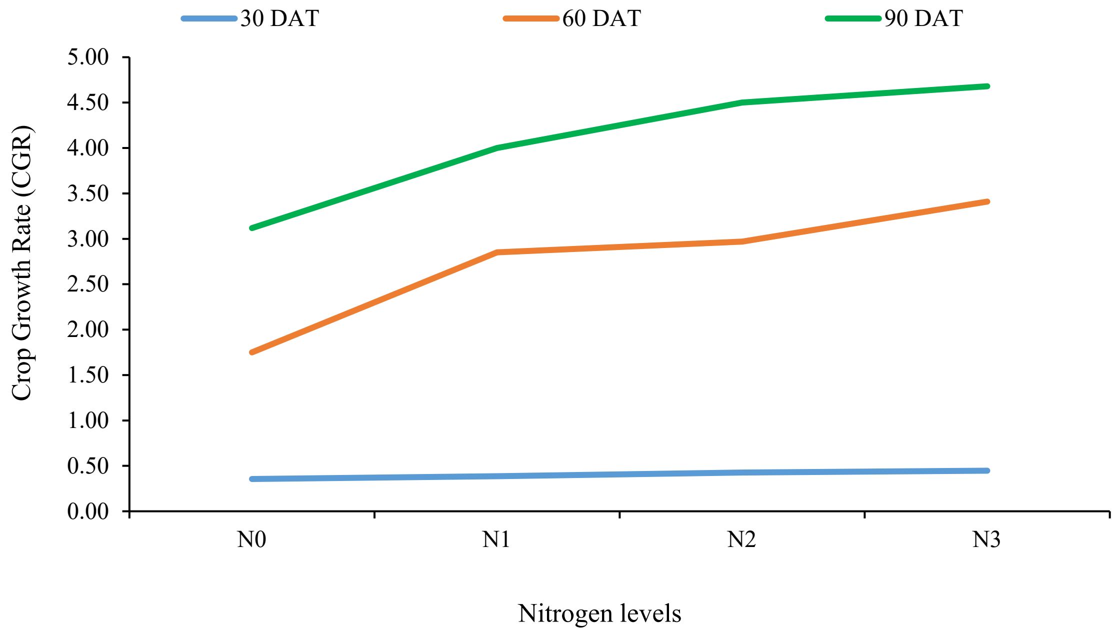

Figure 8. Effect of nitrogen levels on the crop growth rate (CGR) in aromatic rice at different days after transplanting (LSD value = NS, 0.21 and 0.38 at 30, 60 and 90 DAT, respectively) (N_0 - 0 kg N ha^{-1} ,N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.4.3 Interaction effect of variety and nitrogen levels

The interaction effect of different variety and different levels of nitrogen showed significant influence on the crop growth rate (CGR) of the aromatic rice (Table 4 and appendix VII). At 30 DAT, the maximum CGR (0.62 g running m^{-1} day^{-1}) was observed with V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) which was statistically similar with V_3N_2 (0.59 g running m^{-1} day^{-1}) whereas, the minimum CGR (0.23 g running m^{-1} day^{-1}) was observed with V_1N_0 (Badshavog with 0 kg N ha^{-1}) which was statistically identical with V_1N_1 (0.24 g running m^{-1} day^{-1}), V_1N_2 (0.27 g running m^{-1} day^{-1}), V_1N_3 (0.28 g running m^{-1} day^{-1}) and statistically similar to V_2N_0 (0.35 g running m^{-1} day^{-1}) treatment combination. At 60 and 90 DAT, the maximum CGR (5.13 and 5.66 g running m^{-1} day^{-1}, respectively) was found by V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) whereas, the minimum CGR (0.59 and 1.65 g running m^{-1} day^{-1}, respectively) was found by V_1N_0 (Badshavog with 0 kg N ha^{-1}) treatment combination.

4.5 Number of panicles hill^{-1}

4.5.1 Effect of variety

Number of panicles hill^{-1} of aromatic rice showed statistically significant differences due to different rice variety (Table 5 and Appendix VIII). The highest number of panicles hill^{-1} (14.10) was found from V_3 (BRRI dhan34) treatment, while the lowest number (7.09) was recorded from V_1 (Badshavog) treatment which Followed (11.41) by V_2 (Katarivog) treatment. The similar kind of result was recorded by Yin *et al.* (2016).

Table 4. Interaction effect of variety and nitrogen on the crop growth rate (CGR) in aromatic rice

Treatment combination	Crop growth rate (g running m^{-1} day^{-1}) at		
	30 DAT	60 DAT	90 DAT
V_1N_0	0.23 e	0.59 h	1.65 g
V_1N_1	0.24 e	1.02 g	2.21 f
V_1N_2	0.27 e	1.07 g	2.52 f
V_1N_3	0.28 e	1.24 g	2.63 f
V_2N_0	0.35 de	1.78 f	3.13 e
V_2N_1	0.38 d	2.96 d	4.11 d
V_2N_2	0.42 cd	3.08 d	4.66 c
V_2N_3	0.44 c	3.56 c	4.86 c
V_3N_0	0.49 c	2.58 e	3.67 d
V_3N_1	0.54 bc	4.27 b	4.79 c
V_3N_2	0.59 ab	4.45 b	5.43 b
V_3N_3	0.62 a	5.13 a	5.66 a
LSD (0.05)	**0.07**	**0.29**	**0.49**
CV (%)	**13.78**	**11.82**	**10.27**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.5.2 Effect of levels of nitrogen

Number of panicles hill^{-1} of aromatic rice was significantly influenced by the application of different levels of nitrogen (Table 6 and Appendix VIII). The highest number of panicles hill^{-1} (13.33) was recorded from N_3 (120 kg N ha^{-1}) treatment. On the other hand, the lowest number of panicles hill^{-1} (9.00) was observed in N_0 (no nitrogen) treatment. Application of 120 kg N ha^{-1} produced 47.39 % higher panicles hill^{-1} than control treatment. This was might be due to the fact that the number of tillers at this level of nitrogen was so high that even after mortality, it remained significantly higher than that of other levels of nitrogen and this consequently led to a greater number of panicles bearing tillers and panicle at this type of nitrogen management. Similar findings also reported by Puteh and Mondal (2014).

Table 5. Effect of variety on the yield components in aromatic rice

Nitrogen scheduling	Number of panicles hill^{-1}	Panicle length (cm)	Number of grain panicle^{-1}	1000-grain weight (g)
V_1	7.09 c	21.36 c	126.45 c	11.33 c
V_2	11.41 b	22.90 b	138.20 b	13.75 b
V_3	14.10 a	25.03 a	145.45 a	15.50 a
LSD (0.05)	**1.57**	**0.77**	**4.25**	**1.55**
CV (%)	**7.82**	**4.92**	**6.54**	**4.36**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

(V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34)

4.5.3 Interaction effect of variety and nitrogen levels

Interaction effect of variety and nitrogen was found significant on number of panicles hill^{-1} of aromatic rice (Table 7 and appendix VIII). The highest number of panicles hill^{-1} (17.17) was found from the combination of V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}). On the other hand, the lowest number of panicles hill^{-1} (5.00) was found in V_1N_0 (Badshavog with no urea use) treatment combination.

4.6 Panicle length

4.6.1 Effect of variety

The panicle length varied significantly due to variety shown in Table 5 and Appendix VIII. It was observed that BRRI dhan34 (V_3) produced significantly longer (25.03 cm) panicle. The second longer panicle length (22.90 cm) was measured from Katarivog (V_2) and the shortest panicle length (21.36 cm) was measured from Badshavog (V_1). This confirms the report of Ahmed *et al.* (1997) who showed that panicle length was differed due to variety.

Table 6. Effect of nitrogen levels on the yield components in aromatic rice

Nitrogen scheduling	Number of panicles hill^{-1}	Panicle length (cm)	Number of grain panicle^{-1}	1000-grain weight (g)
N_0	9.00 c	21.78 d	127.01 d	12.60 b
N_1	10.28 b	22.87 c	135.37 c	13.51 ab
N_2	10.87 b	23.61 b	140.30 b	13.60 ab
N_3	13.33 a	24.14 a	144.11 a	14.38 a
LSD $_{(0.05)}$	**1.21**	**0.47**	**3.85**	**1.55**
CV (%)	**7.82**	**4.92**	**6.54**	**4.36**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

(N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.6.2 Effect of levels of nitrogen

Panicle length was statistically significant by different levels of nitrogen (Table 6 and Appendix VIII). The longest panicle (24.14 cm) was produced due to application of 120 kg N ha^{-1} (N_3) and shortest (21.78 cm) was produced in control (no urea application) treatment. A similar finding was reported by Hasan *et al.* (2015). Sen and Pandey (1990) also found similar panicle length by applying 38.32 kg N ha^{-1} either in the form of USG or prilled urea.

4.6.3 Interaction effect of variety and nitrogen levels

Interaction of different variety and nitrogen levels significantly influenced the panicle length of aromatic rice (Table 7 and Appendix VIII). The longest panicle (26.45 cm) was recorded from V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) treatment combination. On the other hand, the shortest panicle (20.52 cm) was observed in V_1N_0 (Badshavog with no urea application) treatment combination.

4.7 Number of grain panicle^{-1}

4.7.1 Effect of variety

Number of grains panicle^{-1} was significantly influenced by variety (Table 5 and appendix VIII). The highest number of grains panicle^{-1} (145.45) was found from V_3 (BRRI dhan34). The lowest grains panicle^{-1} (126.45) was obtained from V_1 (Badshavog) treatment which was followed by Katarivog (88.20). BRRI dhan34 produced 37.86% higher number of grains panicle^{-1} than Badshavog. These results agreed with Ahmed *et al.* (1997) who reported that percent filled grain was the highest in Nizersail (a local variety) followed by BR25 and the lowest in BR11 and BR23.

4.7.2 Effect of levels of nitrogen

Significant variation was found in number of grains panicle^{-1} due to the varieties in the aromatic rice field (Table 6 and Appendix VIII). The maximum number of grain panicle^{-1} (144.11) was recorded from N_3 (120 kg N ha^{-1}) treatment and the minimum number of grain panicle^{-1} (127.01) was obtained from N_1 (40 kg N ha^{-1}) treatment. BRRI (2006) reported that grains panicle^{-1} increased with higher N rates up to 120 kg N ha^{-1}. Awan *et al.* (2011) reported that maximum number of grains panicle^{-1} was produced in case of 156 kg N ha^{-1}. Gorgy *et al.*

(2009) found maximum number of grains panicle^{-1} with three equal split of 165 kg N ha^{-1}.

4.7.3 Interaction effect of variety and nitrogen levels

Interaction of variety and nitrogen significantly influenced the grain panicle^{-1} of aromatic rice (Table 7 and Appendix VIII). The maximum number of grain panicle^{-1} (153.74) was recorded from V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) treatment combination. On the other hand, the minimum number of grain panicle^{-1} (118.22) was observed in V_1N_0 (Badshavog with 0 kg N ha^{-1}) treatment combination.

Table 7. Interaction effect of variety and nitrogen on the yield components in aromatic rice

Treatment combination	Number of panicles hill^{-1}	Panicle length (cm)	Number of grain panicle^{-1}	1000-grain weight (g)
V_1N_0	5.00 g	20.52 j	118.22 h	10.49 f
V_1N_1	6.97 f	21.18 i	125.39 g	11.46 ef
V_1N_2	7.37 f	21.72 h	129.32 ef	11.25 d-f
V_1N_3	9.04 e	22.04 g	132.87 e	12.11 d-f
V_2N_0	10.00 de	21.52 h	128.35 f	12.81 de
V_2N_1	10.62 d	22.75 f	136.84 d	13.66 cd
V_2N_2	11.23 d	23.40 e	141.88 c	13.90 cd
V_2N_3	13.78 bc	23.93 d	145.71 c	14.61 bc
V_3N_0	12.00 c	23.30 e	134.45 de	14.50 bc
V_3N_1	13.24 bc	24.67 c	143.88 c	15.41 ab
V_3N_2	14.00 b	25.70 b	149.71 b	15.66 ab
V_3N_3	17.17 a	26.45 a	153.74 a	16.43 a
LSD $_{(0.05)}$	**1.21**	**0.47**	**3.85**	**1.40**
CV (%)	**7.82**	**4.92**	**6.54**	**4.36**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

(V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.8 1000-grain weight

4.8.1 Effect of variety

Weight of 1000 grains showed significant variation among the different varieties (Table 5 and Appendix VIII). BRRI dhan34 (V_3) produced highest 1000 grain weight (15.50 g). On the other hand, the lowest 1000 grain weight (11.33 g) was obtained from Badshavog (V_1). Similar findings were reported by Hossain *et al.* (2007).

4.8.2 Effect of levels of nitrogen

The weight of 1000 grains were significantly influenced by the different rate of nitrogen (Table 6 and Appendix VIII). The maximum 1000-grain weight (14.38 g) was obtained from highest rate of nitrogen (120 kg N ha^{-1}) which was statistically similar with N_2 (13.60 g) and N_1 (13.51 g) whereas, the minimum (12.60 g) was obtained from control no nitrogen application (0 kg N ha^{-1}). Hasanuzzaman *et al*. (2009) reported that application of USG @ 75 kg N ha^{-1} gave the highest thousand grain weight. Gorgy *et al*. (2009) reported that application of 165 kg N ha^{-1} with three equal splits gave maximum value of thousand grain weight. Awan *et al*. (2011) found application of 156 kg N ha^{-1} gave maximum 1000 grain. Islam *et al*. (2008) reported weight of 1000 grain weight was not significantly influenced by N level as it is mostly governed by genetic makeup of the variety.

4.8.3 Interaction effect of variety and nitrogen levels

Interaction of different variety and different levels of nitrogen significantly influenced the weight of 1000 seed of aromatic rice (Table 7 and Appendix VIII). The highest weight of 1000 seed (16.43 g) was recorded from V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) treatment combination which was statistically similar with V_3N_2 (15.66 g) and V_3N_1 (25.41 g). On the other hand, the lowest weight of 1000 seed (10.49 g) was observed in V_1N_0 (Badshavog with 0 kg N ha^{-1}) treatment combination which was statistically similar with V_1N_2 (21.25 g), V_1N_1 (21.46 g) and V_1N_3 (22.11 g).

4.9 Grain yield

4.9.1 Effect of variety

Grain yield varied significantly for different varieties shown in Figure 9 and Appendix IX. The highest grain yield (2.74 t ha^{-1}) was recorded by BRRI dhan34 (V_3). The second highest grain yield (2.13 t ha^{-1}) was recorded from Katarivog (V_2). The lowest grain yield (1.15 t ha^{-1}) was recorded from Badshavog (V_1). This result was similar with Franje *et al.* (1992) who found that yields of modern cultivars improved with increased weeding while yields of traditional cultivars did not. Dissimilar results were found by Reza *et al.* (2010) who stated that Pajam (a local variety) produced the higher grain yield (4.0 t ha^{-1}) than BRRI dhan28 (2.79 t ha^{-1}).

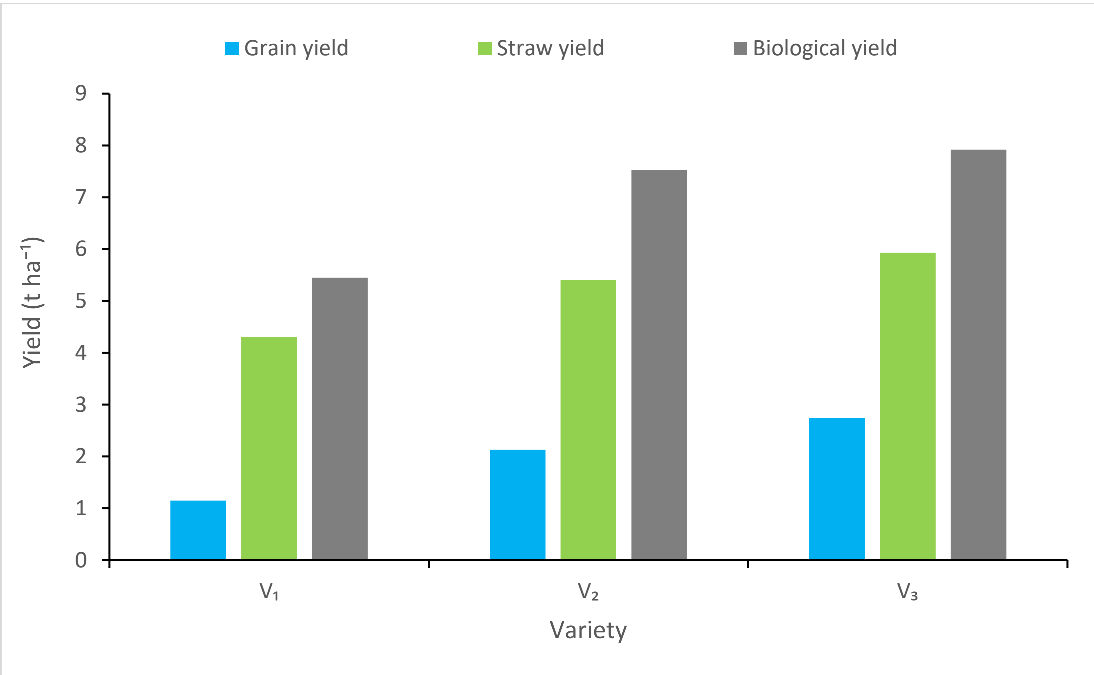

Figure 9. Effect of variety on the yield (t ha^{-1}) in aromatic rice

(LSD value = 0.97, 0.67 and 1.72 at grain yield, straw yield and biological yield, respectively) (V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34)

4.9.2 Effect of levels of nitrogen

Grain yield was significantly influenced by different rate of nitrogen in aromatic rice (Figure 10 and Appendix IX). Critical observation of the data showed that nitrogen rate positively increased the grain yield. Significantly higher grain yield (2.61 t ha^{-1}) with 120 kg N ha^{-1} (N_3), which was significantly higher than remaining treatments. However, the grain yield of 1.13 t ha^{-1} was recorded with application of 0 kg N ha^{-1} (N_0) treatment. These results agree with those obtained by Hussain and Sharma (1991) who observed that the grain yield increased significantly up to the application of higher rate of fertilizer and thereafter declined. The increment of grain yields up to highest rate of fertilizer (120 kg urea ha^{-1}) application might be due to supply of available nutrients to the crop. Further, the increased level of fertilizer decreased grain yield significantly due to excessive plant growth and crop lodging. Placement of nitrogen fertilizer in the form of USG @ 75 kg N ha^{-1} in the present experiment produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave higher grain yield. BRRI (2009) reported that highest grain yield was recorded when N applied as 100 kg N ha^{-1}. BRRI (2006) reported that cultivation of hybrid rice in *boro* required 120 kg N ha^{-1}. Similar results were reported by Hasanuzzaman *et al.* (2009), Masum *et al.* (2008), Mishra *et al.* (2000) who observed nitrogen produced the highest grain yield and proved significantly superior to other sources.

4.9.3 Interaction effect of variety and nitrogen levels

Rice grain yield (t ha^{-1}) varied significantly due to different varietal and nitrogen combinations (Table 8 and Appendix IX). The highest grain yield (3.56 t ha^{-1}) was recorded from BRRI dhan34 and 120 kg N ha^{-1} combination (V_3N_3). On the other hand, the lowest grain yield (0.60 t ha^{-1}) was recorded from Badshavog and no urea application (V_1N_0) treatment combination.

Table 8. Interaction effect of variety and nitrogen on the yield and harvest index in aromatic rice

Treatment combination	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1N_0	0.60 i	3.86 j	4.46 h	13.72 h
V_1N_1	1.13 h	4.27 i	5.40 g	20.92 de
V_1N_2	1.36 gh	4.46 hi	5.82 fg	23.37 cd
V_1N_3	1.51 g	4.60 gh	6.11 f	24.71 bc
V_2N_0	1.09 h	4.71 g	5.80 fg	18.79 g
V_2N_1	2.14 e	5.34 e	7.47 e	28.65 cd
V_2N_2	2.52 d	5.64 d	8.16 d	30.88 bc
V_2N_3	2.76 c	5.93 c	8.69 c	31.76 c
V_3N_0	1.70 f	5.11 f	6.81 e	24.96 f
V_3N_1	2.47 d	5.84 cd	5.31 cd	46.51 a
V_3N_2	3.21 b	6.23 b	9.44 b	34.00 b
V_3N_3	3.56 a	6.54 a	10.10 a	35.25 b
LSD $_{(0.05)}$	**0.23**	**0.21**	**0.46**	**1.28**
CV (%)	**6.92**	**11.42**	**10.71**	**9.27**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34
N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1}

4.10 Straw yield

4.10.1 Effect of variety

There observed significant variation for straw yield due to varietal variation (Figure 9 and Appendix IX). BRRI dhan34 (V_3) recorded the maximum straw yield (5.93 t ha^{-1}) and Badshavog (V_1) recorded the minimum straw yield (4.30 t ha^{-1}). Similar findings were also reported by Hassan *et al.* (2010).

4.10.2 Effect of levels of nitrogen

From Figure 10 and Appendix IX, it was revealed that straw yield was significantly affected due to the different rate of nitrogen application. The maximum straw yield (5.69 t ha^{-1}) was achieved at highest rate of nitrogen (N_3) application (120 kg N ha^{-1}) whereas, the minimum (4.56 t ha^{-1}) was found with the control (N_0) treatment (0 kg N ha^{-1}). More straw yield could be explained as higher capability of hybrid rice to utilize more N through the expression of better growth by accumulating more dry matter. The results confirm the findings of Phattarakul *et al.* (2012). The improvement in yield owing to the application of N-fertilizers might be brought by the beneficial effect of these on nutrient uptake, physiological growth. BRRI (2009) reported application of 150 kg N ha^{-1} gave the highest yield. Hasanuzzaman *et al*. (2009) reported application of 200 kg N ha^{-1} and USG @ 75 kg N ha^{-1} gave highest straw yield. Awan *et al*. (2011) observed application of 156 kg N ha^{-1} gave highest straw yield.

4.10.3 Interaction effect of variety and nitrogen levels

Interaction of nitrogen and variety significantly influenced the straw yield of T. aman rice (Table 8 and Appendix IX). The maximum straw yield (6.54 t ha^{-1}) was recorded from V_3N_3 (BRRI dhan34 with 120 kg N ha^{-1}) treatment combination. On the other hand, the minimum straw yield (3.86 t ha^{-1}) was observed in V_1N_0 (Badshavog rice with no nitrogen application) treatment combination.

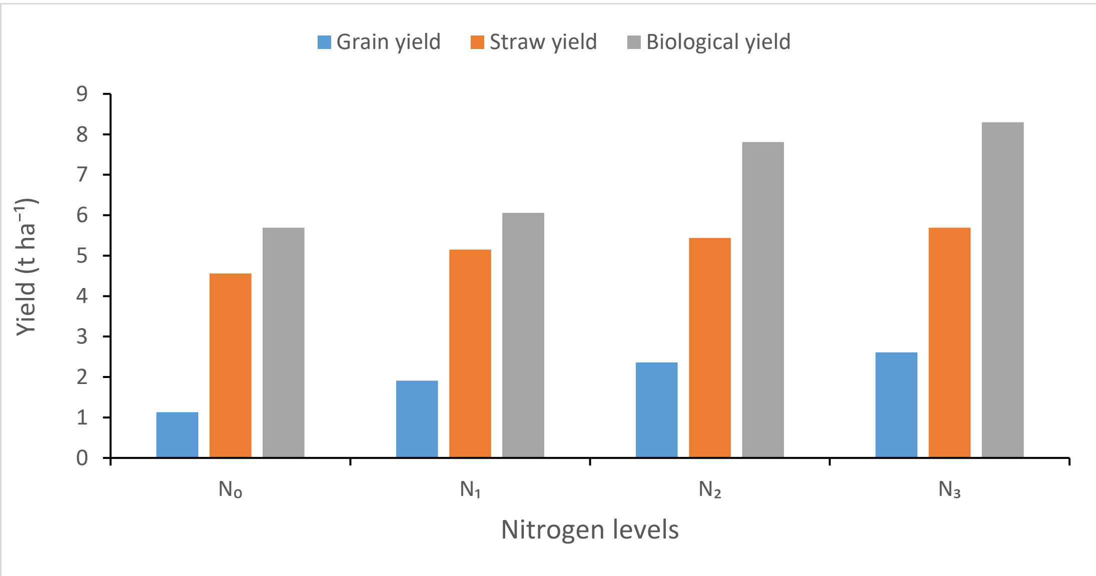

Figure 10. Effect of nitrogen levels on yield (t ha^{-1}) in aromatic rice

(LSD value = 0.45, 0.59 and 1.46 at grain yield, straw yield and biological yield, respectively) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.11 Biological yield

4.11.1 Effect of variety

The biological yield (t ha^{-1}) varied significantly due to variety shown in Figure 9 and Appendix IX. It was observed that BRRI dhan34 (V_3) produced significantly the highest biological yield (7.92 t ha^{-1}) and the lowest biological yield (5.45 t ha^{-1}) was recorded from Badshavog (V_1). Similar results were also observed by Hossen (2000) and Chowdhury (2012).

4.11.2 Effect of levels of nitrogen

Biological yield was significantly influenced by different levels of nitrogen in aromatic rice (Appendix IX). The observation (Figure 10) showed significantly the maximum biological yield of 8.30 t ha^{-1} obtained with 120 kg N ha^{-1} (N_3) that was significantly higher over lower rate of nitrogen. However, the biological yield of 6.06 t ha^{-1} due to 40 kg N ha^{-1} (N_1), was significantly higher over control (5.69 t ha^{-1}) treatment. The result agreed with the findings of Ahmed *et al.* (2005) who observed the effect of nitrogen dose on biological yield (t ha^{-1}) of rice.

4.11.3 Interaction effect of variety and nitrogen levels

It was found that biological yield was affected significantly due to the interaction of variety and different levels of nitrogen (Table 8 and Appendix IX). Maximum biological yield (10.10 t ha^{-1}) was obtained from the combination of BRRI dhan34 × 120 kg N ha^{-1} (V_3N_3) and the minimum (4.46 t ha^{-1}) from Badshavog with control (without nitrogen) treatment combination.

4.12 Harvest index

4.12.1 Effect of variety

Variety showed significant variation in harvest index (Figure 11 and Appendix IX). BRRI dhan34 (V_3) showed the highest harvest index (35.18%) whereas the lowest harvest index (20.68%) in Badshavog (V_1). Similar results were also observed by Hossen (2000) and Chowdhury (2012).

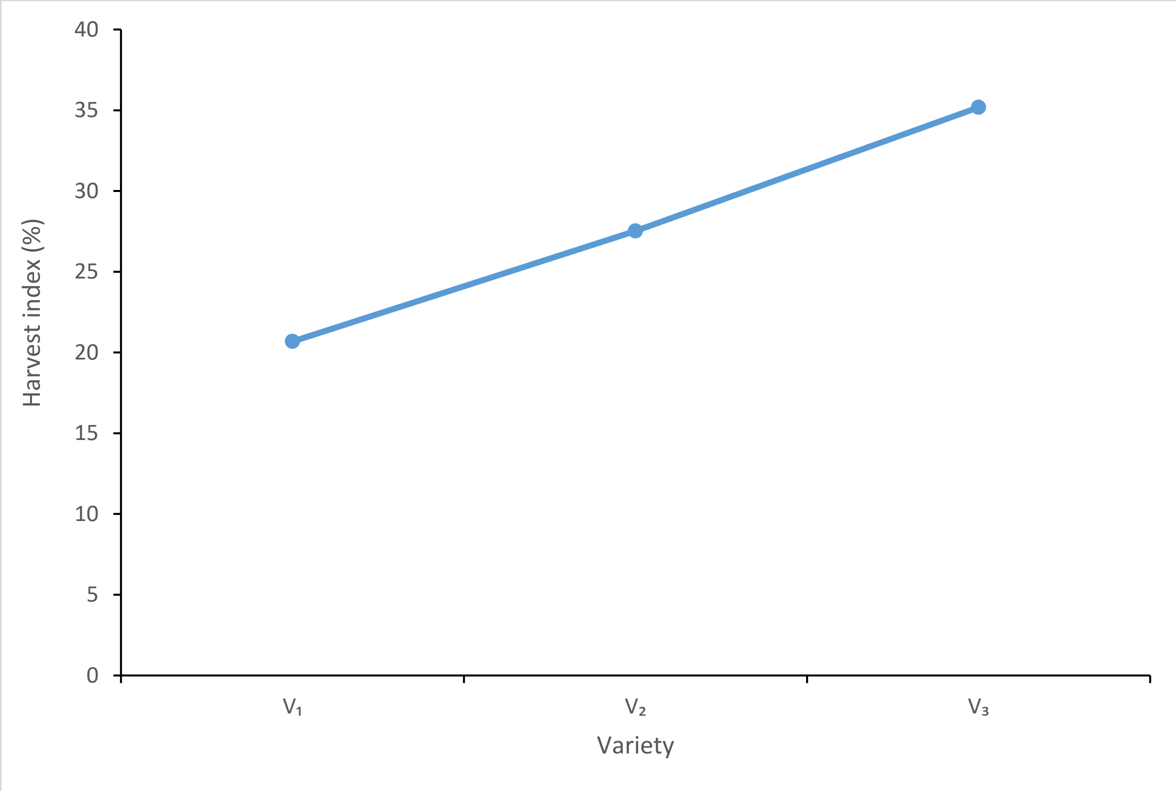

Figure 11. Effect of variety on the harvest index (%) in aromatic rice (LSD value = 1.88)

(V_1 – Badshavog, V_2 – Katarivog and V_3 – BRRI dhan34)

4.12.2 Effect of levels of nitrogen

From Figure 12 and Appendix IX, it was revealed that significant variation in harvest index was observed due to various nitrogen management. The higher value of harvest index (31.52%) was found with 40 kg N ha^{-1} (N_1) which was statistically identical (31.44%) to 120 kg N ha^{-1} (N_3). On the other hand, the lowest value of harvest index (19.86%) was found with control (N_0). Awan *et al.* (2011) reported highest harvest index was found with 156 kg N ha^{-1}.

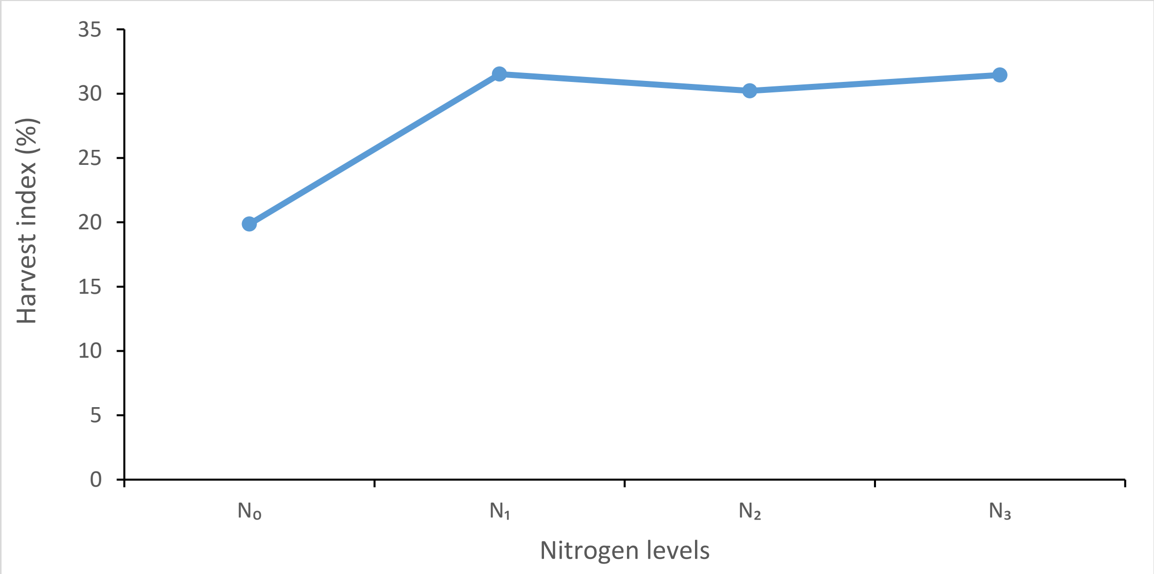

Figure 12. Effect of nitrogen levels on the harvest index (%) in aromatic rice (LSD value = 1.28) (N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

4.12.3 Interaction effect of variety and nitrogen levels

There was observed significant effect on harvest index due to the interaction of variety and different levels of nitrogen in aromatic rice (Table 8 and Appendix IX). Maximum (35.25%) harvest index was found from the combination of BRRI Dhan34 with 120 kg N ha^{-1} (V_3N_3) which was statistically similar (34.00%) of same variety with 80 kg N ha^{-1} (V_3N_2) treatment combination. On the other hand, the minimum harvest index (13.72%) was found from the combination of Badshavog with control (no nitrogen) (V_1N_0) treatment combination.

4.13 Functional relationship between nitrogen dose and grain yield of aromatic rice variety

4.13.1 Relationship between nitrogen dose and grain yield of badshavog

Functional relationship analysis between nitrogen dose and grain yield of badshavog revealed that, increase in dose of nitrogen fertilizer was positively correlated with corresponding increase in grain yield of badshavog variety

(Figure 13). The higher the rate of nitrogenous fertilizer, the higher the possibility of more grain yield of Badshavog variety. The R-squared for the regression model is 0.90, which means 90% of the variance in grain yield ($t \cdot ha^{-1}$) can be explained by nitrogen fertilizer dose (kg ha^{-1}). The remaining 10% can be attributed to unknown, lurking variables or inherent variability.

4.13.2 Relationship between nitrogen dose and grain yield of Katarivog

Functional relationship analysis between nitrogen dose and grain yield of Katarivog revealed that, increase in dose of nitrogen fertilizer was positively correlated with corresponding increase in grain yield of Katarivog variety (Figure 13). The higher the rate of nitrogenous fertilizer, the higher the possibility of more grain yield of Katarivog. The R-squared for the regression model is 0.90, which means 90% of the variance in grain yield (t ha^{-1}) can be explained by nitrogen fertilizer dose (kg ha^{-1}). The remaining 10% can be attributed to unknown, lurking variables or inherent variability.

4.13.3 Relationship between nitrogen dose and grain yield of BRRI Dhan34

Functional relationship analysis between nitrogen dose and grain yield of BRRI Dhan34 revealed that, increase in dose of nitrogen fertilizer was positively correlated with corresponding increase in grain yield of BRRI Dhan34 variety (Figure 13). The higher the rate of nitrogenous fertilizer, the higher the possibility of more grain yield of BRRI Dhan34. The R-squared for the regression model is 0.98, which means 98% of the variance in grain yield (t ha^{-1}) can be explained by nitrogen fertilizer dose (kg ha^{-1}). The remaining 2% can be attributed to unknown, lurking variables or inherent variability.

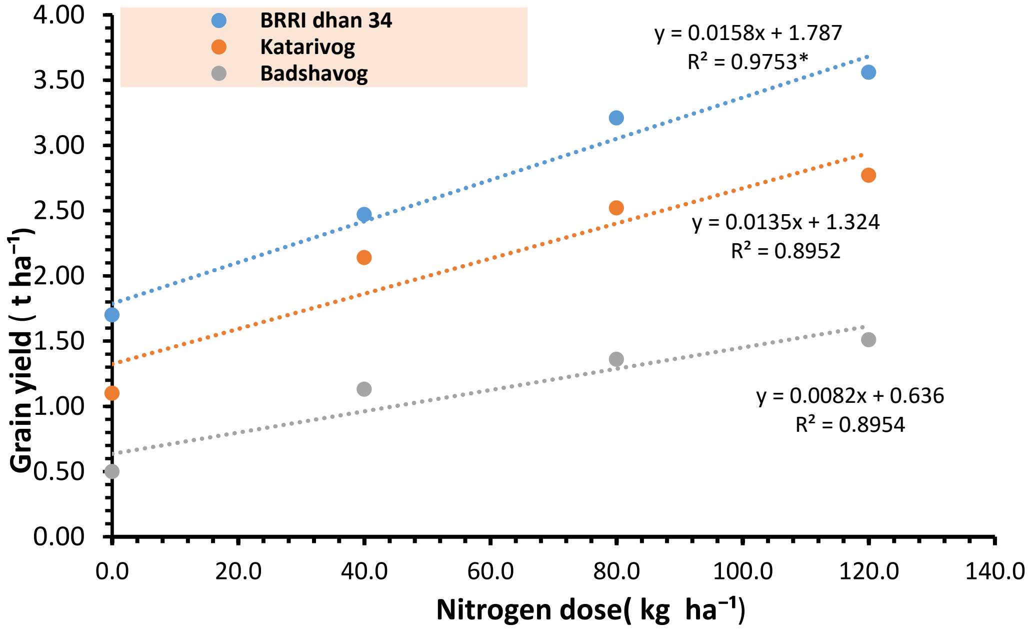

Figure 13. Functional relationship between nitrogen dose and grain yield of aromatic rice variety

(N_0 - 0 kg N ha^{-1} (control), N_1 – 40 kg N ha^{-1}, N_2 – 80 kg N ha^{-1} and N_3 – 120 kg N ha^{-1})

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the *aman* season at field laboratory of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from July 2019 to December 2019 to observe the growth and yield performance of aromatic rice in response to variety and level of nitrogen. The experiment comprised of two factors viz. factor A: Varieties; V_1 = Badshavog, V_2 = Katarivog and V_3 = BRRI dhan34; factor B: Levels of nitrogen; N_0 = Control (0 kg N ha^{-1}/No urea Used), N_1 = 40 kg N ha^{-1}, N_2 = 80 kg N ha^{-1} and N_3 =120 kg N ha^{-1}. This field experiment was laid out in a completely randomized block design (RCBD) with three replications. Data were collected on different aspects of growth, yield attributes and yield of rice.

The result revealed that V_3 (BRRI dhan34) exhibited its superiority to other tested variety Katarivog in terms of seed yield, the former out-yielded over V_2 (Katarivog) by 28.63% higher yield. V_3 (BRRI dhan34) also showed the highest number of tillers hill^{-1} at harvest (17.16), the maximum leaf area index at harvest (5.49), the maximum CGR (5.19 g running m^{-1} day^{-1}), the highest number of panicles hill^{-1} (14.10), the longest panicle (25.03 cm), the highest number of grains panicle^{-1} (145.45), the highest weight of 1000-grains (15.50 g), the maximum straw yield (5.93 t ha^{-1}), the highest biological yield (7.92 t ha^{-1}) and the highest harvest index (35.18%) than other tested variety (Katarivog) in this experiment which supports the findings of Franje *et al.* (1992). On the other hand, the variety Badshavog gave 138.26% lower yield which was significantly lower than BRRI dhan34 variety.

Significant differences existed among different levels of nitrogen with respect to growth, yield and yield attributing parameters of rice. Treatment N_3 (120 kg N ha^{-1}) showed a yield advantage of 0.25 t ha^{-1}, 0.70 t ha^{-1}, 1.48 t ha^{-1} over N_2 (80 kg N ha^{-1}), N_1 (40 kg N ha^{-1}) and N_0 [Control (0 kg N ha^{-1}/No urea Used)], respectively, which was possibly aided by taller plant at harvest (123.13 cm), higher number of tillers hill^{-1} at harvest (17.16), higher leaf area index at 90 DAT (4.44), maximum CGR at 90 DAT (4.68 g running m^{-1} day^{-1}), the highest number of panicles hill^{-1} (13.33), the longest panicle (24.14 cm), the maximum number of grain panicle^{-1} (144.11), the maximum 1000-grain weight (14.38 g), the maximum straw yield (5.69 t ha^{-1}) and the maximum biological yield (8.30 t ha^{-1}). On the other hand, treatment N_2 (80 kg N ha^{-1}) gave similar results to N_3 treatment in some parameters like—plant height, weight of 1000-grains, straw yield and harvest index.

Interaction of variety and different levels of nitrogen significantly influenced all the studied parameters including grain yield of rice. The interaction of V_3N_3 produced the highest grain yield (3.56 t ha^{-1}) than other interactions which may be attributed to the highest number of effective tillers hill^{-1} at harvest (17.78), highest leaf area index (5.39), highest CGR (5.66 g running m^{-1} day^{-1}), the maximum number of panicles hill^{-1} (17.17), longest panicle (26.45 cm), maximum number of grains panicle^{-1} (153.74) and the highest weight of 1000-grains (16.43 g). This interaction also showed the highest straw yield (6.54 t ha^{-1}) and biological yield (10.10 t ha^{-1}). However, interaction of V_3N_2 showed statistically similar value in some of the attributes like—leaf area index at 90 DAT (5.31), weight of 1000-grains (15.66 g) and harvest index (34.00%) with V_3N_3.

CONCLUSION

- ❖ BRRI dhan34 exhibited superiority to cultivars, Badshavog and Katarivog in terms of LAI (5.49), CGR (5.19 g running m^{-1} day^{-1}), panicles hill^{-1} (14.10), grains panicle^{-1} (145.45) and 1000-grains weight (15.50 g). Consequently, it produced 28.63%) higher grain yield over the rest cultivars Badshavog and Katarivog.
- ❖ 120 kg N ha^{-1} application showed a yield advantage of 0.25 t ha^{-1}, 0.70 t ha^{-1}, 1.48 t ha^{-1} over N_2 (80 kg N ha^{-1}), N_1 (40 kg N ha^{-1}) and N_0 (control),

respectively accredited by higher growth and yield contributing parameters.

- ❖ So, BRRI dhan34 along with 120 kg N ha^{-1} performed the best in respect of grain yield.

Recommendation

- ✓ BRRI dhan34 should be cultivated with 120 kg N ha^{-1} for higher yield in *Aman* season.

- ✓ Similar study should be carried out in the different agro-ecological zones (AEZ) of Bangladesh for confirmation of the zonal adaptability.

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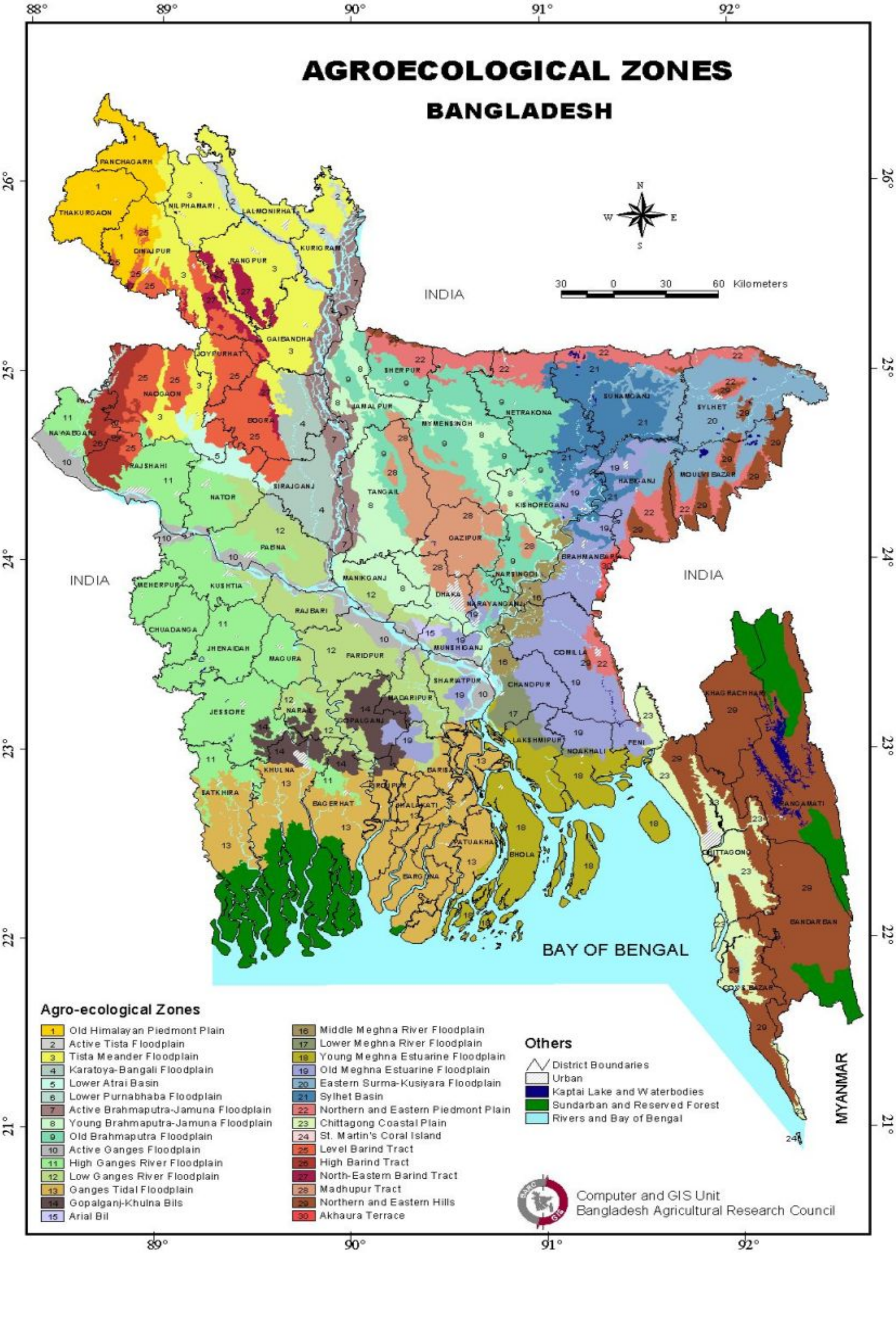
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from July, 2019 to December, 2019

Month	Air temperature (^0C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
July, 2019	37.18	27.04	87	79
August,2019	38.38	28.67	85	101
September, 2019	35.40	26.79	81	67
October, 2019	28.20	19.70	80	35
November, 2019	25.82	14.04	78	24
December, 2019	23.40	8.50	77	5

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix III. Characteristics of experimental fields soil was analysed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV. Analysis of variance (mean square) of plant height at different DAT

Source of variation	Degrees of freedom	Plant height			
		30 DAT	60 DAT	90 DAT	Harvest
Replication	2	5.852	80.983	156.225	6.516
Variety (A)	2	10.897*	49.245*	170.324*	53.933*
Nitrogen	3	6.051*	49.026*	110.420*	3.034*
(B)	6	0.549**	3.452**	9.923**	6.954**
A×B	22	1.305	8.520	29.517	0.585
Error					

*** and ** indicate significant at 5% and 1% level of probability, respectively.**

Appendix V. Analysis of variance (mean square) of number of tillers $hill^{-1}$ at different DAT

Source of variation	Degrees of freedom	Number of tillers $hill^{-1}$			
		30 DAT	60 DAT	90 DAT	Harvest
Replication	2	0.274	0.239	7.238	1.646
Variety (A)	2	11.356*	13.411*	571.676*	207.136*
Nitrogen	3	13.758*	16.141**	546.668**	167.304**
(B)	6	0.104**	0.396*	8.145**	0.001**
A×B	22	0.037	0.283	0.825	6.063
Error					

*** and ** indicate significant at 5% and 1% level of probability, respectively**

Appendix VI. Analysis of variance (mean square) of Leaf area index (LAI) at different DAT

Source of variation	Degrees of freedom	Leaf area index (LAI)		
		30 DAT	60 DAT	90 DAT
Replication	2	0.274	0.239	7.238
Variety (A)	2	11.356*	207.136*	571.676*
Nitrogen (B)	3	13.758*	16.141**	167.304**
A×B	6	0.104**	0.001*	8.145**
Error	22	0.037	0.283	5.825

* and ** indicate significant at 5% and 1% level of probability, respectively

Appendix VII. Analysis of variance (mean square) of Crop growth rate at different DAT

Source of variation	Degrees of freedom	Crop growth rate		
		30 DAT	60 DAT	90 DAT
Replication	2	1.970	41.200	149.040
Variety (A)	2	50.408*	119.856*	205.300^{NS}
Nitrogen (B)	3	9.672^{NS}	26.023*	79.191*
A×B	6	0.577*	6.475*	3.825*
Error	22	2.327	13.856	25.211

* and ** indicate significant at 5% and 1% level of probability, respectively

NS = non-significant

Appendix VIII. Analysis of variance (mean square) of yield components

Source of variation	Degrees of freedom	No. of panicles hill^{-1}	Panicle length	No. of grain panicle^{-1}	1000-grain weight
Replication	2	156.208	80.330	31.342	28.073
Variety (A)	2	62.519*	65.135*	8.090**	46.212*
Nitrogen	3	3.558**	11.910^{NS}	2.122**	25.339*
(B)	6	3.345**	2.393**		2.480*
A×B	22	20.387	48.889	673**	10.007
Error				20.423	

* and ** indicate significant at 5% and 1% level of probability, respectively

NS = non-significant

Appendix IX. Analysis of variance (mean square) of yield

Source of variation	Degrees of freedom	Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	2.765	7.313	6.516	10.002
Variety (A)	2	0.633*	145.606*	53.933*	20.601**
Nitrogen (B)	3	1.753*	12.964**	3.034*	23.761**
A×B	6	0.355*	3.995**	6.954**	11.002**
Error	22	0.365	0.310	0.585	0.002

*** and ** indicate significant at 5% and 1% level of probability, respectively**