GROWTH, YIELD AND QUALITY OF TRANSPLANTED AMAN RICE UNDER DIFFERENT NITROGEN LEVELS

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CERTIFICATE

This is to certify that the thesis entitled "**GROWTH, YIELD AND QUALITY OF TRANSPLANTED AMAN RICE UNDER DIFFERENT NITROGEN LEVELS**" 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 (MS) in AGRONOMY, embodies the results of a piece of *bona fide* research work carried out by **SWARNA SHOME**, Registration No. **12-04770** under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

____

(Prof. Dr. Parimal Kanti Biswas)

Supervisor

DEDICATED

TO

MY BELOVED PARENTS,

THE REASON OF WHAT I BECOME TODAY

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The Author

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ABSTRACT

A field experiment was conducted at the Agronomy farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during July 2017 to December 2017 in Aman season to examine the effect of different nitrogen levels on growth, yield and quality of transplanted aman rice. The experiment consisted of three nitrogen levels (*viz.* 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1}) and four varieties/lines (*viz*. SAU ADL1, BRRI dhan70, BRRI hybrid dhan6 and SAU ADL11). The experiment was laid out in split-plot design with three replications. Nitrogen levels were allocated in main plots and varieties/lines in sub-plots. Results revealed that different growth characters, yield and yield contributing characters and quality characters of transplanted aman rice were significantly influenced by nitrogen, variety and their interactions. Increasing trend was observed with the increasing level of nitrogen from 50 kg ha^{-1} to 150 kg ha^{-1} in case of all crop growth characters. The highest 1000 grains weight (27.29 g), grain yield (4.50 t ha^{-1}), straw yield (8.00 t ha^{-1}) and biological yield (12.78 t ha^{-1}) were obtained from 150 kg N ha^{-1} which were statistically at par with 100 kg N ha^{-1}. The highest harvest index (36.58%) was recorded at 100 kg N ha^{-1}. Maximum hulling percentage (78.66) and milling outturn (75.81%) were recorded from 150 kg N ha^{-1} while the highest protein content (9.60%) was obtained from 100 kg N ha^{-1}. The highest leaf area index (7.40), dry matter $hill^{-1}$ (99.85 g) and 1000 grains weight (31.49 g) were obtained from SAU ADL1 while highest grain yield (5.24 t ha^{-1}) and harvest index (45.44%) were recorded in BRRI hybrid dhan6. Highest hulling percentage (77.74), milling outturn (75.79%), protein content (9.90%), gel consistency (96.32 mm) and lowest imbibition ratio (4.10) were recorded from SAU ADL11. So considering nutritive value and quality purpose, SAU ADL11 has a great potentiality to the breeders. Interaction of 150 kg N ha^{-1} with BRRI hybrid dhan6 gave maximum value of all studied parameters but BRRI dhan70, SAU ADL1 and SAU ADL11 were more responsive to 100 kg N ha^{-1} to produce better yield and quality rice.

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AAC	Apparent Amylose Content
ADL	Agronomy Department Line
ASV	Alkali Spreading Value
AEZ	Agro-Ecological Zone
Anon.	Anonymous
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
cm	Centimeter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
et al.	And others
e.g.	*exempli gratia* (L), for example
etc.	Etcetera
FAO	Food and Agriculture Organization
g	Gram (s)
GC	Gel Consistency
GT	Gelatinization temperature
HI	Harvest Index
i.e.	*id est* (L), that is
IR	Imbibition Ratio
IRRI	International Rice Research Institute
kg	Kilogram (s)
LAI	Leaf Area Index
LSD	Least Significant Difference
m^2	Meter squares
mm	milimeter
MOT	Milling Outturn
M.S.	Master of Science
N	Nitrogen
NGO	Non Governmental Organization
No.	Number
SAU	Sher-e-Bangla Agricultural University
SPAD	Soil Plant Analytical Development
TDM	Total dry matter
var.	Variety
viz.	Videlicet (namely)
t ha^{-1}	Ton per hectare
°C	Degree Centigrade
%	Percentage

CHAPTER 1

INTRODUCTION

“Rice is staple food for more than half of the world’s population. Worldwide, rice is grown on 161 million hectares, with the production of about 713.8 million tonnes with an average productivity of 4.44 tonnes/ha (IRRI, 2014). About 90% of the world’s rice is grown (143 million ha of area with a production of 612 million tonnes of paddy) in Asia (IRRI, 2014). Among the rice growing country, Bangladesh occupies third position in rice area and fourth position in rice production (BRRI, 2017). It plays a vital role in Bangladesh economy providing significant contribution to the Gross Domestic Product (GDP), employment generation and food availability. Rice is widely cultivated cereal crop in Bangladesh. BBS (2013) reported that rice provides about 48% of rural employment, two-third of total calorie and one-half of the total protein ingestion of an average person in the country. Nearly 75% of the total cropped area and above 80% of the total irrigated area is occupied by rice (Imrul *et al.*, 2016). Therefore, it plays a key role in the livelihood of the people of Bangladesh.

But the average yield is relatively low compared to top rice producing countries. The average yield of rice is about 4.5 t ha^{-1} in Bangladesh whereas it is about 6-6.5 t ha^{-1} in Japan, Korea, China (BRRI, 2017). Bangladesh occupies an area of about 11.45 million hectares for rice production and produces 34.5 m MT rice (Baral, 2016). But it is not sufficient to meet the food demand of increasing population. So increasing rice production in a sustainable manner is vital for ensuring food security for the increasing population in Bangladesh.

In fact, ‘Rice security’ is synonymous to ‘Food security’ in Bangladesh as in many other rice growing countries (Brolley, 2015). Rice security is not just an economic issue but also an important parameter for determining social and political stability (Nath, 2015).

But the rate of increase in rice yield is static and if it is not possible to increase the yield of rice furthermore, severe food shortage is likely to occur in near future (Haque and Haque, 2016). So to reach the goal, it is necessary either to increase the crop area or to increase yield per unit area. But due to high population pressure, horizontal expansion of land is not possible. Therefore, increasing yield per unit area is the only means.

Variety itself is a genetic factor which contributes a lot in yield and yield components of a particular crop (Mahmud *et al.,* 2013). Variety is the key component to produce higher yield of rice and any other crop depending upon their differences in genotypic characters, input requirements and response, growth process within the prevailing environmental conditions during the growing season (Alen *et al.*, 2012). Varieties have significant influence on feed and grain yield, protein content, number of spike, 1000 grain weight (Alireza, 2015). In the year 2015, among aman rice varieties high yielding modern varieties covered 73.08% and de-husked yield was 2.69 t ha^{-1} and local varieties covered 20.99% and de-husked yield was 1.65 t ha^{-1} (BBS, 2015). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years but rice production area is decreasing day by day due to high population pressure. This is a big challenge for Bangladesh. Considering the vast potential of aman rice in Bangladesh, it is imperative that rice scientists to develop suitable aman rice varieties with high nutrient content. Bangladesh is a riverine country with plentiful water resources with hot and humid monsoon climate. Monsoon rain occurs normally between the months of June to September. The condition of Bangladesh is blissful for growing aman paddy. All types of land excepting low lands are brought under aman cultivation where planting of seedlings is possible. It is eco friendly cultivation as it is purely a tropical monsoon rain dependent crop and helps to reduce ground water depletion as it’s not depended on irrigation only or less irrigation. Considering above challenges and advantages, rice scientists should focus on aman season and select right variety which will fill up the upcoming demand. In Bangladesh, more than four thousand landraces of rice are adopted in different parts of this country (Hossain *et al*., 2008). Some of these are unique for quality traits including fineness, aroma, taste and protein content (Kaul *et al.,* 1982). But most high quality cultivars are low yielding (Shakeel *et al*., 2005).

Farmers have gradually replaced the local indigenous low yielding rice varieties by high yielding modern varieties only because of getting 20% to 30% more yield per unit land area (Shahjahan, 2007). Use of high yielding varieties and hybrid varieties in Bangladesh has been increased remarkably in recent years and the country has almost reached a level of self sufficiency in rice production (Murshida *et al.,* 2017). Since Bangladesh is sufficient in rice production at present time, it is high time to focus on good rice grain quality and nutrition related research activities specially for aman rice breeding programmers in Bangladesh to reveal its aptitude to combat with malnutrition.

Nitrogen (N) is one of the most important nutrients to determine rice yields (Harrel *et al*., 2011). Nitrogen is applied to meet the needs of the crop during the early growth stages and accumulate in the vegetative part to be utilized for grain formation (Salem *et al*., 2005). Rice yield may be increased by 70-80 percent through proper utilization of nitrogen fertilizer (IFC, 1982). Earlier studies reveal that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Place *et al.,* 1970). It has positive influence on tillers development, yield and yield components of rice (Djaman *et al.*, 2016). An adequate supply of nitrogen to the crop plants during their early growth period is very important for the initiation of leaves and florets primordia (Tisdale and Nelson, 1984). Nitrogen is integral part of structural and functional protein, chlorophyll and nucleic acid (Tilahun, 2019).

Nitrogen (N) is typically the nutrient that most often limits rice yields and hence the nutrient needed in largest quantity among the fertilizer. The fertilizer N recovery efficiency has been found to be around 30%-40% in rice with the current practices (Pathak *et al*., 2003). The main reason of low nitrogen use efficiency is inefficient splitting of N application, including the use of N in excess to the requirement (Shukla *et al.*, 2006). Usually farmers use higher rate of N fertilizer than the recommended dose assuming that increasing N would result in increasing yields (Fan *et al*., 2012) that can negatively affect the sustainability of the production system and increase the production cost. Use of N fertilizer at higher dose makes plants vulnerable to lodging and attractive to insect, pests and diseases (Kumar, 2016). Increased rates of fertilizer nitrogen, may increase the yield but reduce the quality of the grain (Conry, 1995). Nitrogen fertilizer is costly input and its utilization varies from variety to variety. A suitable combination of variety and rate of nitrogen is necessary for better yield (BRRI, 1990).

Although, a number of experiments were done on the effects of nitrogen on the yield and yield components of rice but comparative study on the performance of rice genotypes with modern inbred and hybrid varieties for different levels of nitrogen is very few in

Bangladesh. Keeping above facts in view, the present investigation was planned with the following objectives:

1. To explore the potentiality of rice genotypes concerning various growth, yield and quality contributing characters.
2. To compare the performance of promising rice genotypes with modern inbred and hybrid varieties.
3. To know the response of rice genotypes to different levels of nitrogen compared with modern inbred and hybrid varieties.
4. To find out better combination of nitrogen and rice genotypes to increase the growth, yield and quality of rice.

CHAPTER 2

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the pertinent literature on the impact of different nitrogen levels on growth, yield attributes, yield and quality of transplanted aman rice, which is the related matter of present investigation.

2.1 Effect of nitrogen

A field experiment was carried out at BAU, Mymensingh during Aman season to investigate the effect of nitrogen fertilizer on growth, yield of transplanted Aman rice cv. BRRI dhan46 (Adhikari *et al.*, 2018) comprising of four fertilizer treatments *viz.* 0 kg N ha^{-1}, 40 kg N ha^{-1}, 80 kg N ha^{-1} and 120 kg N ha^{-1}. The results revealed that 80 kg N ha^{-1} produced the tallest plant (113.00 cm), highest number of total tillers $hill^{-1}$ (8.74) and highest number of effective tillers $hill^{-1}$ (6.19). These findings corroborated with those reported by Uddin *et al*. (2013), Singh *et al*. (2000) and Salahuddin *et al*. (2009).

Gewaily *et al.* (2018) reported that plant height, number of days to complete heading increased with the increase in nitrogen fertilizer rate up to 220 kg N ha^{-1}.

Saha *et al*. (2017) reported that most of the cultivars reached the highest yields when N was applied at 150-225 kg ha^{-1}. As the N rate increased up to 225 kg ha^{-1}, 1000-grains weight and seed set rate decreased, whereas the number of grains $panicle^{-1}$ and number of effective panicles increased.

Gholizadeh *et al.* (2017) illustrated that there was a better relationship between rice leaf N content as well as yield with SPAD readings at the panicle formation stage and SPAD values were positively and significantly correlated with rice grain yield.

Haque and Haque (2016) conducted an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur with rice var. BU dhan1 and six nitrogen levels and reported that maximum number of tillers hill^{-1} (14.4) and maximum value of LAI (4.17), highest dry matter production (1138.40 g m^{-2}) was obtained when fertilized with 100 kg N ha^{-1}.

A research was conducted by Gharieb *et al.* (2016) to study the influence of organic and inorganic sources of nutrients as well as antioxidant on rice quality. The experiment was designed in split-split plots with four replications, where main plots were assigned to nitrogen (0, 55, 110 and 165 kg N ha^{-1}). The result indicated that the percentage of hulling, milling and amylose were positively and significantly influenced by nitrogen. The highest values of hulling and milling percentage and amylose content were observed at 165 kg N ha^{-1} followed by 110 kg N ha^{-1}.

Haque *et al.* (2015) executed an experiment at BAU, Mymensingh to evaluate the effect of nitrogen level on yield and yield attributes of transplanted Aman rice with five nitrogen levels *viz.* 0, 40, 80, 100 and 140 kg N ha^{-1} as treatment and BRRI dhan52 as planting material. Results revealed that plant height, total tiller number, effective tiller number, panicle length, grain yield and straw yield increased with increasing nitrogen doses up to 100 kg ha^{-1} followed by a decline. But 1000 grains weight increased with the increment of nitrogen. Similar result was found from the findings of Lawal and Lawal (2002).

A field experiment was executed by Moro *et al.* (2015) to investigate the effect of nitrogen rates on growth and yield of three rice varieties. A randomized complete block design arranged in a split plot consisting of five levels of nitrogen as main treatments and three improved rice varieties as sub-treatments was adopted. Results showed that total number of tillers m^{-2} increased significantly with increasing levels of N as was total dry matter production. However, total number of panicles did not show the same relationship. Total biomass yield increased significantly and linearly with increasing levels of N. Paddy yield significantly increased from 1.7 t ha^{-1} (control) to a maximum of 9.4 t ha^{-1} (90 kg N ha^{-1}) before declining to 5.8 t ha^{-1} (150 kg N ha^{-1}).

Buri *et al*. (2015) reported that total number of tillers m^{-2} significantly increased by 103% over the control for 150 kg N ha^{-1}. Total biomass increased with increasing levels of N up to 150 kg N ha^{-1}, but N greater than 90 kg ha^{-1}, more tillers tended to be unproductive resulting in lower paddy yield. Grain yield also increased with increasing levels of N from 1.7 t ha^{-1} (0 kg N ha^{-1}) to a maximum of 9.4 t ha^{-1} (90 kg N ha^{-1}) and thereafter declined, indicating that higher levels of N suppressed yield. This showed, after 90 kg N ha^{-1}, further N addition seemed to contribute more to vegetative growth (greater straw production) at the expense of reproductive growth (grain production).

Murthy *et al.* (2015) conducted a field experiment on rice to revise the existing fertilizer doses of major nutrients for rabi rice. Results revealed that number of tillers m^{-2}, panicles m^{-2} and dry matter production ha^{-1} was conspicuously augmented by increasing N level from 120 to 180 kg ha^{-1} (50% increase) and further increase did not resulted in significant change. Grain yield was increased by 11.5% and 6.3% due to increase in recommended dose of N from 100% (120 kg ha^{-1}) to 125% and 150%. Grain quality and milling characters were significantly influenced by incremental doses of N. The highest hulling percentage (83.6), milling percentage (78) and % head rice recovery (63.7) was obtained from 120 kg N ha^{-1}. Protein content became maximum (8.94%) at 210 kg N ha^{-1}.

Sandhu *et al.* (2015) observed a positive relationships for milling quality characteristics such as brown rice, total milled rice and head rice percentage with increase in nitrogen fertilizer. Grain protein content also showed a positive relationship. A negative relationship was seen for cooking quality characteristics such as amylose content.

A field experiment was carried out to evaluate the effect of nitrogen level on growth and yield of T. Aman rice cv. Surjomoni (Siddique *et al.*, 2014) with five nitrogen levels (0, 45, 90, 135 and 180 kg N ha^{-1}). They observed that the highest number of panicles $hill^{-1}$ (6.53), panicle length (28.65 cm), grains $panicle^{-1}$ (128.25), grain yield (5.77 t ha^{-1}), straw yield (8.80 t ha^{-1}) and harvest index (39.60%) were obtained with 90 kg N ha^{-1} and the maximum plant height (124.66 cm), tillers $hill^{-1}$ (8.88) and sterile spikelets $panicle^{-1}$ (39.83) were obtained with 180 kg N ha^{-1}. They opined that nitrogen level significantly influenced yield contributing characters and yield except 1000-grains weight.

Yang *et al.* (2014) reported that SPAD values generally increased to a maximum and then gradually decreased in N application plots (75-375 kg N ha^{-1}) during the growing season. Similar seasonal changes in SPAD values have been reported previously in rice (Jiang *et al.,* 2012) and found the highest SPAD value at 225 kg N ha^{-1}.

Reddy *et al.* (2013) studied the effect of 120, 150 and 180 kg ha^{-1} N level on the plant growth (plant height and tiller number), yield attributes (panicle number and length, unproductive tillers, filled grains $panicle^{-1}$, chaffy grains $panicle^{-1}$ and 1000-grains weight), yield, water use efficiency, net returns and N uptake of aerobic rice and application of 150 kg N ha^{-1} was found sufficient for realizing good yields.

Rehman *et al*. (2013) conducted an experiment at Faisalabad, Pakistan and concluded that total dry matter and crop growth rate increased with the application of nitrogen in two splits as 50% at sowing + 50% at anthesis.

Devi *et al*. (2012) conducted an experiment in dry condition and revealed that the grain yield of rice under 150 kg N ha^{-1} was increase as 175 kg N ha^{-1} and superior over 120 kg N ha^{-1}.

Gupta *et al.* (2011) conducted field experiments during 2006-08 to study the response of different nitrogen levels (0, 60, 90, 120, 150 and 180 kg N ha^{-1}). The results revealed that grain yield was maximum up to 120 kg N ha^{-1} which was at par with 150 kg N ha^{-1} and significantly superior over other nitrogen levels.

Naser *et al*. (2011) showed that grain yield, grain $panicle^{-1}$, 1000 grains weight, straw yield, HI and number of bearer tillers (m^{-2}) were increased with increasing N level up to 120 kg ha^{-1}.

Algesan and Rajababu (2011) conducted a field experiment and documented that grain yield of rice and its yield attributing characters *viz.* number of effective tillers m^{-2}, filled grains $panicle^{-1}$ and 1000-grains weight were increased with the application of nitrogen up to 120 kg N ha^{-1}. The study of Murthy *et al.* (2012) also indicated that increasing level of nitrogen progressively increased panicles m^{-2}, filled grains $panicle^{-1}$ grain and straw yield up to 120 kg N ha^{-1}.

Mahajan *et al*. (2011) studied and documented that application of 150 kg N ha^{-1} produced significantly higher yield than that of 120 kg N ha^{-1}.

Baba *et al.* (2010) conducted an experiment with rice (var IR-8) and concluded that growth characters *viz*. plant height, tillers m^{-2} and dry matter production responded significantly to the N levels up to 120 kg ha^{-1} in dry condition.

Singh and Sikka (2010) conducted a field experiment during kharif 2003 to evaluate the effect of date of transplanting, plant population and nitrogen level on fertility status and nitrogen uptake in basmati rice. Nitrogen uptake in different plant parts was not significantly influenced by date of transplanting. The plant population showed a significant and progressive increase in nitrogen uptake with increase in plant population only at the maximum tillering stage, where plant population of 44 hills m^{-2} showed maximum N uptake (27.1 kg ha^{-1}), followed by 33 hills m^{-2} (22.0 kg ha^{-1}) and 25 hills m^{-2} (18.1 kg ha^{-1}). Similarly, a progressive increase in nitrogen uptake was observed with each incremental level of nitrogen at all the growth stages.

Prabhakar *et al.* (2010) conducted an experiment and reported that the application of 160 kg N ha^{-1} was found superior over the other nitrogen levels for yield attributes and grain yield of rice under dry condition.

Choudhary and Pandey (2009) conducted an experiment and concluded that increasing level of N up to 120 kg ha^{-1} increased the growth components like plant height, tillers m^{-2} and dry matter production. Increase in plant height at 120 kg N ha^{-1} was also reported by Singh and Sikka (2010).

Sathiya and Ramesh (2009) carried out a field experiment with direct seeding in dry condition. The results showed that nitrogen management at LCC value of 4 (150 kg N ha^{-1}) produced significantly higher tillers (369.3 m^{-2}) at maximum tillering stage and plant height (81.7 cm) at maturity, grain yield (2915 kg ha^{-1}), straw yield (4956 kg ha^{-1}) and harvest index (37%) than LCC value of 3 (90 kg N ha^{-1}).

Sathiya *et al.* (2008) conducted an experiment to optimize the level and split doses of nitrogen (N) for aerobic rice cultivation. The treatments consisted of five N levels (100, 125, 150, 175 and 200 kg ha^{-1}) in the main plots and three split doses of N (1/4+1/4+1/4+1/4,1/6+1/3+1/3+1/6 and 1/5+1/5+2/5+1/5) on subplots. N was applied at 15 days after sowing (DAS), tillering, panicle initiation and flowering stages. The application of 175 kg N ha^{-1} recorded significantly higher growth attributes, yield attributes and grain yield (4876 kg ha^{-1}) over 100 and 125 kg N ha^{-1}.

Islam *et al.* (2008) reported that imbibition ratio was significantly affected by nitrogen rate and observed that highest imbibition ratio (6.93) was obtained at 100 kg N ha^{-1} in kalijira compared to other nitrogen levels (0, 50 and 150 kg N ha^{-1}).

Xiong *et al.* (2008) conducted a pot experiment to study the effects of nitrogen on caryopsis development and grain quality of rice variety Yangdao 6. They observed that the increased nitrogen fertilizer (urea), especially applied during the booting stage, could evidently increase the milled rice rate, head rice rate and protein content in rice grain compared with control (no nitrogen application) and decrease chalky grain rate and amylose content.

Pandey *et al.* (2007) reported that the increase in the level from 150 to 200 kg N ha^{-1} caused significant improvement in the yield attributes like number of panicle m^{-2}, grains panicle^{-1}, test weight as well as grain and straw yield of rice.

Hao *et al.* (2007) reported that grain protein content increased with nitrogen input fertilizer application. They reported that grain protein content at three levels of nitrogen (80, 160 and 320 kg ha^{-1}) increased 0.23, 0.63 and 1.17% over the control, respectively.

Manjoor *et al.* (2006) studied and stated that the number of productive tillers hill^{-1}, grains panicle^{-1}, 1000-grain weight, panicle length and paddy yield increased from 0 kg N ha^{-1} up to 175 kg N ha^{-1}. Reddy *et al*. (2011) also noted that grain yield of rice increased with the increasing level of nitrogen from 0 to 150 kg N ha^{-1}.

Dwivedi *et al*. (2006) conducted an experiment with five levels of nitrogen (0, 50, 100, 150 and 200 kg N ha^{-1}) on hybrid rice and revealed that growth characters *viz.* plant height, tillers m^{-2} and dry matter accumulation increased significantly with increasing level of nitrogen up to 150 kg N ha^{-1}.

Mhaskar *et al*. (2005a) observed that number of tillers $hill^{-1}$ and dry matter production increased significantly with the successive application of nitrogen from 40 to 120 kg N ha^{-1}.

Budhar (2005) conducted a field experiment on sandy loam soil at Regional Research Station, Paiyur (TNAU) to decide the LCC critical value in direct seeded puddled rice and concluded that plant height, tillers m^{-2}, dry matter production and crop growth rate was significantly maximum at LCC-4 (135 kg N ha^{-1}) which was at par with LCC-5 (165 kg N ha^{-1}).

Red-liang *et al.* (2005) investigated the effect of nitrogen fertilizer quantity on different rice variety quality. In this study they observed that with increasing nitrogen fertilizer reasonably, the milling and nutrititive quality was improved and gel consistency was increased but appearance and edibility quality was decreased.

Pal *et al.* (2005) reported that the grain and straw yields of rice increased significantly with the increase in the doses of fertilizer nitrogen. However, the higher grain and straw yields (4.39 and 6.70 t ha^{-1} in 1999, and 4.41 and 6.78 t ha^{-1} in 2000) respectively were recorded with the application of 140 kg N ha^{-1}.

Singh *et al.* (2005) reported that the grain yield increased significantly with the increasing levels of N up to 90 kg ha^{-1}. Increase in mean grain yield under 30, 60 and 90 kg N ha^{-1} over the control was 24.9, 53.1 and 56.0 percent, respectively.

Luikhan *et al.* (2004) showed that among the nitrogen management practices significant higher grain and straw yields were observed with recommended dose of 150 kg N ha^{-1} applied in 4 splits along with green manure. Similar trend was recorded for the number of panicles, spiketets and filled grains $panicle^{-1}$.

Lal and Sumon (2004) revealed that the application of nitrogen up to 120 kg ha^{-1} significantly increased the grain yield, panicle m^{-2}, grains $panicle^{-1}$ and test weight. Thus yield parameters were increased due to application of higher doses of nitrogen, however, non-significant differences were observed for plant height and number of tillers $plant^{-1}$ at all the doses of nitrogen application (30, 60, 90 and 120 kg ha^{-1}).

El-Batal *et al.* (2004) recorded that nitrogen application increase from 120 to 190 kg N ha^{-1} improved plant height, panicle length, number of filled grains $panicle^{-1}$ and grain yields significantly.

Gunri *et al.* (2004) reported that each unit increase in N level led to significant increase in yield attributing characters and yield of rice. The maximum grain yield was recorded with the highest level of N. The nitrogen use efficiency and apparent nitrogen recovery in percentage were significantly higher at the lower level of N and decreased significantly with the increasing N levels.

Shivay and Singh (2003) studied with different nitrogen levels (0, 75, 150 and 225 kg N ha^{-1}) and concluded that application of 225 kg N ha^{-1} recorded significantly higher panicles m^{-2}, filled grains $panicles^{-1}$, panicle length, grain yield and straw yield.

Raza *et al.* (2003) claimed that number of grains $panicle^{-1}$ and panicle length were significantly higher in N applied in two splits i.e. ½ at tillering and 1/2 at panicle initiation.

Suganthi *et al.* (2003) reported that highest plant height, productive tillers $hill^{-1}$ and dry matter production was recorded at 200 kg N ha^{-1} but it was comparable with 150 kg N ha^{-1}.

Hussain *et al.* (2002) concluded from the present study that N management practice based on SPAD-N measurement with chlorophyll meter at 14 days interval and at the critical growth stages of active tillering, panicle and 10 days after PI would save 45%-60 % of N as compared to blanket recommendations of N.

Meena *et al.* (2002) found that there was a significant increase in grain and straw yield of rice with each successive increase in the level of nitrogen. The highest grain yield of rough rice pooled over 2 years was recorded with 120 kg N ha^{-1}, it was 21.6 % higher over the yield obtained from the control treatment.

Somasundaram *et al.* (2002) reported on the basis of two year experiment on sandy clay loam soil of Tiruchirappalli that significant increase in plant height and dry matter production was observed with successive increase in N levels from 0 to 150 kg ha^{-1}. Additional application of N from 100 to 150 kg ha^{-1} did not show significant improvement in plant height and dry matter production.

Devasenamma *et al.* (2001) reported that tillers m^{-2}, dry matter accumulation, panicles m^{-1}, grains $panicles^{-1}$, 1000-grains weight, panicle length, panicle weight, grain yield and straw yield were increased with increasing level of nitrogen (0, 60, 120 and 180 kg N ha^{-1}). The highest value was obtained with 180 kg N ha^{-1} which was significantly superior to other nitrogen levels.

Maity and Mishra (2001) reported significant improvement in panicles m^{-2}, grains $panicle^{-1}$ and 1000-grains weight with three levels of N (80, 160 and 240 kg N ha^{-1}) but 160 and 240 kg N ha^{-1} were comparable among themselves.

Pandey *et al.* (2001) recorded significant increase in dry matter accumulation, crop growth rate with 150 kg N ha^{-1} up to 90 DAS.

Geetadevi *et al*. (2000) conducted the field trial with different levels of N (0, 50, 100, 150, 200, 250 kg ha^{-1}) in transplanted rice and revealed that highest plant height, productive tillers $hill^{-1}$ and dry matter production was obtained with 150 kg N ha^{-1}.

Ahmed *et al.* (2000) reported significant increase in number of panicles m^{-2} with increasing nitrogen level up to 160 kg N ha^{-1} than other levels (40, 80, 120 and 160 kg N ha^{-1}).

Chander and Pandey (2001) showed that nitrogen at 120 kg ha^{-1} markedly increased the grain as well as straw yields as compared to 60 kg N ha^{-1}. This can be ascribed to improvement in the plant growth, tillers m^{-2} and grains $panicle^{-1}$ at the higher level of nitrogen supply and the uptake of nitrogen per hectare.

Jaiswal and Singh (2001) observed that increasing the level of N improved the yield and yield attributes. Maximum values of yield attributes and grain yield were recorded with the highest level of nitrogen (120 kg ha^{-1}). The grain yield increased by 29.7 and 23.7% with 120 kg N ha^{-1} over 60 kg N ha^{-1} in 1996 and 1997, respectively.

Ebaid and Ghanem (2001) reported that increasing nitrogen levels up to 120 kg N ha^{-1} significantly increased leaf area, yield component and grain yield. Rice growth characteristics namely, tillers m^{-2}, leaf area index, dry matter content, grain yield and its components (i.e., number of panicles m^{-2}, number of grains $panicle^{-1}$, percentage filled grain and 1000 grains weight) were significantly increased when rice was fertilized with 144 kg N ha^{-1}.

Dar *et al.* (2000) observed that the application of 120 kg ha^{-1} nitrogen significantly increased the grain yield by 97% through significant increase in growth and yield attributes of rice than control. Increase in N level up to 120 kg ha^{-1} significantly improved grain yield over 30, 60 and 90 kg N ha^{-1} with a magnitude of superiority of 53, 20 and 13 percent, respectively.

Sharief *et al*. (2000) reported that nitrogen content in grain and straw in direct seeded wet rice were increased with increase in nitrogen level up to 150 kg N ha^{-1} but nitrogen uptake increased significantly only up to 120 kg N ha^{-1}.

Rammohan *et al.* (2000) conducted an experiment to determine the influence of N-levels on the growth and yield of rice in the soils of Karaikal and revealed that the application of 150 kg N ha^{-1} resulted in higher number of productive tillers $hill^{-1}$, number of grains $panicle^{-1}$ and test weight, respectively.

Rajarathinam and Balasabramaniyan (1999) indicated that yield parameters (panicles m^{-2}, panicle weight and length, grains $panicle^{-1}$, filled grains $panicle^{-1}$, 1000-grains weight), grain yield and harvest index were maximum with 200 kg N ha^{-1}.

Kapre *et al.* (1996) conducted experiment on rice cv. Kranti and reported that number of panicles $hill^{-1}$, grains $panicle^{-1}$ and test weight increased significantly with increasing levels of nitrogen up to 150 kg ha^{-1}.

Pandey and Tripathi (1994) reported significantly higher grain yield of rice at higher level of nitrogen up to 120 kg ha^{-1} than that at lower levels, the significant increase in number of panicles m^{-2} and panicle weight contributed to increase in grain yield of rice.

2.2. Effect of variety

Vikram *et al.* (2018) carried out a study for comparative grain quality evaluation of rice varieties. Results revealed that hulling percentage varied from 69.53 to 80.27. Hulling percentage was recorded maximum in MEPH 113 (80.27) followed by Ankur 7042 and minimum was recorded in IR 64 (69.53). The milling percentage ranged from 61.65 to 73.07. Maximum milling percentage was recorded in Pusa RH 42 (73.07) followed by MEPH 113 and minimum was recorded in NDR 2064.

Islam and Salam (2017) conducted an experiment with three varieties and concluded that plant height of the rice cultivars varied significantly due to the differentiation in their genetic characters and also the variation in adaptability with field condition of the locality. The highest grain yield was obtained from BRRI dhan56 and maximum number of total tillers $hill^{-1}$ was obtained from Binadhan-7.

A field trial was executed by Howlader *et al.* (2017) to evaluate among the local T. Aman rice genotypes for obtaining the most productive genotype regarding growth and yield performance under southern region. Four local T. Aman rice genotypes namely Lalchicon, Lalmota, Moulata and Mothamota were used as planting materials The genotype Moulata produced the tallest plant (155.0 cm), highest number of total tillers $hill^{-1}$ (11.80), LAI (2.133) and TDM (16.80 g $hill^{-1}$) at vegetative stage (60 DAT). Similarly, number of maximum effective and minimum non-effective tillers $hill^{-1}$ (10.80 and 1.333), total and filled grains panicle^{-1} (128.50 and 115.80), minimum unfilled grains panicle^{-1} (12.67), thousand grains weight (25.35 g), grain, straw and biological yield (3.657, 6.000 and 9.657 t ha^{-1}, respectively) and HI (37.86%) also higher in Moulata at harvest.

An experiment was executed by Murshida *et al.* (2017) to examine the effect of variety on the growth and yield performance of rice. The experiment consisted of three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14). The highest plant height (90.27 cm), number of total tillers hill^{-1} (7.24), dry matter of shoot hill^{-1} (26.38 g) and dry matter of root hill^{-1} (11.00 g), number of effective tillers hill^{-1} (5.62), panicle length (20.16 cm), number of grains panicle^{-1} (95.03), 1000 grains weight (20.74 g) were found in BRRI dhan29. Variable effect of variety on plant height was also reported by Om *et al.* (1998) and Krisna (2002). Variable effect of variety on number of total tillers hill^{-1} was also reported by BINA (1988) and Nuruzzaman *et al*. (2000) who noticed that number of total tillers hill^{-1} differed among varieties.

Hosen *et al.* (2017) carried out a study to evaluate physicochemical characteristics of rice grains of local traditional and high yielding Aman varieties. A total of 26 rice aman cultivars including 13 local cultivars and 13 high yielding varieties were studied for physicochemical properties. Data revealed that the highest milling outturn 72.5% was found in the BRRI dhan57 and lowest in local variety Sakor (67.4%). The highest milled rice length (6.5 mm) was found in BRRI dhan42 and the highest L/B ratio (3.7) was found in BRRI dhan57 and the lowest was in Sakor (1.9). AAC of these cultivars ranged from 21% (BRRI dhan53) to 28.1 (Subulkua). All the varieties contained more than 7.0% protein content. The highest protein content found in traditional variety Betu (9.1%) and the lowest in HYV BRRI dhan51 and BRRI dhan54 (7%). Maximum cooking time (22.5 min) required for BRRI dhan33 and lowest in Jabsiri (12.5 min). Elongation ratio (ER) of grain of local and modern aman rice varieties varied between 1.2 to 1.6. The highest elongation ratio was found in BRRI dhan51 (1.6). Imbibition ratio (IR) of grain of local and modern Aman rice varieties varied between BRRI dhan57 (2.4) to Subulkua (4.6).

Matin *et al.* (2017) laid out an experiment to study the chemical and cooking quality of nineteen BRRI released high yielding varieties. They reported that amylose content of the varieties range from 19% to 27% and BRRI dhan47 had the highest amylose content (27%) and BRRI dhan56 contained highest protein (9.3%). Alkali spreading value ranged from 3.0 to 7.0 among the tested varieties and imbibition ratio was greater than 3.0 in all the varieties except BRRI dhan43 and BRRI dhan61. They also opined that cooking time was significantly and negatively correlated with alkali spreading value.

Different growth and yield contributing parameters of five modern varieties of rice were compared with two local aman rice cultivars by Chowhan *et al.* (2017). Modern varieties showed superiority in most of the characters over local cultivars. Results revealed that the highest plant height (131 cm), days to maturity (145) and longest panicle length (25.49 cm) were found with Binadhan-13; earliest flowering and days to maturity (72 days and 100 days) were recorded in Binadhan-16, total number of tillers hill^{-1} (19.80) and thousand seeds weight (26.03 g) were also found to be maximum by Binadhan-16; Binnidhan cultivar produced the highest biological yield (24.14 t ha^{-1}). In terms of grain yield, highest was obtained from BRRI dhan71 (6.03 t ha^{-1}) followed by Binadhan-17 (5.05 t ha^{-1}); the lowest was recorded in Binadhan-13 (2.77 t ha^{-1}).

A total of eight BRRI inbred high yielding rice varieties (HYVs) were subjected to evaluate both physicochemical and biochemical characterization (Shozib *et al*., 2017). BRRI dhan62 showed the highest MOT (73%) among the tested HYVs. BRRI dhan28 and BRRI dhan62 had the highest and the lowest AAC (28% and 19%, respectively). BRRI dhan28 had the highest IR (4.3). BRRI dhan49 and BRRI dhan47 had the highest and lowest protein content (8.7% and 6.6%, respectively) among tested HYVs.

The performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan2 in Aman season was investigated with inbred BRRI dhan33 as check variety (Sarker *et al*., 2016). The result revealed that the hybrid varieties exhibited superiority in respect of growth characters such as tillers hill^{-1}, leaves hill^{-1}, total dry matter (TDM) hill^{-1}, leaf area hill^{-1}, leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) over the inbred. The highest TDM hill^{-1} (84.0 g), maximum leaf area hill^{-1} (1787 cm^2), average highest CGR (40.63 g m^{-2} d^{-1}) were observed in Tia and lowest TDM hill^{-1} (70.10 g), minimum leaf area hill^{-1} (1198 cm^{2}), average lowest CGR and RGR (27.26 g m^{-2} d^{-1} and 13.35 mg g^{-1} d^{-1}) were observed in BRRI dhan33. Hybrid varieties produced 24% higher yield over the inbred BRRI dhan33.

Jewel *et al*. (2016) conducted a field experiment at BAU, Mymensingh using four rice varieties namely BRRI dhan28, Hera hybrid2, Binadhan-14 and BRRI dhan58 for investigating the effect of variety on yield performance of modern rice varieties. BRRI dhan58 was found superior to Hera hybrid2, Binadhan-14 and BRRI dhan28 in respect of effective tillers, grains panicle^{-1}, grain yield, biological yield and harvest index.

Paul (2016) carried out a field experiment comprising of 14 rice genotypes to investigate the growth, yield and quality of different Aman rice genotypes in Aman season. Results revealed that the highest grain yield (5.24 t ha^{-1}) was obtained from BRRI dhan66 and lowest (2.28 t ha^{-1}) from SAU ADL7. The highest hulling percentage and milling percentage was in Kataribhog. The highest protein (10.6%) was obtained from SAU ADL7 and the lowest protein (7.5%) was obtained from BRRI dhan66.

Sarker *et al*. (2014) studied the yield and quality of fine aromatic rice affected by variety using three aromatic rice varieties *viz*. BRRI dhan34, BRRI dhan37 and BRRI dhan38. Results revealed that the tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), grain yield (3.71 t ha^{-1}), straw yield (5.11 t ha^{-1}) were recorded in BRRI dhan34. Tyeb *et al*. (2013) and Islam *et al.* (2012) also found the similar results, who opined that variety had variable effect on yield and yield contributing characters of rice. The findings were also consistent with the report of Islam *et al.* (2013), who observed the variable effect of variety on the number of effective tillers hill^{-1}. The highest grain protein content (8.18%) was found in BRRI dhan34 followed by BRRI dhan38 (7.98%) and the lowest one (7.75 %) was observed in BRRI dhan37. This result was similar with Dutta *et al*. (1998) and Alam (2002) who recorded variable protein percentage among varieties.

An experiment was conducted by Islam *et al.* (2013) to evaluate the performance of local aromatic rice cultivars *viz.* Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The rice cultivars varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. The highest plant height (116.00 cm) was found in the variety Morichsail. Number of filled grains panicle^{-1} was found highest (100) with the variety Khaskani and the lowest was recorded in the variety Raniselute. Raniselute produced the highest 1000-grains weight (32.09 g) and the lowest (13.32 g) was recorded from the variety Kalijira. The variety Morichsail produced the highest grain yield (2.53 t ha^{-1}) and the lowest grain yield (1.80 t ha^{-1}) was obtained from Kalijira. The results of various characters studied in the experiments suggested that some good characters exist in local aromatic rice cultivars which can be exploited through breeding.

Mahmud *et al.* (2013) reported that rice cultivars differed significantly in all growth characters, such as plant height, tillers number, chlorophyll content, dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000- grain weight, grain yield and straw yield.

A study was conducted by Islam *et al*. (2009) during Boro and T. Aman seasons of 2002 at Bangladesh Rice Research Institute (BRRI), Gazipur to see the relationship of SPAD (Soil plant analysis development) reading with chlorophyll and N contents of leaves and to determine the critical LCC value for rice crops. Hybrid varieties Sonarbangla-1 and BRRI hybrid dhanl were used for both rice crops and BRRI dhan29 and BRRI dhan31 were used as checks for Boro and T. Aman crops, respectively. Sonarbangla-1, BRRI hybrid dhanl and BRRI dhan29 had similar leaf chlorophyll contents in Boro season. The maximum chlorophyll content (1.6-1.8 mg g^{-1} leaf) was observed at 39-42 soil plant analysis development (SPAD) value. In T. Aman season, the inbred BRRI dhan3l showed lower amount of chlorophyll (1.2-1.4 mg g^{-1} leaf) at 39-42 SPAD value compared to the hybrids Sonarbangla-1 and BRRI hybrid dhanl. The results indicated that the rice leaves showing higher SPAD readings (>35) had higher chlorophyll and nitrogen contents.

An experiment was carried out to know the physicochemical and cooking properties of fine rice varieties (Dipti *et al*., 2002). Among the varieties, milling outturn ranged from 64-70% and highest milling outturn (70%) was found in variety Superfast. Amylose content of tested varieties varied from 18.6 to 28%. Varieties had alkaline spreading value ranged from 3.0-3.9 and imbibitions ratio more than 4.

Shams (2002) opined that the yield of rice depends on its different growth parameters, i.e. leaf area index, dry matter production and its partitioning, tillering, etc.

2.3. Interaction effect of nitrogen and variety

Tilahun (2019) observed that varieties had significant influence on grain yield, protein content, number of spike and 1000 grain weight. Total dry matter and crop growth rate observed due to interaction of N rate and varieties. Low tillering varieties particularly short duration ones gave low number of panicles m^{-2} while high tillering cultivars caused competition and more shading consequently low yield. Nitrogen availability involved directly or indirectly in the enlargement and division of new cells and production of tissues which was responsible for increase in growth characteristics particularly tiller numbers, finally determining the number of panicles and spikelets. N fertilization of rice is affected by varieties, soil type and climatic fluctuations between years, mainly environmental temperature. The interaction effect of varieties and N rate significantly determined 1000 grain weight, straw yield and grain yield of rice.

An experiment was conducted by Hossain *et al.* (2018) to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment consisted of three varieties *viz.* BRRI dhan34, BRRI dhan38 and Sakkorkhora and four fertilizer treatments *viz*. 0, 30, 45, 60 kg N ha^{-1} nitrogen. The result revealed that application of nitrogen significantly influenced the yield of aromatic rice varieties. The number of effective tillers $hill^{-1}$ (12.00), 1000-grain weight (16.69 g), grain yield (3.44 t ha^{-1}), biological yield (8.05 t ha^{-1}), panicle length (29.44 cm) and harvest index (42.76%) were found highest with 45 kg N ha^{-1} but the highest plant height (152.43 cm) and straw yield (4.64 t ha^{-1}) were found from 60 kg N ha^{-1} and all the characters showed the lowest value in control. The variety BRRI dhan38 showed the best performance among the varieties. Interaction effect showed that BRRI dhan38 when fertilized with 45 kg N ha^{-1} produced maximum grain yield (3.72 t ha^{-1}) and the minimal grain yield (2.93 t ha^{-1}) was obtained from BRRI dhan34 fertilized without N.

In order to investigate the effects of nitrogen application rate on grain yield and rice quality, two *japonica* soft super rice varieties, Nanjing 9108 (NJ 9108) and Nanjing 5055 (NJ 5055), were used under seven N levels with the application rates of 0, 150, 187.5, 225, 262.5, 300, and 337.5 kg ha^{-1} (Da-wei *et al.*, 2017). They reported that with the increasing nitrogen application level, grain yield of both varieties first increased and then decreased. The highest yield (10.1 t ha^{-1}) was obtained at 300 kg ha^{-1}. The milling quality and protein content increased, while the appearance quality, amylose content, gel consistency, cooking/eating quality decreased with the increasing nitrogen application. Milling quality was significantly negatively related with the eating/cooking quality whereas the appearance was significantly positively related with cooking/eating quality. These results suggested that nitrogen level significantly affected the yield and rice quality of *japonica* soft super rice. They concluded that the suitable nitrogen application rate for *japonica* soft super rice, NJ 9108 and NJ 5055 was 270 kg ha^{-1}, under which they obtained high yield as well as superior eating/cooking quality.

Saha *et al.* (2017) carried out an investigation with the different levels of nitrogen and various cultivars to find out best rice cultivars and optimum dose of nitrogen under terai region of West Bengal. The experiment was comprised with five cultivars namely, MTU-7029, ANNADA, KHANDAGIRI, SATABDI and GS-3 and three levels of nitrogen: 30, 60 and 90 kg ha^{-1}. MTU-7029 with 90 kg N ha^{-1} produced maximum number of tillers, highest percentage of filled grain, grain yield and straw yield. In this research, it was clear that higher levels of nitrogen influenced most of the growth and yield parameters, considerably.

An experiment was carried out with a view to finding out the impact of variety and levels of nitrogen on the growth performance of transplanted Aman rice (Paul *et al*., 2016). The experiment comprised of four varieties *viz*. BRRI dhan33, BRRI dhan34, BRRI dhan39 and BRRI dhan46, and four levels of nitrogen *viz.* control (no urea), prilled urea (50 kg N ha^{-1}), one pellet (0.9 g) of USG/4 hills of two adjacent rows (30 kg N ha^{-1}) was applied at 10 days after transplanting (DAT) and two pellets of

USG (0.9 g each) one applied at 10 DAT and the another at 45 DAT/4 hills of two adjacent rows (60 kg N ha^{-1}). BRRI dhan34 fertilized with two pellets of USG (0.9 g each) one applied at 10 DAT and another at 45 DAT/4 hills of two adjacent rows (60 kg N ha^{-1}) appeared as the promising combination in respect of growth performance of HYV transplanted Aman rice.

A field trial was conducted by Hussain *et al.* (2016) to examine the effect of source and doses of nitrogen on transplanted Aman rice. Three varieties, BR11, BRRI dhan30 and BRRI dhan39 were compared at three doses of nitrogen, prilled urea @ 125 kg N ha^{-1}, USG @ 170 kg N ha^{-1} and USG @ 70 kg N ha^{-1}. Grain and straw yield were highest (4.05 and 4.69 t ha^{-1}, respectively) in BR11. The lowest grain yield (3.55 t ha^{-1}) was produced by BRRI dhan30. BRRI dhan39 produced the highest (101.04 cm) plant height. Effect of PU and USG significantly influenced all the growth and yield attributes except plant height. Grain and Straw yields were highest (4.25 and 4.83 t ha^{-1}, respectively) from the USG 70 kg N ha^{-1} (1 g/pellet). The placement of USG (70 kg N ha^{-1}) appeared as the best one in respect of partial factor productivity of nitrogen and agronomic efficiency of nitrogen (AEN).

A field experiment was conducted by Shukla *et al.* (2015) to study the performance of rice varieties in relation to nitrogen level under irrigated conditions. Twenty one treatment combinations, comprising three nitrogen levels (40, 80 and 120 kg ha^{-1}) allotted to the main plots and seven varieties (IET 21288, Jaldidhan, Varalu, IET 21296, IET 21278, Aditaya and Dantensavari) to the subplots, were tested in split-plot design with three replications. Application of 120 N kg ha^{-1} proved significantly superior to 40 kg N ha^{-1} and produced maximum grain yield (49.88 q ha^{-1}) and straw yield (93.10 q ha^{-1}) over 80 N kg ha^{-1}. Among different rice varieties, Dantensavari produced significantly higher grain yield (45.56 q ha^{-1}) and straw yield while the rest of the varieties remained differed for different traits. The treatment combination of Dantensavari with 120 N kg ha^{-1} was found to be best in producing grain yield (58.39 q ha^{-1}) followed by IET 21278 (56.78 q ha^{-1}).

Abedin *et al.* (2015) executed a field trial to evaluate the performance of tidal local aman rice as influenced by USG application at non tidal condition. Varietal response was significant on plant height, SPAD value, dry matter accumulation, grain yield when USG applied at BPI stage.

Buri *et al*. (2015) also reported that two varieties (Sikamo and Jasmine 85) interacted with 60 kg N ha^{-1} level to 150 kg N ha^{-1} gave significantly taller plants. Effect of both N and variety interaction showed that Sikamo at 120 and 150 kg N ha^{-1} gave significantly higher biomass than Sikamo or Jasmine 85 fertilized at 0 or 30 kg N ha^{-1}. There were also no significant differences in number of effective tillers produced in the variety x N rate interaction. Grain yield was significantly higher for Sikamo and Jasmine 85 fertilized at 90 kg N ha^{-1} than the other entire N x Variety interactions except Marshall at 90 kg N ha^{-1} and both Sikamo and Jasmine fertilized at 120 kg N ha^{-1}.

Chamely *et al.* (2015) conducted an experiment at BAU, Mymensingh with three varieties (BRRI dhan28, BRRI dhan29 and BRRI dhan45) and five rates of nitrogen (control, 50 kg, 100 kg, 150 kg and 200 kg N ha^{-1}). They opined that variety and nitrogen had significant effect on total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, panicle length, grain yield, straw yield and harvest index. They found that BRRI dhan29 with 200 kg N ha^{-1} produced highest grain yield (5.82 t ha^{-1}).

Jisan *et al*. (2014) conducted a field trial to examine the yield performance of some transplanted Aman rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties *viz.* BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N *viz.* 0, 46, 60 and 75 kg ha^{-1}. Variety, levels of N and their interactions exerted significant influence on yield contributing characters and yield of transplanted Aman rice. BRRI dhan52 fertilized with 75 kg N ha^{-1} produced highest number of effective tillers $hill^{-1}$ (14.03), grains $panicle^{-1}$ (171.40) and 1000-grain weight (27.39 g) grain yield (6.60 t ha^{-1}).

An experiment was carried out by Tayefe *et al.* (2014) to investigate the effect of nitrogen (N) fertilizer levels on yield and yield components of rice (Hashemi, Ali kazemi and Khazar). In this experiment, four treatments including: control (no N fertilizer); 30 kg N ha^{-1}, 60 kg N ha^{-1} and 90 kg N ha^{-1} were compared. Results showed that total biomass (8386 kg ha^{-1}), grain yield (3662 kg ha^{-1}), plant height (127.9 cm), tillers m^{-2} (250.22), panicles m^{-2} (235.8) and total grain panicle^{-1} (103.8) reached the highest value at high nitrogen level. Among the varieties, the highest total biomass (7734 kg ha^{-1}), grain yield (3414 kg ha^{-1}), unfilled percent (20.16) and total grain panicle^{-1} (78.2) belonged to Khazar. Significantly, tiller m^{-2} (250.83) and panicle m^{-2} (235.91) were obtained from Hashemi. Ali kazemi produced maximum 1000-grains weight (28.99 g). Among the different N application levels, significant difference was observed in all quality parameters except gelatinization temperature (GT); the highest amylose content (AC) was obtained from no N fertilizer treatment and significantly highest gel consistency (GC) was obtained from treatment 60 kg N ha^{-1}. In general, GC was increased with N-fertilizer application and only result was changed from 60 kg N ha^{-1} to 90 kg N ha^{-1} and was reduced. Whereas AC was reduced from no N fertilizer to 60 kg N ha^{-1}, and the result was reversed from 60 kg N ha^{-1} to 90 kg N ha^{-1}. Meanwhile, the interaction effect of variety × nitrogen fertilizer did not show significant difference between all quality parameters except of GC.

Luka *et al*. (2013) reported that significant effect on TDM (total dry matter) and CGR (crop growth rate) was observed due to N rate and varieties. NERICA 4 variety showed increases in TDM when N was applied at 65 kg ha^{-1} and further increase to 130 kg ha^{-1} produced similar results. NERICA 8 variety however produced statistically similar TDM throughout the fertilizer levels. The crop growth rate for NERICA 4 was increased with application of 65 kg N ha^{-1} but further increase to 130 kg N ha^{-1} depressed CGR, however for NERICA 8 CGR was similar throughout all the N levels.

A field trial was conducted by Abou- Khalifa (2012) to evaluate some rice varieties under different nitrogen levels with four varieties and five nitrogen levels. Main results indicated that tillering, panicle initiation, root length, heading date, grains filling rates (GFR) at five stages, leaf area index, chlorophyll content, number of tillers m^{-2}, 1000-grains weight, number of grains panicle^{-1}, panicle length (cm) and grain yield (t ha^{-1}) reached the highest value at 220 kg N ha^{-1}. Sakha 106 gave the highest value to all studied characters.

Reddy *et al.* (2011) studied rice varieties at varied N levels for their response under aerobic and transplanted situations in double split plot design with two replications. The grain yield obtained both under aerobic and transplanted condition were comparable in Naveen, MTU 1010 and Erramallelu. On the other hand, varieties IR-64, Tellahamsa, Erramallelu, Rajendra, hybrid ARB-17 (1) K-06, MTU 1010 and Erramallelu recorded higher yields under transplanted condition. The grain yield increased significantly with increase in N level from 0 to 50, 100 and 150 kg ha^{-1}.

Braham and Srivastav (2008) studied the response of new rice (*Oryza sativa* L.) varieties to nitrogen levels at Kanpur, Uttar Pradesh. Performance of NDR 359 (local check) was rated to be the best, particularly at lower and higher levels of nitrogen. Rice varieties CSAR 515-1 at 150 kg N ha^{-1} and CSAR 442 at 100 kg N ha^{-1} performed equally well.

Hossain *et al.* (2008) executed an experiment to evaluate the effect of different nitrogen levels (30, 60, 90 and 120 kg ha^{-1}) on the performance of four rice varieties (BRRI dhan38, Kalijira, badshabhog and tulsimala) during Aman season. They observed that Tulsimala with 120 kg N ha^{-1} produced tallest plant (162.9 cm), BRRI dhan38 with 120 kg N ha^{-1} produced maximum number of tillers $hill^{-1}$ (16.86) , highest grain yield (4.17 t ha^{-1}) and BRRI dhan38 with 60 kg N ha^{-1} produced highest HI (43.93%).

Sabir *et al.* (2007) reported that the rice variety ADTRHI with 150 kg N ha^{-1} produced higher number of productive tiller $plant^{-1}$, number of spikelets $panicle^{-1}$, test weight and seed yield as compared to CORH2 variety.

Ye *et al*. (2007) reported that the response of different rice cultivars to N-application was not the same. Significant genetic differences existed among genotypes for yield increase with N application, N use efficiency, N accumulation, and distribution in rice under different soil.

Lar *et al.* (2007) reported that application of nitrogen up to 150 kg ha^{-1} significantly increased the plant height, number of panicles $hill^{-1}$, panicle weight, panicle length, number of filled grains $panicle^{-1}$, test weight and fertility percent of rice, respectively.

There was a significant increase in grain, straw and biological yield of rice variety "Pusa sungandh-5" with 150 kg N ha^{-1}.

Yadav *et al.* (2002) found that the long duration varieties, i.e., Mahsuri (142 days) and Swarna (157 days) produced significantly higher dry matter than medium duration Sarjoo 52 (129 days) and mid-early (121 days) IR 36. The former and later group of varieties remained on par Swarna produced significantly higher grain yield of 5.86 t ha^{-1} which showed an increase of 1.11, 1.69 and 1.70 t ha^{-1} over Sarjoo 52, Mahsuri and IR 36, respectively. Application of 120 kg N ha^{-1} produced highest grain yield of 5.54 t ha^{-1} which was higher by 2.24, 0.70 and 0.30 t ha^{-1} over 0, 40 and 80 kg N ha^{-1}, respectively.

Tripathi and Jaiswal (2002) found that the various hybrids responded differently with nitrogen levels. HRI 120, HRI 126 and HRI 160 produced highest yields at 120 kg N ha^{-1} while HRI 122, ExPH 204, NDRH 2 and NDR 359 produced highest grain yield at 180 kg N ha^{-1}. Thus it was concluded that for obtaining higher grain yield of rice HRI 120 may be sown with 180 kg N ha^{-1}.

Chandra (2002) concluded that Pusa 615, HKR 228 and RP 2144 rice varieties were high yielder over Taraori Basmati and it was possible to achieve economic optimum grain yield using these varieties applied with 90 kg N ha^{-1}.

Ebaid and El-Hissewy (2000) indicated that increasing nitrogen fertilizer levels from 0 up to 165 kg N ha^{-1} significantly increased hulling percentage and amylose content in Sakha101 rice cultivar.

CHAPTER 3

MATERIALS AND METHODS

The present investigation entitled **“Growth, yield and quality of transplanted aman rice under different nitrogen levels”** was carried out during Aman season of 2017 (July-December/2017) at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The details of materials used, experimental procedures followed and techniques adopted during the course of investigation are being described in this chapter. Climatic and edaphic conditions prevailing during crop season, selection of site, cropping history of field and other experimental details are also being presented.

3.1. Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

Experimental field was attached to the main irrigation channel connecting to the farm water source for quick, regular and timely irrigation. Proper drainage facility was also provided in order to remove excess water during experimental period.

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of “The Madhupur Tract”, AEZ-28 (Anon., 1988). This is a region of complex relief and represents the red lateritic soil of Madhupur area. The soil of this region has clayey texture and contains large quantity of iron and aluminium. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3. Climate and weather condition

The climate is sub-tropical, characterized by high temperature, high relative humidity and heavy rainfall. It falls in the region of south-west monsoon and generally monsoon starts from mid-June and continued up to October. The mean average annual rainfall is 2730 mm out of which nearly 80-90 % is received between June to October.

The meteorological data related to the weather conditions of the experimental site prevailing during Aman season, 2017 with respect to rainfall, relative humidity and temperature obtained from Bangladesh meteorological department presented in the Appendix III & IV.

3.1.3.1. Rainfall

Monsoon shower was quite heavy during the year of experimentation. The total rainfall of 1540 mm was recorded during the cropping period. Out of which 373 mm rainfall was recorded during seedling stage, 943 mm precipitation occured between active tillering and maximum tillering stage of rice. However, 172 mm rain was recorded between panicle initiation to panicle emergence stage of crop. A little rainfall occurred between milk to maturity stage.

3.1.3.2. Temperature

Temperature is one of the major meteorological variable influencing germination, growth and development of plants in a given agro-climatic condition. The mean maximum temperature ranged between 26.4ºC to 31.4ºC and the mean minimum temperature ranged between 14.1ºC to 26.3ºC during experimental period of 2017.

3.1.3.3. Relative humidity

The relative humidity varied between 73% to 83% during the experimental period 2017. It attained the maximum level during vegetative phase. Minimum relative humidity was recorded during the maturity period of the crop.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils are clay loam in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH ranges from 5.4-5.6. The experimental area was flat having available irrigation and drainage system and above flood level.

3.1.5. Cropping history of the experimental field

The production potential of the experimental field can be judged from its cropping history. The details of the cropping history of the experiment field for preceding crops of the experimentation are given in Table 1.

Table 1. Cropping history of the experimental plot

Year	Crops		
2014-2015	Boro rice	Fallow	Aman rice
2015-2016	Boro rice	Fallow	Aman rice
2016- 2017	Boro rice	Fallow	**Aman rice**

It may be a concern that mainly only rice has been taken in the plots prior to the start of experiment.

3.2. Details of the experiments

3.2.1 Treatments

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

A. Nitrogen levels (3)

1. N_1 (50 kg N ha^{-1})
2. N_2 (100 kg N ha^{-1})
3. N_3 (150 kg N ha^{-1})

B. Variety/Line (4):

1. V_1 (SAU ADL1)
2. V_2 (BRRI dhan70)
3. V_3 (BRRI hybrid dhan6)
4. V_4 (SAU ADL11)

3.2.2 Experimental Design

The experiment was laid in a split-plot design with three replications having nitrogen in the main plots and variety/line in the sub-plots. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 3.0 m × 2.2 m. The distances between plot to plot and replication to replication were 1 m. The layout of the experiment has been shown in Appendix II.

3.3 Crop/Planting Material

Two rice varieties BRRI dhan70 and BRRI hybrid dhan6 along with two rice genotypes SAU ADL1 and SAU ADL11 were used as planting material.

3.3.1. Salient features of BRRI dhan70

BRRI dhan70, a high yielding aromatic variety of Aman season was developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh and was released in 2014. It was developed by the method of hybridization. It takes about 130 days to mature. It attains a plant height of 125 cm. The grain is very long, slender, aromatic and white. 1000-grains weight is about 20 g. The average grain yield is about 4.8 t ha^{-1}. Amylose content is 21.7%.

3.3.2. Salient features of BRRI hybrid dhan6

BRRI hybrid dhan6, a hybrid variety for Aman season was developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR1361H) of the variety was derived from a cross combination (IR79156A/BRRI20R) and was released in 2017. It takes about 110-115 days to mature. It attains a plant height of 105-110 cm. The grain is long and slender. 1000-grains weight is about 22.6 g. The average grain yield is about 6.0-6.5 t ha^{-1}. Amylose content is 24% and protein content is 9%.

3.3.3. Salient features of SAU ADL1

SAU ADL1 is a rice line of Aman season provided by an NGO named Suranjana. According to previous study by Paul (2016), it takes about 134 days to mature. It has hulling percentage (76.97) and milling degree (87.71%). The grain is coarse. 1000-grains weight is about 31.06 g. The average grain yield is about 3.5 t ha^{-1}. Its protein content is 10%.

3.3.4. Salient features of SAU ADL11

SAU ADL11 is a rice line of Aman season provided by an NGO named Suranjana. According to previous study by Paul (2016), it takes about 137 days to mature. It attains a plant height of 107 cm. It has hulling percentage (74.93) and milling degree (90.99%). The grain is medium, slender and aromatic. The average grain yield is about 3.61 t ha^{-1}. Its protein content is 10.1%.

3.4. Crop management

3.4.1. Seed collection

Seeds of a line were initially collected from an NGO named Suranjana from which two lines SAU ADL1 and SAU ADL11 were named under various field observations by the Agronomy department of Sher-e-Bangla Agricultural University. Seeds of another two varieties BRRI dhan70 and BRRI hybrid dhan6 were collected from Bangladesh Rice Research Institute, Gazipur.

3.4.2 Seed sprouting

Seeds were soaked in water in a bucket for 24 hours. Seeds were then taken out of water and kept tightly in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.4.3 Preparation of seedbed

A common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. No fertilizer was used in the nursery bed.

3.4.4. Seed sowing

Sprouted seeds were sown on the seedbed on 10^{th} July, 2017 for raising seedlings for transplanting. The sprouted seeds were sown as uniformly as possible.

3.4.5. Preparation of experimental land

The experimental field was first ploughed on 27^{th} July 2017 with the help of a tractor drawn disc plough, later on 1^{st} August, 2017 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on 3^{th} August 2017 according to experimental specification. Individual plots were cleaned and finally leveled with the help of a wooden plank so that no water pocket could remain in the puddled field.

3.4.6. Fertilizer application

The experimental field was fertilized with 80, 80 and 20 kg ha^{-1} of P_2O_5, K_2O and S applied in the form of triple super phosphate (TSP), muriate of potash (MoP) and gypsum, respectively. The entire amounts of triple super phosphate, muriate of potash and gypsum were applied as basal dose during final land preparation and mixed properly by a tractor drawn plough with soil. Urea was top-dressed in three installments, after seedling recovery, during the vegetation stage and at 7 days before panicle initiation as per requirement for treatment as 25 g urea $plot^{-1}$ for 50 kg N ha^{-1}, 50 g urea $plot^{-1}$ for 100 kg N ha^{-1} and 75 g urea $plot^{-1}$ for 150 kg N ha^{-1}.

3.4.7. Transplanting of seedlings

25 days old seedlings were uprooted from seedbed carefully on 5th August, 2017 and were kept in soft mud in shade**.** The seedbeds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted with 20 cm × 20 cm spacing on the well-puddled plots. In each plot, there were 11 rows, each row contains 15 hills of rice seedlings.

3.4.8. Intercultural operations

3.4.8.1 Gap Filling

Gap filling was done twice for maintaining uniform plant population. First gap filling was done one week after transplanting and second gap filling was done one week after first gap filling.

3.4.8.2. Weeding

The crop was infested with some weeds during the early stage of crop establishment. Three hand weedings were done to reduce crop competition with weed. First weeding was done at 15 days after transplanting followed by second weeding at 15 days after first weeding. Third weeding was done 15 days after second weeding.

3.4.8.3. Application of irrigation water

Irrigation water was added to each plot as and when necessary. All the plots were kept irrigated maintaining about 5 cm water level. Frequency of irrigation was reduced after panicle emergence and grain filling stage. The field was kept dried 7 days before harvesting.

3.4.8.4. Plant protection measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying Furadan @ 10 ml/10 liter of water for 5 decimal lands on 10th September and by Actara @ 10 ml/10 liter of water on 26th September and 12th October 2017. Crop was protected from birds and rats during the grain filling period. Rat was controlled by using field trap and poisonous bait. The field was covered by net and kept watching properly, especially during morning and afternoon to control birds.

3.5 Harvesting

The crop was harvested depending upon the maturity of plant. Harvesting was done by serrated edged sickles manually from each plot. Harvesting was started at 110 days and continued up to 138 days. Maturity of crop was determined when 80% of the grains became matured. Five pre-selected hills were harvested from each plot from which different data were collected and 3.96 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield.

3.6. Threshing

Threshing was done plot wise by pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were determined and converted to ton ha^{-1}.

3.7 Recording of data

Experimental data were determined from 20 days of growth duration and continued until harvest. The followings data were determined during the experiment.

A. Crop growth characters

i. Plant height (cm) at 20 days interval and at harvest
ii. Number of tillers $hill^{-1}$ at 20 days interval and at harvest

iii. Leaf area index at 40, 60 and 80 DAT

iv. Dry weight of plant at 50, 70, 90 DAT and at harvest

v. SPAD value at 50 and 70 DAT

B. Yield and yield contributing characters

i. Number of effective tillers hill^{-1}

ii. Number of ineffective tillers hill^{-1}

iii. Length of panicle (cm)

iv. Number of rachis branches panicle^{-1}

v. Number of filled grains panicle^{-1}

vi. Number of unfilled grains panicle^{-1}

vii. Number of total grains panicle^{-1}

viii. Weight of 1000-grains

ix. Grain yield

x. Straw yield

xi. Biological yield

xii. Harvest index

C. Grain quality characters

i. Hulling percentage

ii. Milling outturn

iii. Protein content

iv. Apparent amylose content

v. Alkali spreading value

vi. Imbibition ratio

vii. Gel consistency

3.8 Detailed procedures of recording data

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

A. Crop growth characters

i. Plant height (cm)

Five plants from each plot were randomly selected and marked for recording the plant height which were taken at 20, 40, 60, 80 DAT and at harvest. The height of five tagged rice plants in net plot area was measured from the base of the plant to the tip of the flag leaf before heading and after heading and at harvest plant height was taken up to the tip of the panicle. The plant height was expressed as average plant height in centimeter.

ii. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 20, 40, 60, 80 DAT and at harvest from five randomly pre-selected hills and was expressed as number hill^{-1}

iii. Leaf area index (LAI)

Data on leaf area index was taken at 40, 60 and 80 DAT. Leaf area index was estimated measuring the length and average breadth of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

iv. Dry weight of plant (g)

The plants of 2 hills plot^{-1} uprooted from second line were oven dried until reached to a constant weight and then the weight was measured by a digital weighing machine and finally calculated as g hill^{-1}. From which the weight of dry matter hill^{-1} was calculated at 50, 70, 90 DAT and at harvest.

v. SPAD value

Minolta Camera Company developed a portable chlorophyll meter or SPAD (Soil-Plant Analyses Development) meter which can be used to estimate chlorophyll levels in leaves. N is the key element in chlorophyll molecules that capture sunlight used in photosynthesis. Thus chlorophyll meter provides instant crop N status as SPAD value in a nondestructive manner (Minolta, 1989). The computed values by this device represents the whole content of chlorophyll (a, b) in plant, (Feibo *et al.*, 1998; Ichie *et al.*, 2002; Ramesh *et al.*, 2002). Five plants per plot were selected randomly and SPAD values at 50 and 70 DAT were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf.

B. Yield and yield contributing characters

i. Effective tillers hill^{-1}

The tiller which beared panicle, was considered as effective tiller. The number of effective tillers of 5 selected hills was recorded and finally averaged for counting the effective tillers number hill^{-1}.

ii. Ineffective tillers hill^{-1}

The tiller having no panicle was regarded as ineffective tillers. The number of ineffective tillers of 5 selected hills was recorded and finally averaged for counting the ineffective tillers number hill^{-1}.

iii. Panicle length (cm)

Ten panicles randomly selected from each plot were harvested separately. The length of panicles was measured in centimeter from basal node of the rachis to apex of each panicle and finally the average length of panicle was worked out.

iv. Rachis branches of panicle

Rachis branches of 10 panicles were recorded and then the average was determined for each plot.

vi. Filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present on 10 panicles was recorded and the average value was determined.

vii. Unfilled grains panicle^{-1}

Unfilled grain means the absence of any kernel inside in and such grain present on each of 10 panicles were counted and finally the mean was calculated.

viii. Total grains panicle^{-1}

The sum of number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}.

x. Weight of 1000-grains (g)

One thousand cleaned dried seeds were counted randomly from each sample and then oven dried up to a constant weight and then weighed by using a digital electric balance and the mean weight was expressed in gram.

xi. Grain yield (t ha^{-1})

Harvested bundles of rice plants from the central 3.96 m^2 of each plot (leaving border areas) were threshed and winnowed separately. After winnowing the grain was sun dried plot wise upto 12% moisture content and then their weight was recorded by digital electrical balance. The grain yield obtained from net plot was finally converted into t ha^{-1}.

Straw yield (t ha^{-1})

Straw yield was determined from the central 3.96 m^2 area of each plot. After separating of grains, the straw was dried in the sun to a constant weight and finally converted to t ha^{-1}.

xiii. Biological yield (t ha^{-1})

The sum of grain yield and straw yield was regarded as biological yield. Biological yield was calculated with the following formula.

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

xiv. Harvest index (%)

It denotes the ratio of economic yield (grain yield) to biological yield (grain yield+ straw yield) and was calculated with following formula (Donald, 1963; Gardner *et al.*, 1985).

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

C. Grain quality characters

i. Hulling percentage

A 100 g sample of paddy was dehulled in a laboratory huller. And the weight of dehusked kernel was recorded. Hulling percentage was computed as:

$$\text{Hulling percentage (HP)} = \frac{\text{Weight of dehusked kernel}}{\text{weight of paddy}} \times 100$$

ii. Milling outturn (%)

Milling outturn (MOT) was determined by dehulling 200 g rough rice in Satake Rice mill, followed by 45 second polishing in a satake rice grain Testing Mill TM-05.

$$\text{Milling outturn (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

iii. Protein content (%)

Standard micro Kjeldahl procedure of AOAC (1995) was used for the determination of nitrogen and crude protein was estimated by multiplying the nitrogen content by a factor 5.95. Nitrogen present in the sample was converted to ammonium sulphate by digestion at 380°C with sulphuric acid in presence of a catalyst mixture. Ammonia liberated by distilling the digest with sodium hydroxide solution is absorbed by boric acid and titrated with HCl for quantitative estimation (AOAC, 1995).

$$\text{Nitrogen (\%)} = \frac{\{(\text{mL HCl for sample - mL HCl for blank}) \times N_{HCl} \times 0.014\} \times 100}{\text{Weight of sample (g)}}$$

Where, N_{HCl} = Normality of HCl

Protein (%) = Nitrogen (%) × 5.95

iv. Apparent amylase content (%)

Apparent amylase content (AAC) was determined by the procedure of Juliano (1971). Hundred mg of rice powder was accurately taken into a 100 mL volumetric flask and 1 mL (95%) ethanol and 9 mL NaOH (1N) were added carefully. Then the flask was incubated overnight at room temperature to gelatinize the starch and then made the volume up to the mark with distilled water. About 5 mL portion of the starch solution was pipette into another 100 mL volumetric flask and 1 mL (1N) glacial acetic acid, 2 mL of iodine solution were added and made the volume up to the mark with distilled water. The mixture was shaken and after waiting 20 minutes, absorbance was measured at 620 nm in a spectrophotometer (Spectronic 20).

$$\text{Apparent amylose (\%)} = \frac{\text{Absorbance} \times \text{slope} \times \text{dilution factor} \times 100}{\text{Weight of sample (mg)}}$$

v. Alkali spreading value (ASV)

Alkali spreading value (ASV) was determined according to the procedure of Little *et al.* (1958). A duplicate set of six whole-milled kernels without cracks was selected and placed in a plastic box (5 cm × 5 cm × 2.5 cm). 10 milliliter of 1.7% potassium hydroxide (KOH) solution was added. The samples were arranged to provide enough space between kernels to allow for spreading. The boxes were covered and incubated for 23 hours in a 30°C oven. Starchy endosperm was rated visually based on a 7-point numerical spreading scale (Graham, 2002). A rating for spreading of 1-3 was classified as high (75-79^{o}C), 4-5 as intermediate (70-74^{o}C) and 6-7 as low (55-69^{o}C) gelatinization temperature (Juliano, 1990).

vi. Imbibition ratio (IR)

Volumes of cooked and milled rice were measured by water displacement method. Five grams of milled rice was placed in a graduated cylinder containing 50 ml of water and the change in volume was noted. Five grams of milled rice was cooked and then the cooked rice was placed in the same cylinder and the change in volume was measured. The imbibition ratio (IR) is the ratio of change in the volume of cooked to raw rice (Dipti *et al.*, 2002).

vi. Gel consistency (mm)

A rapid, simple test, complementary to the test for amylose content, was developed based on the consistency of a cold 4.4% milled rice paste in 0.2 M KOH (Cagampang *et al.*, 1972). Gel consistency (GC) was measured by the length of the cold gel in the culture tube held horizontally for 0.5 to 1 h. than 61 mm). 10 whole-milled rice grains was placed in the Wig-L-Bug amalgamator and ground for 40 sec to give a fine flour (100 mesh). One hundred mg of powder was weighed in duplicate into the culture tubes. Ethyl alcohol (0.2 mL of 95%) containing 0.025% thymol blue was added and 2.0 mL of 0.2 M KOH was added with a pipette. The contents were mixed using a Vortex Genie mixer with speed set at 6. The samples were cooked in a vigorously boiling water bath for 8 min, making sure that the tube contents reached 2/3 the height of the tube. The test tubes were removed from the water bath and left to stand at room temperature for 5 min. The tubes were cooled in an ice-water bath for 20 min and laid horizontally on a laboratory table lined with millimeter graphing paper. The total length of the gel was measured in mm from the bottom of the tube to the gel front.

According to Graham (2002),

- Very flaky rice with hard GC (length of gel, 40 mm or less). 40 mm or less).
- Flaky rice with medium GC (length of gel, 41 to 60 mm).
- Soft rice with soft GC (length of gel, more than 61 mm).

Medium or soft GC is preferred over hard GC in almost all regions of Asia.

3.9 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and using Statistix 10 package and the mean differences were adjudged by LSD technique (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The results of the experiment as influenced by different treatments have been summarized and presented in this chapter with the help of appropriate tables and figures. The results of the statistical analysis were critically perused and the inferences derived from the analysis have been presented in this chapter. Salient experimental results presented in the preceding chapter have been discussed with suitable causes and wherever necessary it has been supported with relevant facts as generated by various scientists working within country and abroad.

4.1 Crop growth characters

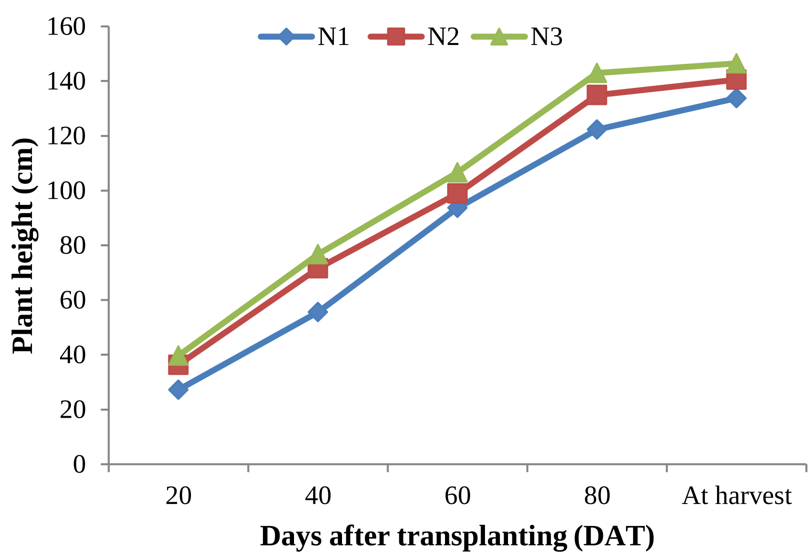
Various growth characters like plant height and number of tillers m^{-2} are directly or indirectly responsible for modifying the yield contributing characters and finally the grain yield. In present study, plant growth was studied with respect to plant height, number of tillers m^{-2}, leaf area index, SPAD value and dry matter production $hill^{-1}$ at different growth stages.

4.1.1 Plant height

4.1.1.1 Effect of nitrogen

Plant height is not a yield component especially in grain crops but it indicates the influence of various nutrients on plant metabolism. Nitrogen had significant influence on plant height (Figure 1 and Appendix V). It was revealed from the Figure 1 that plant height increased with the advancement of crop growth and varied significantly with different levels of nitrogen. At 20 DAT, the tallest plant (39.73 cm) was obtained from 150 kg N ha^{-1} and the shortest plant (27.23 cm) was obtained from 50 kg N ha^{-1}. Similar trend of plant height was observed at 40 DAT. At 60 DAT, the highest plant height (106.64 cm) was obtained from 150 kg N ha^{-1} and lowest plant height (93.69 cm) was obtained from 50 kg N ha^{-1} and both were statistically similar with the plant height (98.93 cm) obtained from 100 kg N ha^{-1}. At

80 DAT, the tallest plant (142.98 cm) was obtained from 150 kg N ha^{-1} which was statistically similar with the plant height (134.91 cm) obtained from 100 kg N ha^{-1}. The shortest plant (122.26 cm) was produced by 50 kg N ha^{-1}. Similar trend of observation for plant height was recorded at harvest. This result was consistent with Saha *et al.* (2017) who opined that this was probably due to higher uptake of applied nitrogen and greater availability of soil nutrients. Application of nitrogen increased plant height was reported elsewhere (Zannat *et al.*, 2014; Jisan *et al.*, 2014; Kirttania *et al.*, 2013; Siddique *et al.*, 2014; Metwally *et al.*, 2011a). Similar results were observed by Gewaily *et al.* (2018), Moro *et al.* (2015), Hossain *et al.* (2008), Fageria and Wilcox (1977) and Thakur and Singh (1987) who reported that plant height was increased significantly due to nitrogen application. Hossain *et al.* (2008) stated that the increase in plant height was due to various physiological processes including cell division and cell elongation of the plant. Chaturved (2005) also scrutinized the same result who concluded that the increase in plant height in response to application of N fertilizers was probably due to enhanced availability of nitrogen which enhanced



N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

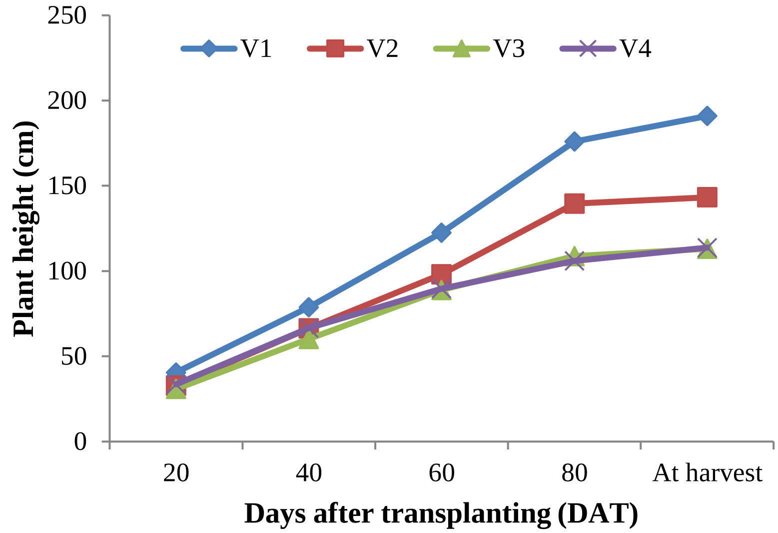
Figure 1. Effect of nitrogen on plant height of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$ = 1.72, 3.26, 10.84, 9.29 and 6.28 at 20, 40, 60, 80 DAT and harvest, respectively).

more leaf area resulting in higher photo assimilates and thereby resulted in more dry matter accumulation. But Tayefe *et al*. (2014) found no significant effect of nitrogen on plant height.

4.1.1.2 Effect of variety

Plant height is a growth character of rice which contribution is more efficient to enhance the straw yield in case of the tallest plant which produces the higher yield of straw (Howlader *et al.*, 2017).

The plant height of transplanted aman rice significantly varied among studied materials at 20, 40 60, 80 DAT and harvest, respectively (Figure 2 and Appendix V). The results showed that SAU ADL1 produced the tallest plant (43.02 cm, 88.95 cm, 122.48 cm, 176.95 cm and 191.28 cm) at 20, 40, 60, 80 DAT and harvest, respectively. At 20 DAT the lowest plant height (30.83 cm) was obtained from BRRI hybrid dhan6 which was statistically similar with the plant height of BRRI dhan70 (30.83 cm). BRRI hybrid dhan6 also produced the shortest plant (60.22 cm) at 40 DAT. At 60 DAT, 80 DAT and at harvest, BRRI hybrid dhan6 produced the shortest plant (88.94 cm, 108.87 cm and 113.12 cm, respectively) which were statistically similar with the plant height of SAU ADL11 (89.57 cm, 105.94 cm and 113.74 cm at 40, 60 80 DAT and at harvest, respectively). Difference in plant height of the cultivar/varieties was mainly due to their variation in genetic make-up. Similar results were reported by Chowhan *et al*. (2017), Murshida *et al*. (2017), Sarkar *et al.* (2016), Paul (2016), Ray *et al.* (2015), Sarkar (2014), Islam *et al*. (2013), Kirttania *et al.* (2013), Khatun (2001) who also recorded variable plant height due to varietal differences. Hossain *et al*. (2014) found that the variation in plant height was observed due to the variation in genetic variability and adaptability in studied area. Tanaka (1980) showed that the height of a rice plant was positively correlated to the length of the maturation cycle. A taller plant is more susceptible to lodging and responds less well to nitrogen (Yoshida, 1978).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 2. Effect of variety on plant height of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$ = 2.45, 3.29, 6.28, 5.29 and 8.94 at 20, 40, 60, 80 DAT and harvest, respectively).

4.1.1.3 Interaction effect of nitrogen and variety

Interaction between nitrogen and variety played an important role on plant height. Plant height was significantly influenced by the interaction effect of nitrogen and variety (Table 2 and Appendix V). At 20 DAT, the tallest plant (42.87 cm) was obtained from SAU ADL1 fertilized with 150 kg N ha^{-1} (N_3V_1) which was statistically similar with the plant height obtained from the treatment combination N_2V_1 (42.40 cm), N_3V_3 (38.87 cm) and N_3V_4 (38.80 cm). The shortest plant (19.68 cm) was obtained from the treatment combination N_1V_3. At 40 DAT, the highest plant height (90.53 cm) was recorded in SAU ADL1 fertilized with 150 kg N ha^{-1} (N_3V_1) followed by N_2V_1 (83.43 cm). The lowest plant height (45.77 cm) was recorded from the treatment combination N_1V_3. At 60 DAT, the highest plant height (125.09 cm) was obtained from SAU ADL1 fertilized with 150 kg N ha^{-1} (N_3V_1) which was statistically similar with N_2V_1 (125.07 cm) and N_1V_1 (117.27 cm). The lowest plant height (81.98 cm) was recorded from the treatment combination N_1V_3 which was statistically similar with N_2V_3 (84.63 cm), N_2V_4 (86.17 cm), N_1V_2 (89.99 cm) and N_1V_4

(88.53 cm). At 80 DAT, the tallest plant (186.56 cm) was obtained from the treatment combination N_3V_1 which was statistically similar with N_2V_1 (182.16 cm). The shortest plant (95.96 cm) was obtained from N_1V_3 which was statistically similar with N_1V_4 (99.67 cm) and N_2V_4 (103.95 cm). At harvest, the highest plant height (193.18 cm) was recorded from the treatment combination N_3V_1 which was statistically similar with N_2V_1 (192.33 cm) and N_1V_1 (187.34 cm). The lowest plant height (100.07 cm) was obtained from N_1V_3 which was statistically similar with N_2V_3 (111.40 cm), N_2V_4 (112.33 cm) and N_1V_4 (113.31 cm). This result was consistent with Saha *et al.* (2017), Paul *et al.* (2016), Shukla *et al.* (2015), Fageria and Santos (2015), Jisan *et al.* (2014), Sarkar *et al.* (2014) and Hossain *et al.* (2008).

Table 2. Interaction effect of nitrogen and variety on plant height of transplanted aman rice at different crop growth stages

Treatment combinations	Plant height (cm) at different days after transplanting (DAT)				
	20	40	60	80	At harvest
N_1V_1	36.42 cd	62.33 e	117.27 ab	168.51 b	187.34 a
N_1V_2	26.50 e	54.90 f	86.99 ef	124.89 d	134.43 cd
N_1V_3	19.68 f	45.77 g	81.98 f	95.96 g	100.07 g
N_1V_4	26.33 e	59.43 ef	88.53 ef	99.67 fg	113.31 efg
N_2V_1	42.40 ab	83.43 b	125.07 a	182.16 a	192.33 a
N_2V_2	33.50 d	69.39 cd	99.84 cd	146.32 c	145.19 bc
N_2V_3	33.93 d	64.30 de	84.63 ef	107.21 ef	111.40 fg
N_2V_4	35.60 cd	69.27cd	86.17 ef	103.95 fg	112.33 fg
N_3V_1	42.87 a	90.53 a	125.09 a	186.56 a	193.18 a
N_3V_2	38.40 bc	74.80 c	107.27 bc	147.73 c	150.10 b
N_3V_3	38.87 abc	70.60 c	100.20 cd	123.45 d	127.91 de
N_3V_4	38.80 abc	70.87 c	94.01 de	114.19 e	115.57 ef
LSD $_{(0.05)}$	4.24	2.71	10.88	9.16	15.04
CV (%)	7.18	4.88	6.36	4.00	6.25

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

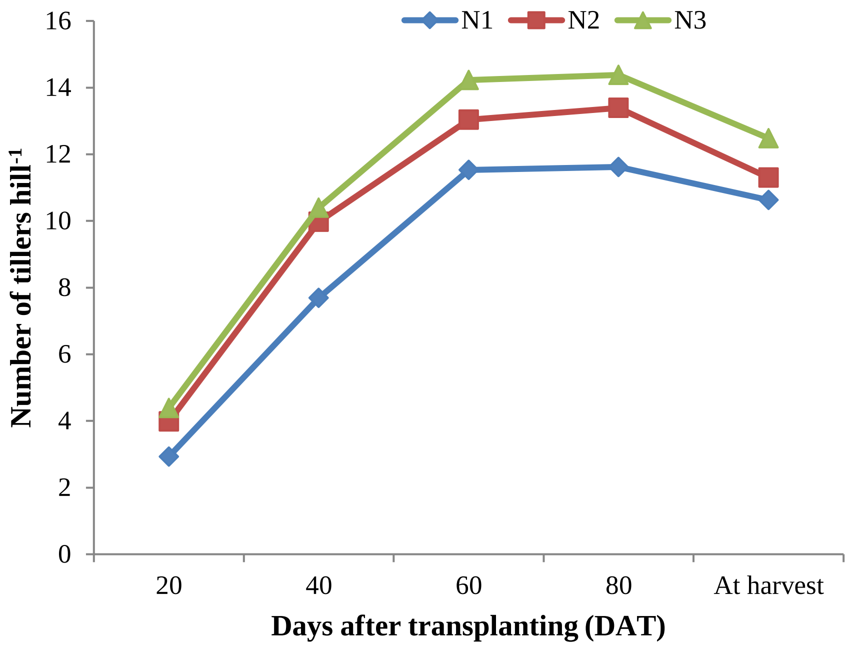
4.1.2 Number of tillers hill^{-1}

Number of tillers per unit area is the most important component of yield. More the number of tillers, especially fertile tillers, the more will be the yield (Chaturved, 2005).

4.1.2.1 Effect of nitrogen

Nitrogen fertilization rates exerted significant effect on number of tillers of transplanted aman rice varieties (Figure 3 and Appedix VI). Number of tillers hill^{-1} of rice increased significantly over time by gradual elevation of nitrogen fertilizer up to 60 days of transplanting afterwards showed a falling trend. Nevertheless, maximum number of tillers hill^{-1} was recorded from 150 kg N ha^{-1} at 20, 40, 60, 80 DAT and at harvest (4.39, 10.4, 14.23, 14.38 and 12.48, respectively). At 40 DAT, the tillers number (10.4) observed at 150 kg N ha^{-1} was statistically similar with the tillers number (9.97) observed at 100 kg N ha^{-1}. The lowest number of tillers hill^{-1} was observed at all sampling dates (2.93, 7.69, 11.53, 11.62 and 10.63 at 20, 40, 60, 80 DAT and at harvest, respectively) when the crop was fertilized with 50 kg N ha^{-1}. Growth promoting effect of N on plant can be explained on the basis of the fact that N supply increases the number and size of meristematic cells which leads to formation of new shoots (Lawlor, 2002). Furthermore, N application increases the levels of cytokinin which affects cell wall extensibility (Arnold *et al.*, 2006). It is therefore, logical to speculate that N was involved directly or indirectly in the enlargement and division of new cells and production of tissues which in turn were responsible for increase in growth characteristics particularly tillers number of rice. Nitrogen helps in the development of auxin, promoting growth of lateral buds which ultimately led to the formation of tillers (Kumar, 2016). The reduction of tiller number plant^{-1} at later growth stage might be due to tiller mortality under intra plant competition for growth resources (Haque and Haque, 2016). These results were full compliance with those of by Siddque *et al*. (2014), Pathan *et al.* (2010) and Biswas (2001) who recorded increased number of tillers hill^{-1} with increased nitrogen levels. These findings corroborated with those reported by Adhikari *et al.* (2018) who opined that number of total tillers hill^{-1} decreased progressively with the decrease in the amount of nitrogen fertilizer.

A similar findings were also scrutinized by Moro *et al.* (2015), Ethan *et al.* (2011), Hossain *et al.* (2008), Rahman *et al.* (2007a), Chaturved (2005), Hossain *et al.* (2002), Tunio *et al.* (2002), Biswas and Salokhe (2001) and Mes-quita and Pinto (2000).



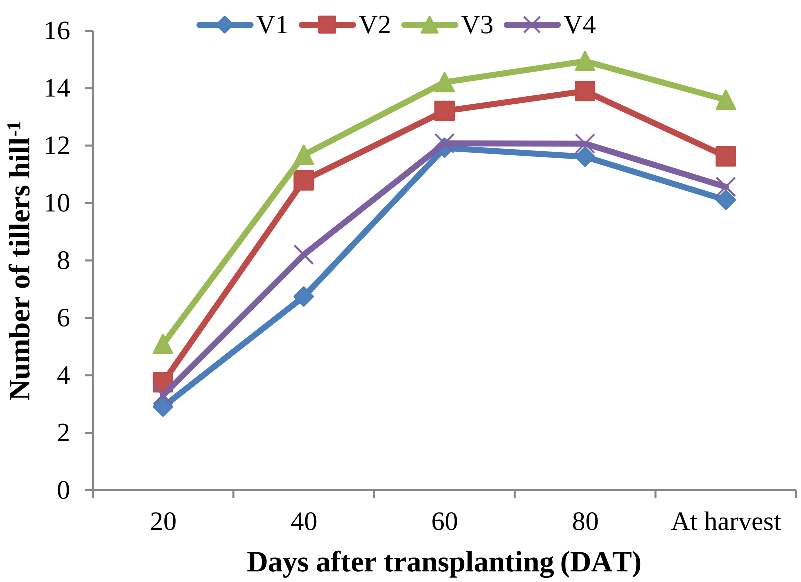
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 3. Effect of nitrogen on number of tillers $hill^{-1}$ of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 0.40, 0.80, 0.95, 0.33 and 0.44 at 20, 40, 60, 80 DAT and harvest, respectively).

4.1.2.2 Effect of variety

Tiller production was affected markedly by the variety (Figure 4 and Appendix VI). Tiller number in most of the variety increased almost exponentially up to 60 days after transplanting which was considered as active tilling phase. After that a gradual decline in tiller number was noticed towards maturity due to side tiller mortality and initiation of panicle primordia. The maximum number of tillers $hill^{-1}$ was observed in the variety BRRI hybrid dhan6 at all sampling dates. Number of tillers produced by BRRI hybrid dhan6 were 5.09, 11.68, 14.21, 14.94 and 13.60 at 20, 40, 60, 80 DAT and harvest, respectively. At 60

DAT, the number of tillers hill^{-1} produced by BRRI dhan70 (13.21) was statistically similar with BRRI hybrid dhan6. SAU ADL1 produced minimum number of tillers hill^{-1} at 20, 40, 60 80 DAT and at harvest (2.91, 6.74, 11.92, 11.61 and 10.11, respectively). At 20, 60 and 80 DAT, number of tillers hill^{-1} (3.31, 12.08 and 12.07, respectively) produced by SAU ADL11 was statistically similar with SAU ADL1. Similar trend of variation in number of tillers hill^{-1} among different varieties was observed at harvest. Islam *et al.* (2013) also found the similar results who stated that variation in tiller number might be due to the differences in their genetic make up. The result was also consistent with the findings of Chowhan *et al*. (2017), Murshida *et al.* (2017), Howlader *et al.* (2017), Sarkar *et al.* (2016), Jisan *et al*. (2014), Kirttania *et al.* (2013) and Hossain *et al.* (2008) who found variable effect of variety on number of tillers hill^{-1}. Mahmud *et al.* (2013) showed that rice cultivars differed significantly in all growth characters especially tillers number. With the decrease of tillers hill^{-1}, yield also decease considerably (Hoque, 2004).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 4. Effect of variety on number of tillers hill^{-1} of transplanted aman rice at different crop growth stages (LSD$_{(0.05)}$= 0.63, 0.85, 1.01, 0.66 and 0.55 at 20, 40, 60, 80 DAT and harvest, respectively).

4.1.2.3 Interaction effect of nitrogen and variety

The combined effect of nitrogen and variety significantly affected number of tillers hill^{-1} (Table 3 and Appendix VI). A trend of increase in the number of tillers hill^{-1} with the increasing levels of nitrogen was observed in all the studied materials. Rapid increase in tiller number was observed up to 60 days after transplanting and then it followed a falling trend towards maturity. It was observed that the interaction of 150 kg N ha^{-1} with BRRI hybrid dhan6 (N_3V_3) produced maximum number of tillers hill^{-1} at all sampling dates (6.27, 13.53, 15.87, 16.87 and 15.13 at 20, 40, 60, 80 DAT and at harvest, respectively) which was statistically similar with the combination of 100 kg

Table 3. Interaction effect of nitrogen and variety on number of tillers hill^{-1} of transplanted aman rice at different crop growth stages

Treatment combinations	Number of tillers hill^{-1} at different days after transplanting (DAT)				
	20	40	60	80	At harvest
N_1V_1	2.47 e	5.80 g	11.20 fg	10.20 f	9.8 hi
N_1V_2	2.73 de	8.2 c-f	11.67 efg	12.50 d	10.93 efg
N_1V_3	3.67 cd	9.40 c	12.27 d-g	12.67 d	12.33 cd
N_1V_4	2.86 de	7.37 ef	10.97 g	11.10 ef	9.20 i
N_2V_1	3.5 cde	7.67 def	11.70 efg	12.17 de	10.06 ghi
N_2V_2	4.20 c	11.77 b	13.93 bcd	13.87 c	11.27 ef
N_2V_3	5.33 ab	12.10 ab	14.50 abc	15.30 b	13.33 b
N_2V_4	2.87 de	8.33 cde	12.03 efg	12.23 de	10.80 efg
N_3V_1	2.77 de	6.77 fg	12.87 c-f	12.47 d	10.47 fgh
N_3V_2	4.33 bc	12.40 ab	14.93 ab	15.33 b	12.67 bc
N_3V_3	6.27 a	13.53 a	15.87 a	16.87 a	15.13 a
N_3V_4	4.20 c	8.90 cd	13.23 b-e	12.87 cd	11.67 de
LSD (0.05)	1.09	1.46	1.75	1.14	0.95
CV (%)	16.82	9.12	7.89	5.08	4.82

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

N ha^{-1} with BRRI hybrid dhan6 (N_2V_3) at all sampling dates except 80 DAT and at harvest. At 20 DAT, N_1V_1 produced minimum number of tillers hill^{-1} (2.47) which was statistically similar with N_1V_2 (2.73), N_3V_1 (2.77), N_1V_4 (2.86) and N_2V_4 (2.87). At 40 DAT, minimum number of tillers hill^{-1} was obtained from N_1V_1 (5.80) which was statistically similar with N_3V_1 (6.77). At 60 DAT, N_1V_4 produced minimum number of tillers hill^{-1} (10.97) which was statistically similar with N_1V_1 (11.20), N_1V_2 (11.67), N_2V_1 (11.70), N_2V_4 (12.03) and N_1V_3 (12.27). At 80 DAT, the lowest number of tillers hill^{-1} was obtained from N_1V_1 (10.20) which was statistically similar with N_1V_4 (11.10). At harvest, N_1V_4 produced minimum number of tillers hill^{-1} (9.20) which was statistically similar with N_1V_1 (9.8) and N_2V_1 (10.06). Similar result was also depicted by Saha *et al.* (2017), Jisan *et al.* (2014), Paul *et al.* (2016), Abou-Khalifa (2012), Hossain *et al.* (2008) who reported that increasing nitrogen level along with varieties gave higher number of tillers hill^{-1}.

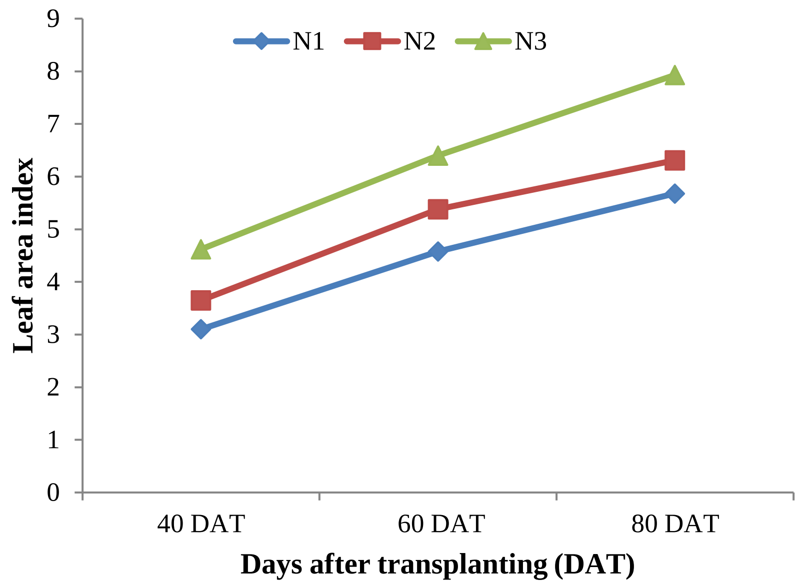
4.1.3 Leaf area index (LAI)

4.1.3.1 Effect of nitrogen

Results depicted in Figure 5 and Appendix VII showed that nitrogen level had significant effect on leaf area index (LAI) at all dates of sampling. The LAI increased progressively with increase in the level of nitrogen from 50 kg N ha^{-1} to 150 kg N ha^{-1}. Leaf area index progressively increased and achieved its maximum value at 80 DAT. At 80 DAT, highest LAI (7.93) was observed when fertilized with 150 kg N ha^{-1} and the lowest value (5.68) was recorded at 50 kg N ha^{-1}. Similar trend was also observed at 40 and 60 DAT.

In case of any plant, leaves are important organs which have an active role in photosynthesis. To achieve high yield, maximization of leaf area is an important factor of the crop (Singh and Agarwal, 2001). The increasing trend of LAI at higher nitrogen levels can be attributed to the positive effect of nitrogen on both leaf development and leaf area duration of the variety (Fageria, 2007; Fageria and Baligar, 2005). Progressive increment in LAI of the variety up to certain days may be due to the fact that addition of nitrogen triggers increased number of leaves plant^{-1} and expansion of individual leaf. The increase in leaf number as well as size due to enough nutrition can be expected in terms of possible increase in nutrient absorption capacity of the variety through better root development and increased translocation of carbohydrates from source to growing grains (Singh and

Agarwal, 2001). These results were in agreement with those obtained by Paul *et al.* (2016). Ray *et al.* (2015), Lampayan *et al.* (2010), Shibu *et al.* (2010) and Azarpour *et al.* (2011) who also stated that high nitrogen levels resulted to higher LAI in rice. Similar phenomenon was reported by Paul *et al.* *(*2014). Ray *et al.* (2015) who opined that increase in leaf area index would result in the corresponding increase in the grain yield of transplanted Aman rice.



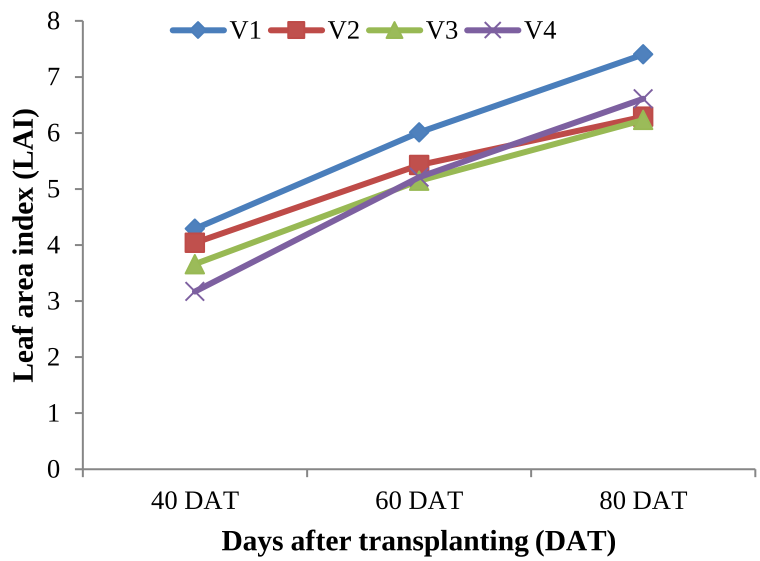
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 5. Effect of nitrogen on leaf area index of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 0.24, 0.60, 0.38 at 40, 60 and 80 DAT, respectively).

4.1.3.2 Effect of variety

It was revealed from the Figure 6 and Appendix VII that leaf area index increased continuously with the advancement of crop growth up to 80 DAT and varied significantly among cultivars. The highest LAI was observed in SAU ADL1 at all the dates of taking observation (4.29, 6.01 and 7.40 at 40, 60 and 80 DAT, respectively) followed by BRRI dhan70 at 40 and 60 DAT and SAU ADL11 at 80 DAT. At 40 DAT, the lowest LAI was observed in SAU ADL11 (3.17). At 60 DAT, no significant difference observed in case of

LAI among the cultivars except SAU ADL1. At 80 DAT, minimum LAI was found in BRRI hybrid dhan6 (6.23) which was statistically at par with BRRI dhan70 (6.29). The variation in leaf area might be due to the variation in leaf number and length and breadth of leaves in plant. Mondal *et al.* (2005) stated that the variation in LAI could be attributed due to the changes in number of leaves and the rate of leaf expansion and abscission. Variation in LAI among different varieties also reported by Howlader *et al.* (2017), Sarker *et al.* (2016), Paul (2016) and Paul *et al*. (2013).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 6: Effect of variety on leaf area index of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 0.17, 0.33, 0.25 at 40, 60 and 80 DAT, respectively).

4.1.3.3 Interaction effect of nitrogen and variety

The interaction effect of nitrogen and variety significantly influenced LAI (Table 4 and Appendix VII). A trend of increase in the value of LAI was observed in each studied material with the increasing levels of nitrogen. At 40 DAT, the maximum LAI (5.47) was produced by BRRI dhan70 fertilized with 150 kg N ha^{-1} (N_3V_2) which was statistically at par with LAI produced by SAU ADL1 with 150 kg N ha^{-1} (N_3V_1). The minimum LAI

(2.61) produced by SAU ADL11 with 50 kg N ha^{-1} (N_1V_4). At 60 and 80 DAT, Maximum LAI (7.21 and 8.96, respectively) was also observed in SAU ADL1 fertilized with 150 kg N ha^{-1}. At these two sampling dates, Minimum LAI was observed in BRRI dhan70 fertilized with 50 kg N ha^{-1} (4.23 and 4.98, respectively) and at 60 DAT it was statistically similar with N_1V_3 (4.42) and N_1V_4 (4.45). Similar observation was recorded by Paul *et al.* (2016), Ray *et al.* (2015) and Abou-Khalifa (2012).

Table 4. Interaction effect of nitrogen and variety on leaf area index (LAI) of transplanted aman rice at different crop growth stages

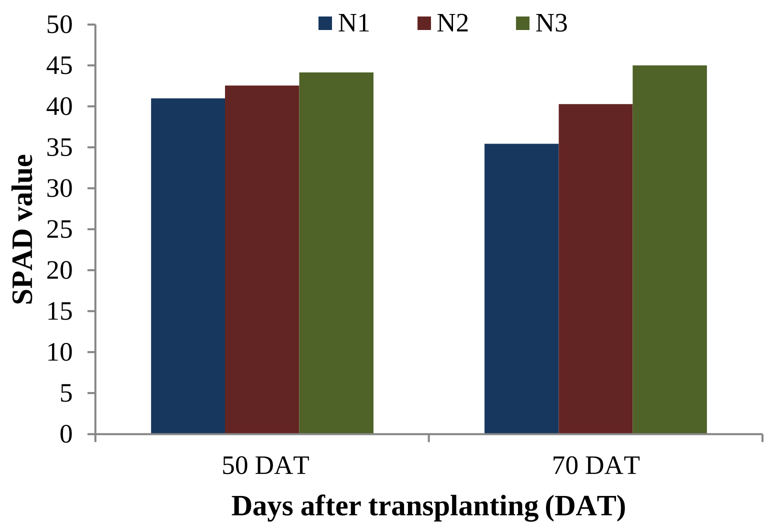
Treatment combinations	**LAI at different days after transplanting (DAT)**		
	40	**60**	**80**
N_1V_1	3.41 d	5.21 d	6.30 d
N_1V_2	3.25 de	4.23 e	4.98 f
N_1V_3	3.11 e	4.42 e	5.51 e
N_1V_4	2.61 f	4.45 e	5.91 de
N_2V_1	4.28 b	5.61 cd	6.94 c
N_2V_2	3.40 de	5.51 cd	6.12 d
N_2V_3	3.83 c	5.19 d	6.05 d
N_2V_4	3.11 e	5.20 d	6.12 d
N_3V_1	5.19 a	7.21 a	8.96 a
N_3V_2	5.47 a	6.54 b	7.80 b
N_3V_3	4.04 bc	5.86 c	7.13 c
N_3V_4	3.80 c	5.99 bc	7.81 b
LSD $_{(0.05)}$	0.29	0.58	0.44
CV (%)	4.53	6.19	2.17

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.1.4 SPAD value

4.1.4.1 Effect of nitrogen

A critical analysis of mean data (Appendix VIII) revealed that different nitrogen levels had significant influence on SPAD value at 50 and 70 DAT. SPAD value increased with the increase of nitrogen level at all sampling dates (Figure 7). At 50 and 70 DAT, maximum SPAD value (44.14 and 45.01, respectively) was recorded from 150 kg N ha^{-1} followed by 100 kg N ha^{-1} (42.57 and 40.31, respectively). Minimum SPAD value (41.01 and 35.46, respectively) was recorded at 50 kg N ha^{-1}. Similar result was recorded by Abedin *et al.* (2015), Yang *et al.* (2014), Jiang *et al*. (2012) and Hassan *et al*. (2009) who opined that SPAD value showed significant difference under variable nitrogen levels. Yang *et al.* (2014) reported that SPAD values generally increased to a maximum and then gradually decreased in N application plots during the growing season. Similar seasonal changes in SPAD values have been reported previously in rice (Jiang *et al.*, 2012). Maqsood *et al.* (2013) reported that nitrogen rate had a significant effect on chlorophyll content.

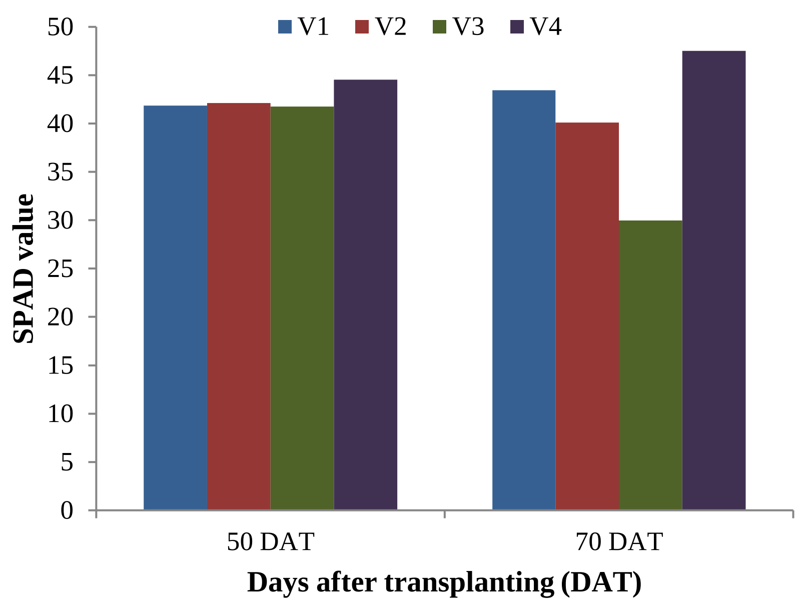


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 7. Effect of nitrogen on SPAD value of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 1.39 and 1.74 at 50 and 70 DAT, respectively).

4.1.4.2 Effect of variety

Variety had significant effect on SPAD value (Figure 8 and Appendix VIII). Both at 50 and 70 DAT, highest SPAD value (44.55 and 47.53, respectively) was observed in SAU ADL11. At 50 DAT, the lowest SPAD value (41.75) was observed in BRRI hybrid dhan6 which was statistically at par with SAU ADL1 and BRRI dhan70. At 70 DAT, the lowest SPAD value (29.99) was observed in BRRI hybrid dhan6. The second lowest SPAD value (40.09) was observed in BRRI dhan70. Similar findings were reported by Islam *et al.* (2009) who stated that chlorophyll content in rice leaves mostly varied with varieties and seasons. This result was also consistent with Paul (2016) and Mian *et al.* (2009) who reported variation in SPAD value among varieties. Munshi (2005) reported that grain yield was positively correlated with chlorophyll content and showed that high yielding genotypes also showed higher chlorophyll content in rice genotypes.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 8. Effect of variety on SPAD value of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 0.92 and 3.2 at 50 and 70 DAT, respectively).

4.1.4.3 Interaction effect of nitrogen and variety

A perusal of data (Table 5 and Appendix VIII) revealed that the combined effect of nitrogen and variety significantly affected the SPAD value. A trend of increase in SPAD value was observed in each variety with the increasing levels of nitrogen. The highest SPAD value was recorded from SAU ADL11 when fertilized with 150 kg N ha^{-1} (N_3V_4) at all sampling dates (46.86 and 51.39 at 50 and 70 DAT, respectively). At 70 DAT, N_3V_4 was statistically similar with N_2V_4 (46.31) and N_3V_1 (45.86). At 50 DAT, minimum SPAD value was obtained from N_1V_3 (39.20) which was statistically similar with N_1V_1 (40.69). At 70 DAT, the lowest SPAD value (20.57) was recorded from N_1V_3. This result was consistent with Abedin *et al.* (2015) who also found that interaction effect of nitrogen and variety had significant influence on SPAD value at different growth stage. Abou-Khalifa (2012) also reported significant variation in chlorophyll content due to interaction effect of nitrogen and variety.

Table 5. Interaction effect of nitrogen and variety on SPAD value of transplanted aman rice at different crop grpwth stages

Treatment combinations	SPAD value at different days after transplanting (DAT)	
	50	**70**
N_1V_1	40.69 de	40.58 c-f
N_1V_2	40.92 cd	35.78 fg
N_1V_3	39.20 e	20.57 h
N_1V_4	43.23 b	44.90 bcd
N_2V_1	42.00 bcd	43.87 b-e
N_2V_2	42.23 bcd	40.10 def
N_2V_3	42.47 bc	30.97 g
N_2V_4	43.55 b	46.31 ab
N_3V_1	42.92 b	45.86 abc
N_3V_2	43.19 b	44.38 bcd
N_3V_3	43.58 b	38.42 f
N_3V_4	46.86 a	51.39 a
LSD $_{(0.05)}$	1.59	5.55
CV (%)	2.17	8.03

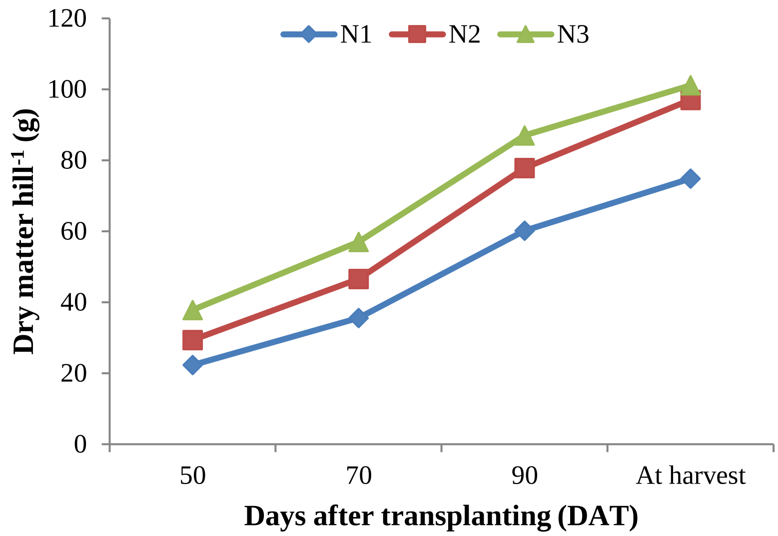
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.1.5 Dry matter production

The dry matter production is the cumulative effect of all the growth characters *viz.* plant height and number of tillers which are the indicator of higher chlorophilic area resulted in higher dry matter production per unit area (Terashima and Evans, 1988). Dry matter production by rice plants increased progressively with the advancement of growth stages and reached its peak at maturity (Haque and Haque, 2016).

4.1.5.1 Effect of nitrogen

Results depicted in Figure 9 and Appendix IX showed that nitrogen had significant impact on dry matter production. Dry matter hill^{-1} increased with the increase of nitrogen throughout the growth period and at harvest. The maximum dry matter hill^{-1} was obtained at all sampling date when 150 kg N ha^{-1} was applied (37.85 g, 56.99 g, 86.98 g and 101.14 g at 50, 70, 90 DAT and at harvest, respectively). The second highest dry matter hill^{-1} was recorded at 100 kg N ha^{-1} at all sampling date (29.38 g, 46.60 g, 77.81 g and 97.06 g at 50, 70, 90 DAT and at harvest, respectively). The minimum dry matter hill^{-1} was recorded when fertilized with 50 kg N ha^{-1} (22.30 g, 35.54 g, 60.15 g, 74.87 g at 50, 70, 90 DAT and at harvest, respectively). Murthy *et al.* (2015), Tayefe *et al.* (2014) also found the similar results. These results were also confirmed by Devi *et al*. (2012) and Manjoor *et al.* (2006). Chaturved (2005) in his research presented that dry matter accumulation increased significantly with N fertilizer application in rice at all the growth stages of the crop. Elevated nitrogen supply can boost dry matter content through production of photo assimilates via leaves which is the center of plant growth during vegetative stage and later distribution of assimilates to the reproductive organs (Dordas and Sioulas, 2008 and Azarpour *et al.*, 2014). Furthermore, dry matter production in rice is significantly related to intercept photosynthetically active radiation (Kiniry *et al.*, 2001). Low N concentrations in plant leaves have been described as a limiting factor for reducing radiation use efficiency and biomass productivity (Sinclair and Shelly, 1999) resulting lower dry matter production of rice. To develop crop growth models, information on dry matter production and partitioning between diverse plant parts is crucially needed (Sheng and Hunt, 1991) which conspicuously influenced by nitrogen fertilizer application. Murthy *et al.* (2015) also opined that increased levels of N favours greater absorption of nutrients resulting in rapid expansion of foliage, better accumulation of photosynthates and eventually resulting in increased growth structure.



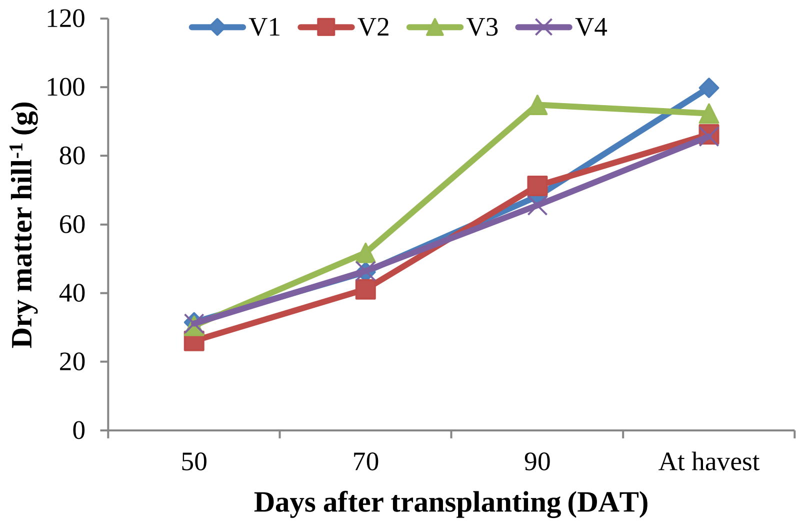
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 9. Effect of nitrogen on dry matter hill^{-1} of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 4.86, 8.83, 8.27, 4.88 at 50, 70, 90 DAT and harvest, respectively).

4.1.5.2 Effect of variety

Varietal variation significantly influenced dry matter production (Figure 10 and Appendix IX). At 50 DAT, accumulation of maximum dry matter hill^{-1} (31.52 g) was recorded in SAU ADL1 which was statistically at par with SAU ADL11 (31.13 g) and BRRI hybrid dhan6 (30.51 g). The minimum dry matter hill^{-1} (26.09 g) was recorded in BRRI dhan70. At 70 DAT, maximum dry matter hill^{-1} (51.80 g) was obtained from BRRI hybrid dhan6 which was statistically similar with SAU ADL11 (46.44 g). The minimum dry matter hill^{-1} (41.16 g) was produced by BRRI dhan70 which was statistically similar with SAU ADL1 (46.12 g). At 90 DAT, maximum dry matter hill^{-1} (94.88 g) was produced by BRRI hybrid dhan6 followed by BRRI dhan70 (71.29 g). The minimum dry matter hill^{-1} (65.55 g) was produced by SAU ADL11 which was statistically similar with SAU ADL1 (68.20 g). At harvest, maximum dry matter hill^{-1} (99.85 g) was produced by SAU ADL1 followed by

BRRI hybrid dhan6 (92.36 g). The minimum dry matter hill^{-1} (85.64 g) was recorded in SAU ADL11 which was statistically similar with BRRI dhan70 (86.25 g). Murshida *et al*. (2017), Howlader *et al.* (2017), Tayefe *et al*. (2014) also reported difference in dry matter production due to varietal variation. Sarkar *et al*. (2016) also found similar results who opined that dry matter production increased with age of rice plant. The increase of TDM was dependent on the leaf area production as reported by Chandra and Das (2007). Razzaque *et al*. (2009) reported that TDM increased with increasing plant age up to physiological maturity and high yielding varieties always maintained higher TDM.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 10. Effect of variety on dry matter hill^{-1} of transplanted aman rice at different crop growth stages ($LSD_{(0.05)}$= 3.96, 5.46, 8.27, 3.20 at 50, 70, 90 DAT and harvest, respectively).

4.1.5.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly influenced dry matter production (Table 6 and Appendix IX). At 50 DAT, the highest dry matter hill^{-1} (39.59 g) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4) which was statistically similar with N_3V_3 (38.11 g), N_3V_1 (37.88 g) and N_3V_2 (35.82 g). The lowest dry matter hill^{-1} (17.45 g) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with N_1V_3 (22.74 g) and N_1V_4 (22.85 g). At 70 DAT, the highest dry matter hill^{-1} (62.90 g) was obtained from BRRI hybrid dhan6 fertilized with 150 kg N ha^{-1} (N_3V_3) which was statistically similar with N_3V_4 (55.83 g), N_3V_1 (55.39 g) and N_3V_2 (53.82 g). The lowest dry matter hill^{-1} (28.12 g) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with N_1V_1 (36.47 g) and N_1V_4 (37.52 g). At 90 DAT, the highest dry matter hill^{-1} (110.11 g) was obtained from BRRI hybrid dhan6 fertilized with 150 kg N ha^{-1} (N_3V_3) followed by N_2V_3 (97.77 g). The lowest dry matter hill^{-1} (52.82 g) was obtained from BRRI dhan70

Table 6. Interaction effect of nitrogen and variety on dry matter hill^{-1} of transplanted aman rice at different crop growth stages

Treatment combinations	Dry matter hill^{-1} (g) at different days after transplanting (DAT)			
	50	70	90	At harvest
N_1V_1	26.17 cd	36.47 ef	57.03 f	84.84 c
N_1V_2	17.45 e	28.12 f	52.82 f	68.38 d
N_1V_3	22.74 de	40.07 de	76.77 d	73.85 d
N_1V_4	22.85 de	37.52 def	53.97 f	72.39 d
N_2V_1	30.53 bc	46.49 bcd	70.92 de	107.21 a
N_2V_2	24.99 cd	41.53 de	74.90 de	94.04 b
N_2V_3	30.67 bc	52.43 bc	97.77 b	95.77 b
N_2V_4	30.94 bc	45.96 cd	67.66 e	90.95 b
N_3V_1	37.88 a	55.39 abc	76.66 d	107.49 a
N_3V_2	35.82 ab	53.82 abc	86.14 c	96.32 b
N_3V_3	38.11 a	62.90 a	110.11 a	107.45 a
N_3V_4	39.59 a	55.83 ab	75.02 de	93.59 b
LSD $_{(0.05)}$	6.86	9.45	7.71	5.55
CV (%)	13.42	11.88	5.99	3.56

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically at par with N_1V_4 (53.97 g) and N_1V_1 (57.03 g). At harvest the highest dry matter hill^{-1} (107.49 g) was obtained from SAU ADL1 fertilized with 150 kg N ha^{-1} (N_3V_1) which was statistically at par with N_3V_3 (107.45 g) and N_2V_1 (107.21 g). The lowest dry matter hill^{-1} (68.38 g) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with N_1V_4 (72.39 g) and N_1V_3 (73.85 g).

4.2 Yield and yield attributes

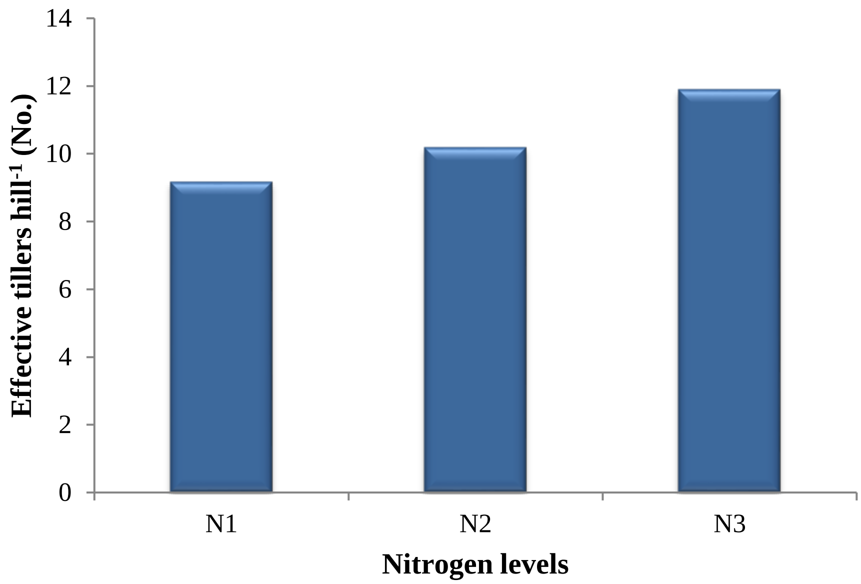
Yield attributing characters *viz*. number of effective tillers, number of ineffective tillers, panicle length (cm), rachis branches panicle^{-1}, number of filled grains panicle^{-1} and weight of 1000-grains (g) are responsible for modifying the grain yield. Yield contributing characters depend on the efficient translocation of photosynthates from source (leaf) to sink. The final yield of rice is the result of the successful completion of growth and development activities which in turn depends on the genetic potential of the genotype, the environmental conditions to which it is exposed during the course of its life cycle and agronomic management efficiencies. In present study, yield was studied with respect to effective tillers hill^{-1}, ineffective tillers hill^{-1}, panicle length (cm), rachis branches panicle^{-1}, grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, weight of 1000-grains, grain yield, straw yield, biological yield and harvest index.

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of nitrogen

Results depicted in Figure 11 and Appendix X indicated that number of effective tillers hill^{-1} was affected noticeably with adding nitrogen fertilizers. Number of effective tillers hill^{-1} progressively increased with the increase of nitrogen levels and achieved its maximum value (11.9) when fertilized with 150 kg N ha^{-1}. The minimum number of effective tillers hill^{-1} (9.17) was recorded at 50 kg N ha^{-1}.

The number of effective tillers rather than total number of tillers contributes more to enhance productivity of rice plant (Haque and Haque, 2016). Nevertheless, the number of productive tillers depends on environmental conditions especially nutrient during tiller bud initiation and subsequent developmental stages (Power and Alessi, 1978 and Marsle, 1985). The lower of tiller number in present study was attributed to the failure in competition for nitrogen at lower level and aggravate death of the tillers due to mutual shading (Fageria *et al*., 1997).

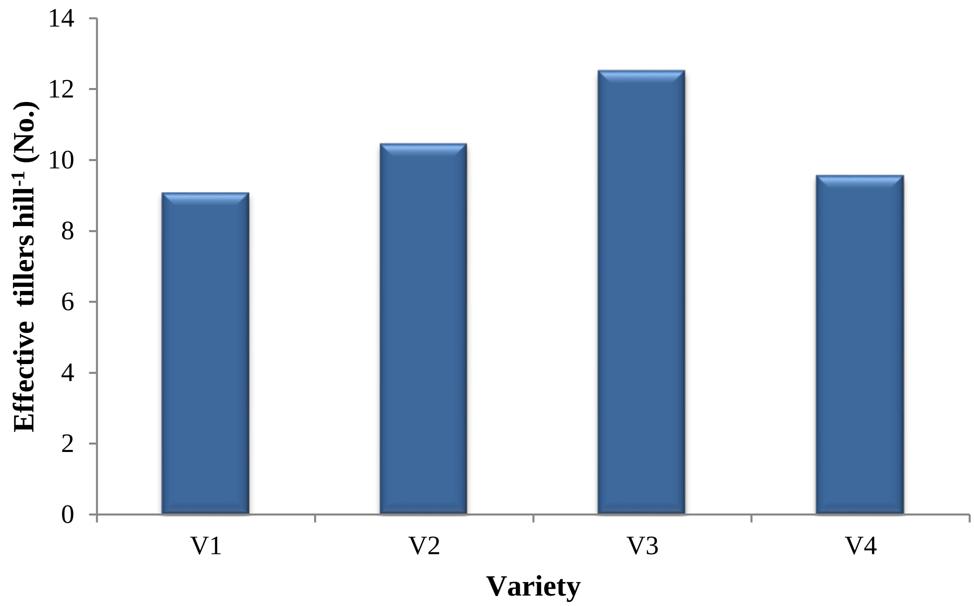


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 11. Effect of nitrogen on effective tillers hill^{-1} of transplanted aman rice ($LSD_{(0.05)}$= 0.39).

4.2.1.2 Effect of variety

Variety had significant influence on number of effective tillers hill^{-1} (Figure 12 and Appendix X). The number of effective tillers hill^{-1} ranged from 9.09 to 12.53 among tested materials. The maximum number of effective tillers hill^{-1} (12.53) was obtained from BRRI hybrid dhan6 followed by BRRI dhan70 (10.47). The minimum number of effective tillers hill^{-1} (9.09) was recorded from SAU ADL1 which was statistically at par with SAU ADL11 (9.58). Similarly, significant variation among the rice varieties regarding effective tillers hill^{-1} was also found by Howlader *et al.* (2017), Murshida *et al*. (2017) and Islam *et al*. (2013) who stated that the reason of difference in effective tillers hill^{-1} was the genetic makeup of the variety, which was primarily influenced by heredity. The above result of variability in effective tillers hill^{-1} was also in agreement with many workers (Sarkar *et al.*, 2016; Yang *el al.*, 2007; Shrirame and Muley, 2003 and Munshi, 2005). This result was also supported by Chowdhury *et al*. (1993) and Anonymous (1991) who stated that effective tillers hill^{-1} varied with the variety.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 12. Effect of variety on effective tillers hill^{-1} of transplanted aman rice (LSD$_{(0.05)}$= 0.55).

4.2.1.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly influenced number of effective tillers hill^{-1} (Table 7 and Appendix X). Number of effective tillers hill^{-1} increased in all the varieties with the increase in nitrogen levels. The maximum number of effective tillers hill^{-1} (14.47) was recorded from BRRI hybrid dhan6 (N_3V_3) when fertilized with 150 kg N ha^{-1} followed by BRRI hybrid dhan6 fertilized with 100 kg N ha^{-1} (N_2V_3). The minimum number of effective tillers hill^{-1} (7.93) was recorded from SAU ADL11 fertilized with 50 kg N ha^{-1} (N_1V_4) which was statistically similar with N_1V_1 (8.67) and N_2V_1 (8.80). Hossain *et al.* (2018), Shukla *et al.* (2015) and Jisan *et al.* (2014) also reported the similar findings. Kamara *et al.* (2011) found no significant effect due to interaction of variety and nitrogen.

Table 7. Interaction effect of nitrogen and variety on effective and ineffective tillers hill^{-1} of transplanted aman rice

Treatment combinations	Effective tillers hill^{-1}	Ineffective tillers hill^{-1}
N_1V_1	8.67 gh	1.40 bc
N_1V_2	9.27 fg	1.67 a
N_1V_3	10.80 de	1.53 ab
N_1V_4	7.93 h	1.27 c
N_2V_1	8.80 gh	1.00 d
N_2V_2	10.00 ef	1.27 c
N_2V_3	12.33 b	1.00 d
N_2V_4	9.6 fg	1.20 cd
N_3V_1	9.8 f	0.67 e
N_3V_2	12.13 bc	0.53 e
N_3V_3	14.47 a	0.67 e
N_3V_4	11.20 cd	0.47 e
LSD $_{(0.05)}$	0.95	0.24
CV (%)	5.34	13.27

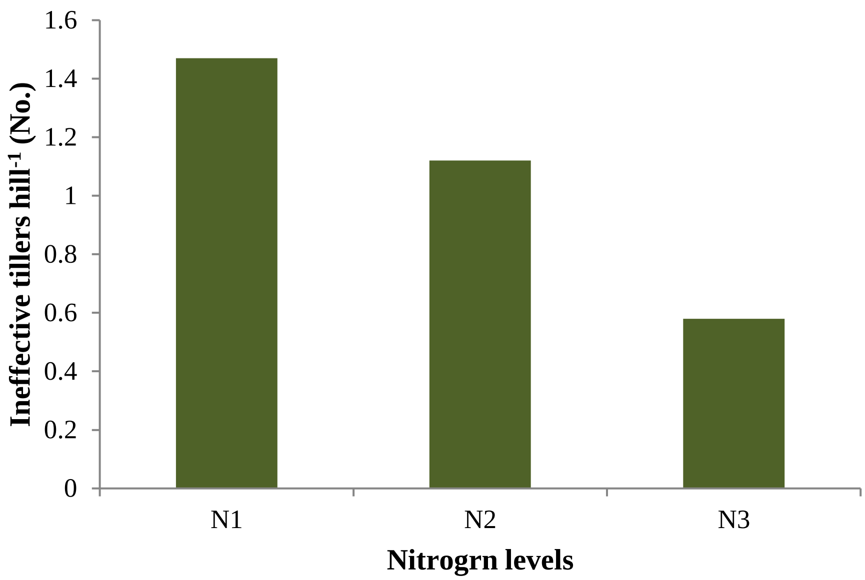
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.2.2 Number of ineffective tillers hill^{-1}

4.2.2.1 Effect of nitrogen

Results depicted in Figure 13 and Appendix X showed that nitrogen significantly influenced number of ineffective tillers hill^{-1}. Number of ineffective tillers hill^{-1} was negatively related with nitrogen levels that number of ineffective tillers hill^{-1} decreased with the increase of nitrogen level. The maximum number of ineffective tillers hill^{-1} (1.47) was obtained from 50 kg N ha^{-1} followed by 100 kg N ha^{-1}. The minimum number of ineffective tillers $hill^{-1}$ (0.58) was obtained from 150 kg N ha^{-1}.

This might be due to the competition for assimilates exists between developing panicles and young tillers during the beginning of panicle development causing suppression of growth of many young tillers therefore they may senesce without producing panicle (Dofing and Karlsson, 1993; Fageria and Baligar, 2001). Similar results were also reported by other authors (Mendhe *et al*., 2002; Uddin *et al.*, 2011).



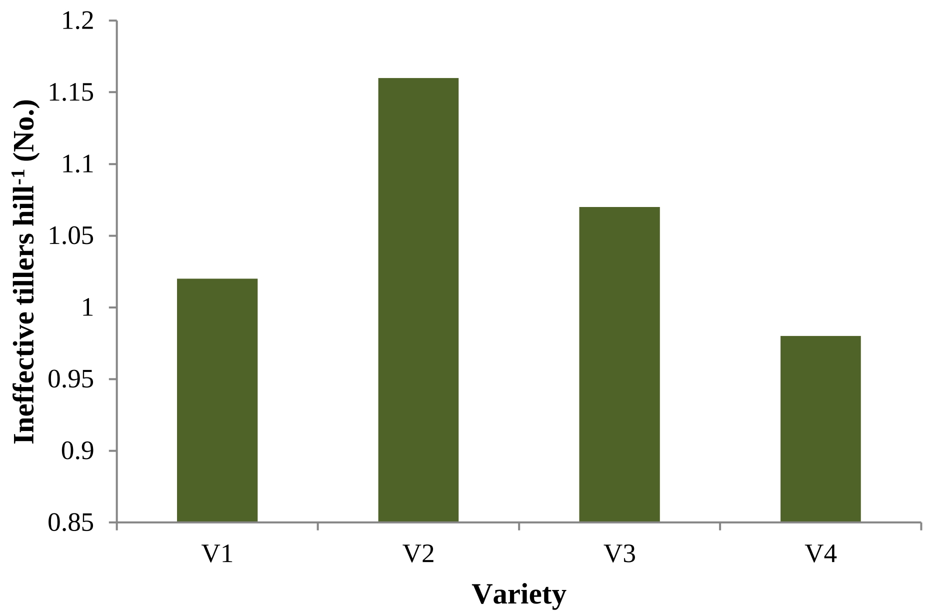
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 13. Effect of nitrogen on ineffective tillers $hill^{-1}$ of transplanted aman rice ($LSD_{(0.05)}$= 0.1).

4.2.2.2 Effect of variety

Results obtained in the present study revealed that variety had significant effect on number of ineffective tillers $hill^{-1}$ (Figure 14 and Appendix X). The range of number of ineffective tillers $hill^{-1}$ varied from 0.98 to 1.02 among the studied materials. The highest number of ineffective tillers $hill^{-1}$ (1.16) was produced by BRRI dhan70 which was statistically similar with SAU ADL1 and BRRI hybrid dhan6. The lowest number of ineffective tillers $hill^{-1}$ (0.98) was produced by SAU ADL11.

Similar observation was reported by Sarkar *et al.* (2016). The variation in production of non effective tillers was found due to its genetic variation and also the different types of tiller mortality possibility at harvest (Howlader *et al.,* 2017).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 14. Effect of variety on ineffective tillers hill^{-1} of transplanted aman rice (LSD$_{(0.05)}$= 0.14).

4.2.2.3 Interaction effect of nitrogen and variety

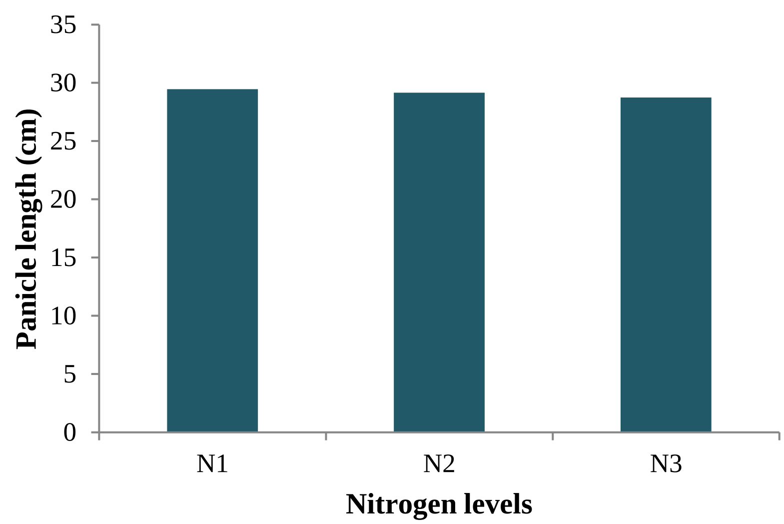
A perusal of data (Table 7 and Appendix X) revealed that number of ineffective tillers hill^{-1} varied significantly due to the interaction effect of nitrogen and variety. Number of ineffective tillers hill^{-1} decreased with the increase in nitrogen level among the varieties. The highest number of ineffective tillers hill^{-1} (1.67) was recorded from the interaction of BRRI dhan70 with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with the interaction effect of BRRI hybrid dhan6 with 50 kg N ha^{-1} (N_1V_3). The lowest number of ineffective tillers hill^{-1} (0.47) was found from the combination of SAU ADL11 with 150 kg N ha^{-1} (N_3V_4) which was statistically at par with N_3V_2 (0.53), N_3V_1 (0.67) and N_3V_3 (0.67).

Significant impact on ineffective tillers due to interaction effect of variety and nitrogen was also reported by Hossain *et al.* (2008).

4.2.3 Panicle length

4.2.3.1 Effect of nitrogen

Nitrogen had no significant effect on panicle length (Figure 15 and Appendix XI). The panicle length ranged from 28.74 cm to 29.47 cm due to different nitrogen levels which was statistically similar with one another. Tilahun (2019), Siddque *et al.* (2014) also found no significant effect of nitrogen on panicle length. These results were supported by the results of Sharma and Mishra (1986). But Gewaily *et al.* (2018), Kumar (2016), Metwally *et al.* (2011b). Metwally *et al.* (2017) and Yoseftabar (2013) reported that panicle length increased significantly with increased levels of nitrogen.

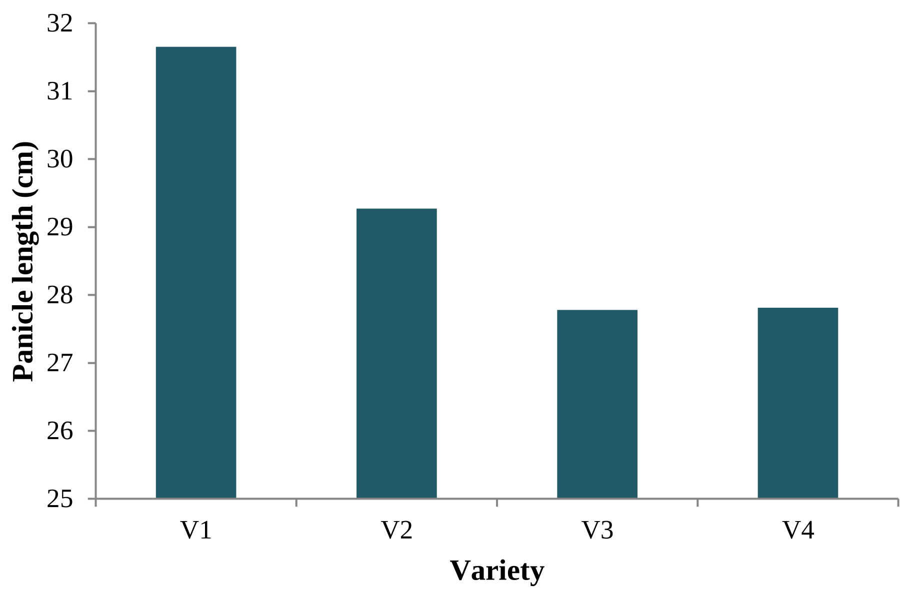


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 15. Effect of nitrogen on panicle length of transplanted aman rice.

4.2.3.2 Effect of variety

Citation of the data regarding panicle length revealed that variety had significant influence on panicle length (Figure 16 and Appendix XI). The panicle length varied from 27.78 cm to 31.65 cm among the tested materials. Among the studied materials, V_1 (SAU ADL1) produced longest panicle (31.65 cm) followed by BRRI dhan70 (29.27 cm). BRRI hybrid dhan6 produced shortest panicle (27.78 cm) which was statistically similar with SAU ADL11 (27.81 cm). This result was consistent with findings of Chowhan *et al.* (2017), Murshida *et al.* (2017), Sarkar *et al.* (2016), Paul (2016), Sarkar (2014), Ashrafuzzaman *et al.* (2009), Idris and Matin (1990) and Anon. (1993) who reported that panicle length significantly varied among varieties. Islam *et al.* (2013) opined that the variation in panicle length might be mainly due to genetic background of the variety.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 16. Effect of variety on panicle length of transplanted aman rice ($LSD_{(0.05)}$=1.02).

4.2.3.3 Interaction effect of nitrogen and variety

An appraisal of mean data showed that interaction effect of variety and nitrogen significantly influenced panicle length (Table 8 and Appendix XI). SAU ADL1 with 100 kg N ha^{-1} (N_2V_1) produced longest panicle (32.92 cm) which was statistically similar with the panicle length produced by SAU ADL1 and 150 kg N ha^{-1} (N_3V_1). SAU ADL11 with 150 kg N ha^{-1} (N_3V_4) produced the shortest panicle (27.01 cm) which was statistically at par with N_2V_3 (27.12 cm), N_1V_3 (27.58 cm), N_1V_4 (27.52 cm), N_2V_2 (27.76 cm) and N_3V_3 (28.63 cm). A similar finding was also scrutinized by Hossain *et al.* (2018), Saha *et al.* (2017), Shukla *et al.* (2015), Sarkar *et al*. (2014), Abou-Khalifa (2012) and Hossain *et al*. (2008) who opined that length of panicle varied significantly from cultivars to cultivars and also under levels of nitrogen application. But Gewaily *et al.* (2018) found no significant effect of rice variety and nitrogen for this trait.

Table 8. Interaction effect of nitrogen and variety on yield contributing characters of transplanted aman rice

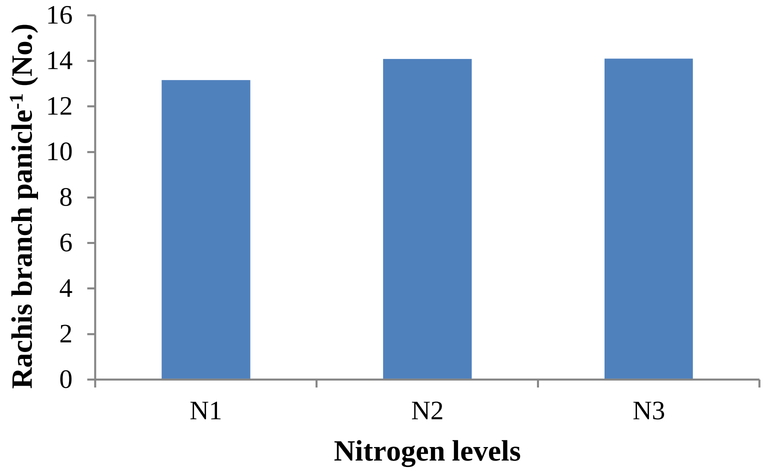
Treatment combinations	Panicle length (cm)	Rachis branch panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains Panicle^{-1}	Total grains panicle^{-1}
N_1V_1	30.56 bcd	13.67 abc	128.07 fg	51.60 ab	179.67 de
N_1V_2	29.28 cde	13.70 abc	162.43 cd	48.50 abc	188.13 cde
N_1V_3	27.58 ef	11.03 d	129.15 fg	23.33 def	147.60 f
N_1V_4	27.52 ef	14.23 ab	116.73 g	53.77 a	170.50 ef
N_2V_1	32.92 a	14.07 abc	134.87 efg	45.47 abc	180.33 de
N_2V_2	27.76 ef	14.50 ab	172.70 bc	25.70 de	221.20 b
N_2V_3	27.12 f	12.49 cd	188.00 b	18.50 ef	211.33 bc
N_2V_4	28.90 de	15.27 a	140.90 def	44.17 bc	185.07 cde
N_3V_1	31.46 ab	14.93 ab	154.30 cde	44.67 bc	198.97 bcd
N_3V_2	30.76 bc	14.55 ab	189.80 b	31.00 d	220.80 b
N_3V_3	28.63 ef	11.73 cd	237.00 a	16.17 f	253.23 a
N_3V_4	27.01 f	15.20 a	155.43 cde	42.80 c	198.23 bcd
LSD (0.05)	1.77	2.44	22.32	8.48	28.00
CV (%)	3.55	10.34	8.18	13.31	8.32

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.2.4 Rachis branch panicle^{-1}

4.2.4.1 Effect of nitrogen

There was no significant difference in rachis branch panicle^{-1} due to different nitrogen levels (Figure 17 and Appendix XI). Numerically the maximum rachis branches (14.10) was obtained from N_3 treatment (150 kg N ha^{-1}) which was statistically at par with two other treatment (N_2 and N_1).

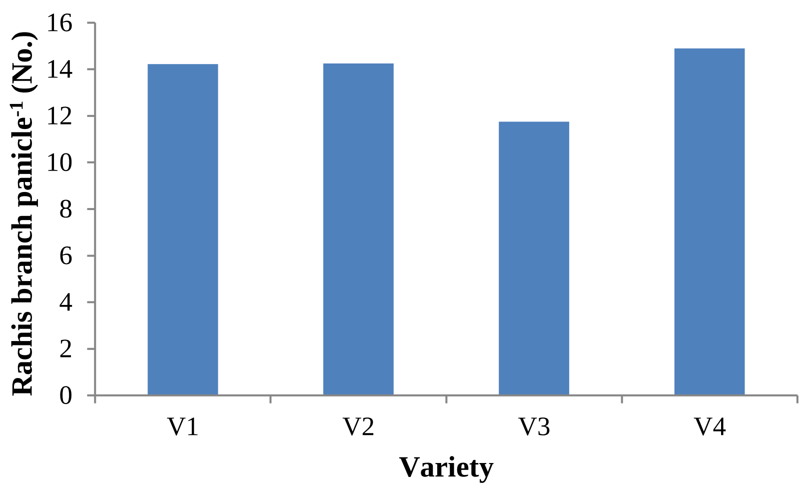


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 17. Effect of nitrogen on rachis branch panicle^{-1} of transplanted aman rice.

4.2.4.2 Effect of variety

Results depicted in the Figure 18 and Appendix XI revealed that among the studied materials, the maximum number of rachis branch panicle^{-1} (14.90) was observed in V_4 (SAU ADL11)



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 18. Effect of variety on rachis branch panicle^{-1} of transplanted aman rice ($LSD_{(0.05)}$= 1.41).

which was significantly superior to BRRI hybrid dhan6 (11.75) while statistically at par with rest of the varieties . Paul (2016) also reported difference in rachis branch panicle^{-1} among rice genotypes. Yamagishi *et al.* (2003) opined that high yielding variety had a relatively large number of primary rachis-branches as compared with the secondary rachis-branches.

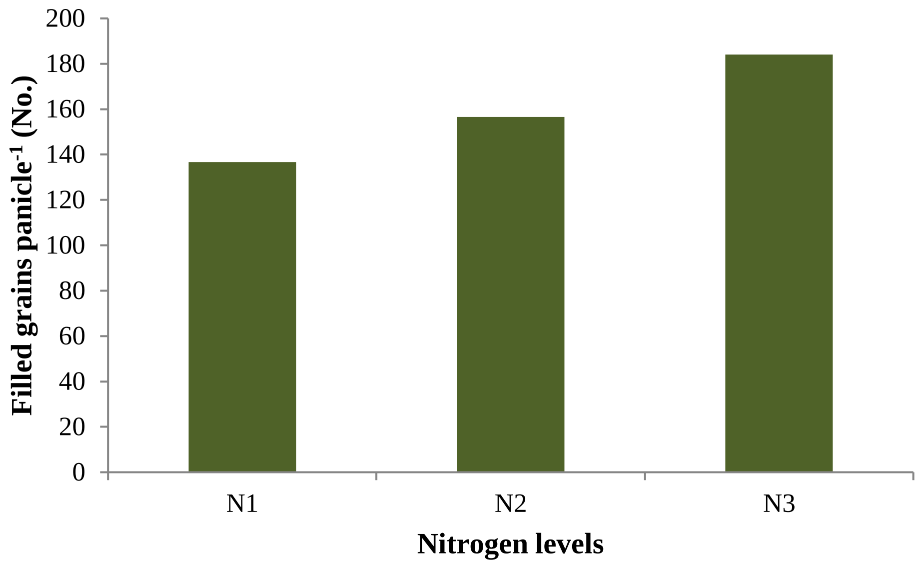
4.2.4.3 Interaction effect of nitrogen and variety

A perusal of data (Table 8 and Appendix XI) showed that interaction effect of nitrogen and variety significantly influenced rachis branch panicle^{-1}. The maximum rachis branch panicle^{-1} (15.27) was obtained from SAU ADL11 fertilized with 100 kg N ha^{-1} (N_2V_4) which was statistically similar with N_3V_4 (15.20), N_3V_1 (14.93), N_2V_2 (14.50), N_3V_2 (14.44), N_1V_4 (14.23), N_2V_1 (14.07), N_1V_2 (13.70) and N_1V_1 (13.67). The minimum rachis branch panicle^{-1} (11.03) was obtained from N_1V_3 which was statistically similar with N_2V_3 (11.73) and N_3V_3 (12.49).

4.2.5 Filled grains panicle^{-1}

4.2.5.1 Effect of nitrogen

A close scrutiny of data regarding filled grains panicle^{-1} showed that different nitrogen levels produced significant effect (Figure 19 and Appendix XI). The highest number of filled grains panicle^{-1} (184.13) was produced by N_3 (150 kg N ha^{-1}) followed by N_2 (100 kg N ha^{-1}). The lowest number of filled grains panicle^{-1} (136.66) was produced from N_1 (50 kg N ha^{-1}). Optimum amount of nitrogen fertilizer produces maximum number of filled grains and minimum number of unfilled grains panicle^{-1}. These findings were in agreement with the findings of Lawal and Lawal (2002) who reported that adequate supply of nitrogen was essential for grain development of rice and to increase filled grains panicle^{-1}. Higher number of grains panicle^{-1} at higher nitrogen rate might be due to higher nitrogen absorption which favored formation of higher number of branches panicle^{-1} (Rahman *et al.*, 2007b). This result was also in line with the findings of Gewaily *et al.* (2017), Sorour *et al.* (2016) and Murthy *et al.* (2015). The rice genotypes differed significantly in their response to nitrogen levels. This might be due to source sink interaction, meaning maximum proportion of N source is used to produce maximum spikelets panicle^{-1} and grain filling (Noor, 2017).

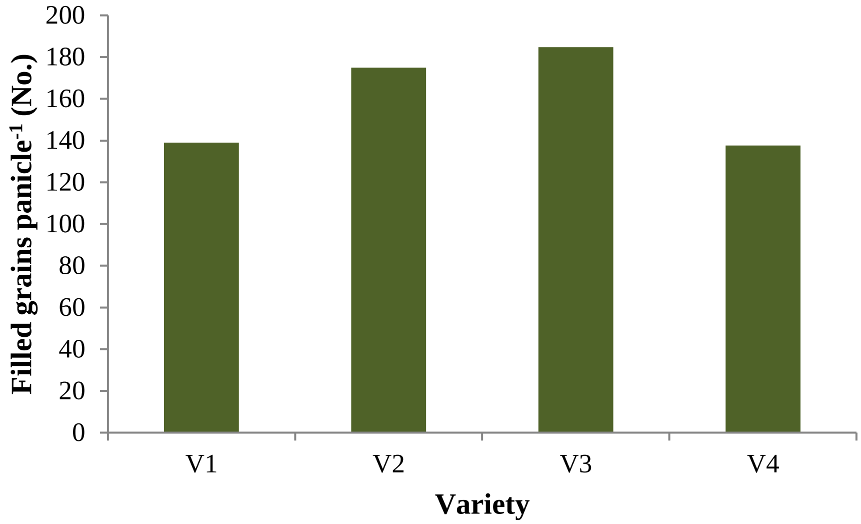


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 19. Effect of nitrogen on filled grains panicle^{-1} of transplanted aman rice (LSD$_{(0.05)}$= 12.98).

4.2.5.2 Effect of variety

Result obtained in the present study revealed that filled grains panicle^{-1} varied significantly from cultivars to cultivars (Figure 20 and Appendix XI). Among the tested materials, V_3 (BRRI hybrid dhan6) produced highest number of filled grains panicle^{-1} (184.72) which was statistically at par with V_2 (BRRI dhan70). The lowest number of filled grains panicle^{-1} (137.69) was produced by V_4 (SAU ADL11) which was statistically similar with V_1 (SAU ADL1). This result was in agreement with Sarkar *et al*. (2014), Islam *et al.* (2013) and Mahmud *et al*. (2013) who opined that the variation in filled grains panicle^{-1} was recorded due to genotypic differences of varieties. The results were also supported by Singh and Gangwer (1989). Dutta *et al.* (2002) who observed that yield was affected by the filled grains panicle^{-1}. Kiani and Nematzadeh (2012) observed that filled grains panicle^{-1} correlated significantly with grain yield.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 20. Effect of variety on filled grains panicle^{-1} of transplanted aman rice ($LSD_{(0.05)}$= 12.89).

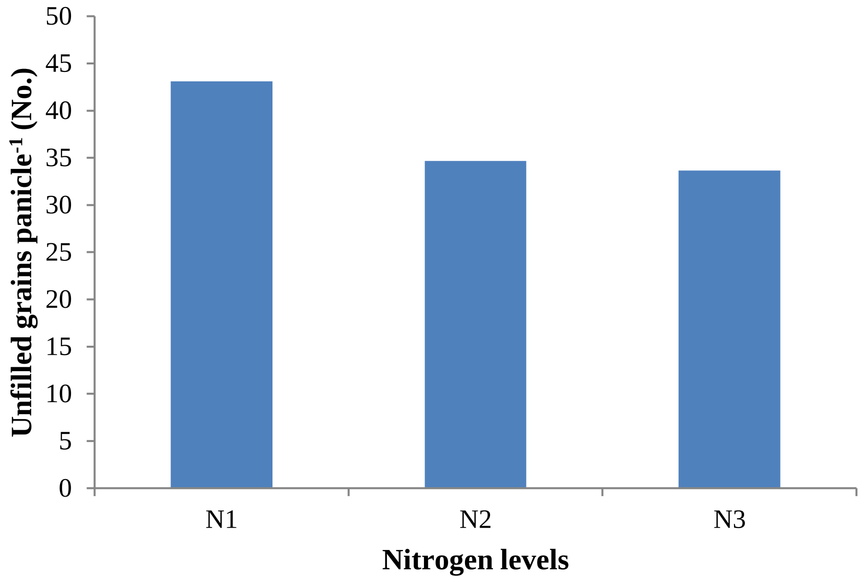
4.2.5.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant influence on filled grains panicle^{-1} (Table 8 and Appendix XI). Number of filled grains panicle^{-1} increased with the increase of nitrogen levels in all the studied materials. The highest number of filled grains panicle^{-1} (237.00) was recorded in N_3V_3. The lowest number of filled grains panicle^{-1} (116.73) was recorded in N_1V_4 which was statistically similar with N_1V_1 (128.07), N_1V_3 (129.15) and N_2V_1 (134.87). Significant impact due to interaction of variety and nitrogen also reported by Hossain *et al.* (2018), Gewaily *et al.* (2018), Saha *et al*. (2017) and Shukla *et al*. (2015).

4.2.6 Unfilled grains panicle^{-1}

4.2.6.1 Effect of nitrogen

Nitrogen had significant effect on unfilled grains panicle^{-1} (Figure 21 and Appendix XI). Number of unfilled grains panicle^{-1} was reversal to that of filled grains at variable nitrogen levels. The number of unfilled grains panicle^{-1} under different nitrogen levels showed a trend that number of unfilled grains decreased with the increase of nitrogen levels. The maximum number of unfilled grains panicle^{-1} (43.09) was produced by 50 kg N ha^{-1}. The minimum number of unfilled grains panicle^{-1} (33.66) was recorded when 150 kg N ha^{-1} was applied which was statistically at par with 100 kg N ha^{-1}. These results were similar to those obtained by Metwally *et al.* (2010) and Ghoneim (2014). The variability in number of filled or unfilled grains panicle^{-1} was dependent on many factors such as genotypes, cultural techniques and growing environment of the crop (Maloch and Kinzer, 2006). Excessive as well as low application of nitrogen fertilizer causes lower number of filled grains and higher number of unfilled grains panicle^{-1} of rice (Haque and Haque, 2016). Tayefe *et al.* (2014) found no significant effect of nitrogen on unfilled grains.

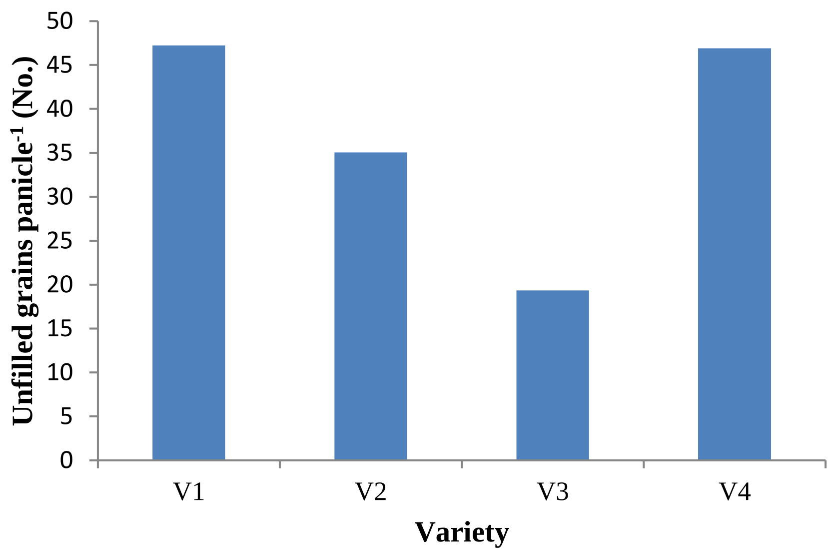


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 21. Effect of nitrogen on unfilled grains panicle^{-1} of transplanted aman rice (LSD$_{(0.05)}$= 3.32).

4.2.6.2 Effect of variety

Among the undesirable traits, number of unfilled grains panicle^{-1} was important one and played a vital role in yield reduction (Islam *et al.*, 2013). Varietal difference had significant influence on unfilled grain panicle^{-1} (Figure 22 and Appendix XI). The maximum number of unfilled grains panicle^{-1} (47.24) was observed in V_1 (SAU ADL1) which was statistically similar with V_4 (SAU ADL11). The minimum number of unfilled grains panicle^{-1} (19.33) was observed in V_3 (BRRI hybrid dhan6). The maximum unfilled grains decreased the final yield as well as minimum unfilled grains increase the grain yield (Howlader *et al*., 2017). Significant influence of variety on unfilled grains panicle^{-1} was also reported by Chowhan *et al.* (2017) who stated that though most of the modern varieties had few unfilled grains panicle^{-1} but here cultural management and environmental conditons might have affected this character. This result also corroborated with Sarkar *et al.* (2016), Islam *et al.* (2013), Chowdhury *et al.* (1993) and Anon. (1993).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 22. Effect of variety on unfilled grains panicle^{-1} of transplanted aman rice ($LSD_{(0.05)}$= 4.90).

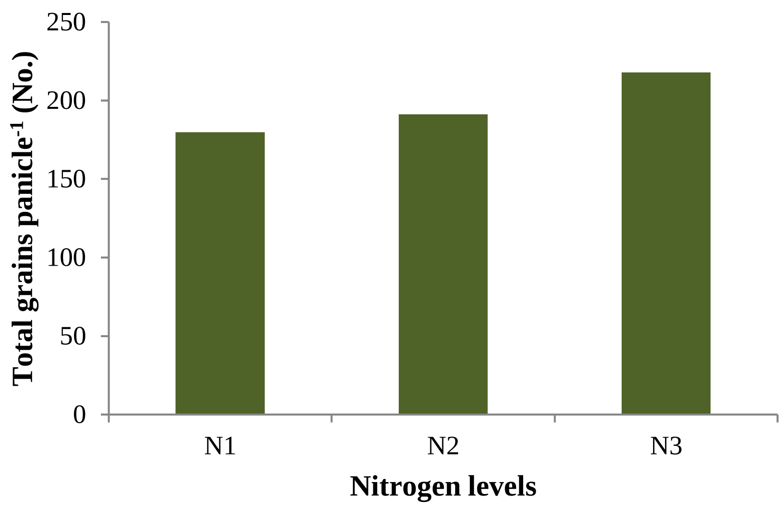
4.2.6.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant influence on unfilled grains panicle^{-1} (Table 8 and Appendix XI). The number of unfilled grains panicle^{-1} decreased with the increase in nitrogen level in all the varieties. The highest number of unfilled grains panicle^{-1} (53.77) was recorded for the combination of SAU ADL11 with 50 kg N ha^{-1} (N_1V_4) which was statistically similar with N_1V_1 (51.60), N_1V_2 (48.50) and N_2V_1 (45.46). The lowest number of unfilled grains panicle^{-1} (16.17) was observed in N_3V_3 which was statistically similar with N_2V_3 (18.50) and N_1V_3 (23.33). Gewaily *et al.* (2018) did not find any significant effect due to interaction of variety and nitrogen.

4.2.7 Total grains panicle^{-1}

4.2.7.1 Effect of nitrogen

Results obtained in the present study revealed that nitrogen had significant effect on total grains panicle^{-1} (Figure 23 and Appendix XI). The maximum grains panicle^{-1} (217.81) was obtained from N_3 (when 150 kg N ha^{-1} was applied) followed by N_2 (100 Kg N ha^{-1}) and minimum number of grains panicle^{-1} (179.74) was recorded in N_1 (50 kg N ha^{-1}). Higher number of grains panicle^{-1} at higher nitrogen rate might be due to higher nitrogen absorption which favored formation of higher number of branches panicle^{-1} (Rahman *et al.*, 2007a). This results were in agreement with Adhikari *et al.* (2018), Haque and Haque (2016), Siddique *et al.* (2014), Tayefe *et al.* (2014), Satpute *et al*. (2015), Singh *et al.* (2009), Reddy and Pattar (2006), Budhar (2005) and Chopra and Chopra (2000).

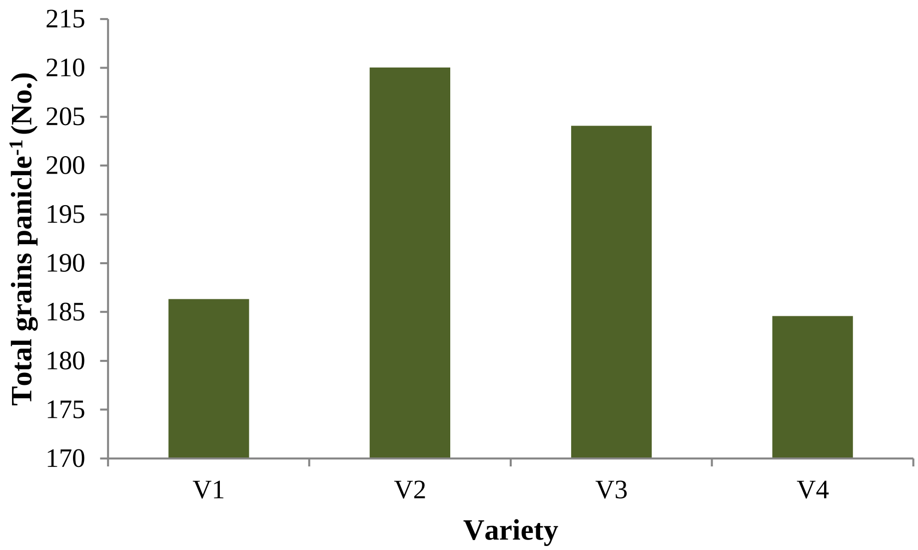


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 23. Effect of nitrogen on total grains panicle^{-1} of transplanted aman rice ($LSD_{(0.05)}$= 13.75).

4.2.7.2 Effect of variety

Varietal difference significantly influenced total number of grains panicle^{-1} (Figure 24 and Appendix XI). The highest number of total grains panicle^{-1} (210.04) was recorded in BRRI dhan70 which was statistically similar with BRRI hybrid dhan6 (204.06). The lowest number of total grains panicle^{-1} (186.32) was obtained from SAU ADL1 which was statistically similar with SAU ADL11 (184.60). This result was in line with the findings of Howlader *et al.* (2017), Murshida *et al.* (2017) and Tayefe *et al*. (2014).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 24. Effect of variety on total grains panicle^{-1} of transplanted aman rice (LSD$_{(0.05)}$=16.17).

4.2.7.3 Interaction effect of nitrogen and variety

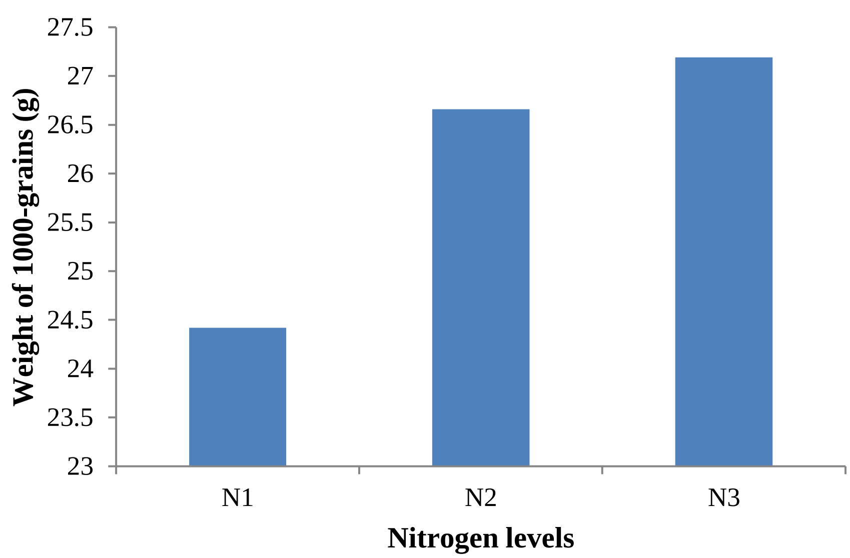
A perusal of data revealed that interaction effect of nitrogen and variety significantly affected total grains panicle^{-1} (Table 8 and Appendix XI). The highest number of total grains panicle^{-1} (253.23) was produced by BRRI hybrid dhan6 fertilized with 150 kg N ha^{-1} (N_3V_3) followed by N_2V_2 (221.20) and N_3V_2 (220.80). The lowest total grains panicle^{-1} (147.60) was recorded from N_1V_3 which was statistically similar with N_1V_4 (170.50).

This result was in agreement with Sarkar *et al.* (2014), Abou- Khalifa (2012) and Hossain *et al.* (2008).

4.2.8 Weight of 1000-grains

4.2.8.1 Effect of nitrogen

Nitrogen had little significant effect on weight of 1000-grains (Figure 25 and Appendix XII). Among the nitrogen levels, lowest one produced minimum 1000-grains weight and other two produced 1000-grains weight statistically at par with each other. The maximum weight of 1000-grains (27.19 g) was obtained when 150 kg N ha^{-1} was applied which was statistically similar with 100 kg N ha^{-1}. The minimum weight of 1000 grains (24.42 g) was obtained when 50 kg N ha^{-1} was applied. In case of thousand grains weight, the variation was very low among the treatments as it was known to be genetically controlled character. Similar results were found by other scientists (Ahmed *et al.*, 2005, Maske *et al.*, 1997) with nitrogen fertilizer management and concluded that there was little opportunity to improve grain size through agronomic management. Moro *et al.* (2015),



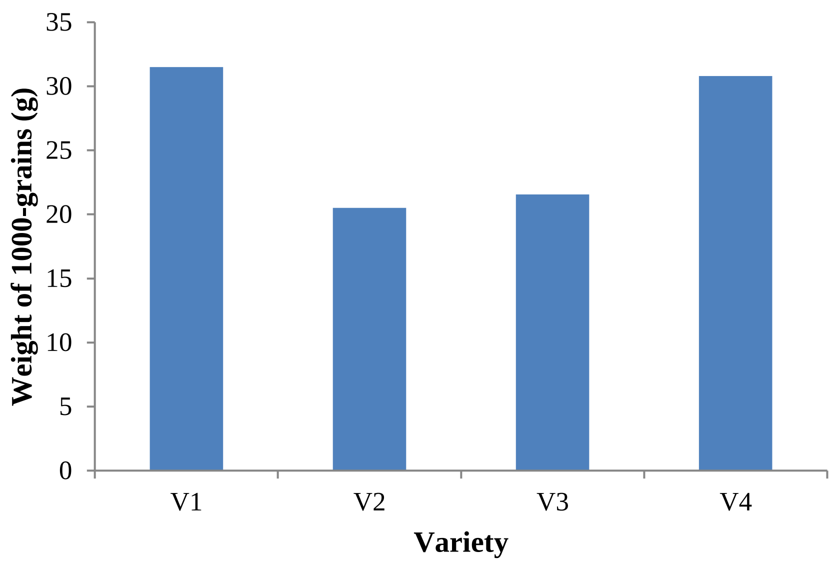
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 25. Effect of nitrogen on weight of 1000-grains of transplanted aman rice ($LSD_{(0.05)}$= 0.76).

Tayefe *et al*. (2014) and Siddique *et al.* (2014) also found no significant effect of nitrogen on 1000 grains weight. But the promoting effects of nitrogen on 1000-grains weight were reported by Metwally *et al.* (2010), Ghanbari-Malidareh (2011) and Sorour *et al.* (2016). Tayefe *et al.* (2014) reported that seed weight was typically of minor importance in determining rice yield which accounts for only 3% variation in yield.

4.2.8.2 Effect of variety

Variety had significant effect on weight of 1000-grains (Figure 26 and Appendix XII). The maximum weight of 1000-grains (31.49 g) was obtained from SAU ADL1 followed by SAU ADL11 (30.80 g). The minimum weight of 1000-grains (20.50 g) was recorded in BRRI dhan70 and second lowest 1000-grains weight (21.56 g) in BRRI hybrid dhan6. SAU ADL1 produced higher grain weight due to large size coarse grain and BRRI dhan70 produced lower grain weight due to long, slender and fine grain. Roy *et al*. (2014) studied on 12 rice varieties and found difference in weight of 1000-grains due to morphological and varietal variation. Mondal *et al*. (2005) stated that 1000-grain weight differed significantly among the 17 aman cultivars studied.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 26. Effect of variety on weight of 1000-grains of transplanted aman rice ($LSD_{(0.05)}$= 0.60).

Similar result was also recorded by Murshida *et al*. (2017), Chowhan *et al.* (2017) and Howlader *et al.* (2017), Sarkar *et al*. (2016), Islam *et al*. (2013), Sarkar (2003), Tunio *et al.* (2002), Khatun (2001) Singh *et al.* (1986) and Dhal and Misra (1993). Islam *et al.* (2013) opined that grain yield had significant positive relationship with 1000-grains weight.

4.2.8.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly influenced weight of 1000-grains (Table 9 and Appendix XII). The maximum 1000-grains weight (32.22 g) was recorded from N_2V_4 which was statistically at par with N_3V_4 (32.15 g), N_2V_4 (32.22 g) and N_2V_1 (32.10 g). The minimum 1000-grains weight (19.19 g) was obtained from the interaction N_1V_2 which was statistically similar with N_1V_3 (20.04 g). Hossain *et al.* (2018), Saha *et al.* (2017), Shukla *et al.* (2015), Fageria and Santos (2015) Jisan *et al.* (2014), Abou-Khalifa (2012) and Hossain *et al.* (2008) also found significant effect due to interaction of nitrogen and variety.

Table 9. Interaction effect of nitrogen and variety on weight of 1000-grains, yield and harvest index of transplanted aman rice

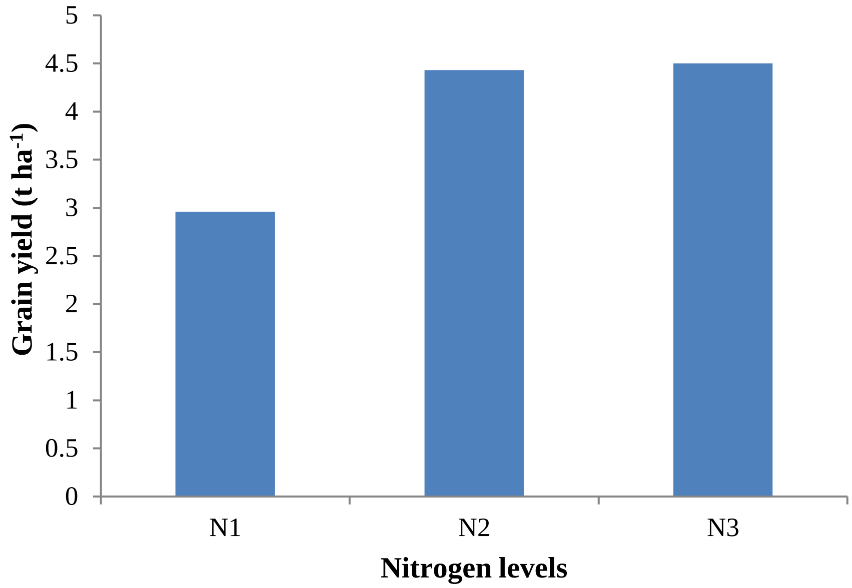
Treatment combinations	Weight of 1000-grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_1V_1	30.41 b	2.52 g	8.09 b	10.61 d	23.67 e
N_1V_2	19.19 g	2.98 f	5.80 d	8.78 ef	33.67 bc
N_1V_3	20.04 fg	3.82 de	5.01 e	8.83 e	43.00 a
N_1V_4	28.02 c	2.53 g	4.98 e	7.52 f	33.33 bc
N_2V_1	32.10 a	3.84 d	9.90 a	13.73 a	27.67 de
N_2V_2	20.80 ef	4.67 c	8.18 b	12.84 ab	36.33 b
N_2V_3	21.53 e	5.70 b	6.44 cd	12.13 bc	46.33 a
N_2V_4	32.22 a	3.54 de	6.53 c	10.06 de	35.33 bc
N_3V_1	31.97 a	3.64 de	9.99 a	13.64 a	26.67 e
N_3V_2	21.52 e	4.70 c	8.34 b	13.04 ab	36.67 b
N_3V_3	23.12 d	6.22 a	7.15 c	13.37 ab	47.00 a
N_3V_4	32.15 a	3.44 e	6.53 c	11.07 cd	31.33 cd
LSD $_{(0.05)}$	1.04	0.35	0.72	1.30	4.12
CV (%)	2.32	5.19	5.81	6.68	6.85

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.2.9 Grain yield

4.2.9.1 Effect of nitrogen

Nitrogen had significant effect on grain yield (Figure 27 and Appendix XII). Grain yield increased significantly with the increase of nitrogen levels up to 100 kg N ha^{-1} and then the increase for 150 kg N ha^{-1} was not statistically significant. The highest grain yield (4.50 t ha^{-1}) was recorded for 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1}. The lowest grain yield (2.96 t ha^{-1}) was obtained when 50 kg N ha^{-1} was applied. The grain yield at 100 kg and 150 kg N ha^{-1} indicated that the varieties are highly efficient in nitrogen use at 100 kg N ha^{-1} that causes corresponding increase in growth and yield components and after that the efficiency reached almost at plateau except hybrid variety. It revealed that excess N rates did not give extra benefit regarding to grain yield. Application of 100 and 150 kg N ha^{-1} increased panicle $hill^{-1}$, grains $panicle^{-1}$, filled grains $panicle^{-1}$ and seed size which ultimately increased the yield of the rice variety. Grain yield of rice plant is highly relying on the number of spike-bearing tillers produced by each plant, filled grains and grains weight (Huang *et al.*, 2011). The yield of rice depends on its different growth parameters, i.e. leaf area index, dry matter production and its partitioning, tillering, etc. (Shams, 2002). The increment of grain yield in this study at higher nitrogen levels might be due to efficient absorption of nitrogen and other elements which raise the production and translocation of the dry matter from source to sink (Ebaid and Ghanem, 2000; Morteza *et al*., 2011). Wang-Dan *et al.* (2008) reported that rice yield was significantly increased by N. Similar results were found elsewhere (Adhikari *et al.*, 2018, Sen *et al*., 2011, Stalin *et al.*, 2008 and Salahuddin *et al.*, 2009). The studies by Koutroubas and Ntanos (2003) and Gharib *et al.* (2011) also reported that increasing nitrogen level up to 150 kg N ha^{-1} enhanced grain yield. Moro *et al.* (2015), Tayefe *et al*. (2014) and Siddique *et al.* (2014) found an increasing trend in grain yield with an increase in levels of nitrogen up to 90 kg N ha^{-1} and further increase in nitrogen application decreased grain yield. Artacho *et al.* (2009) illustrated that grain yield showed a significant quadratic response to N fertilization.

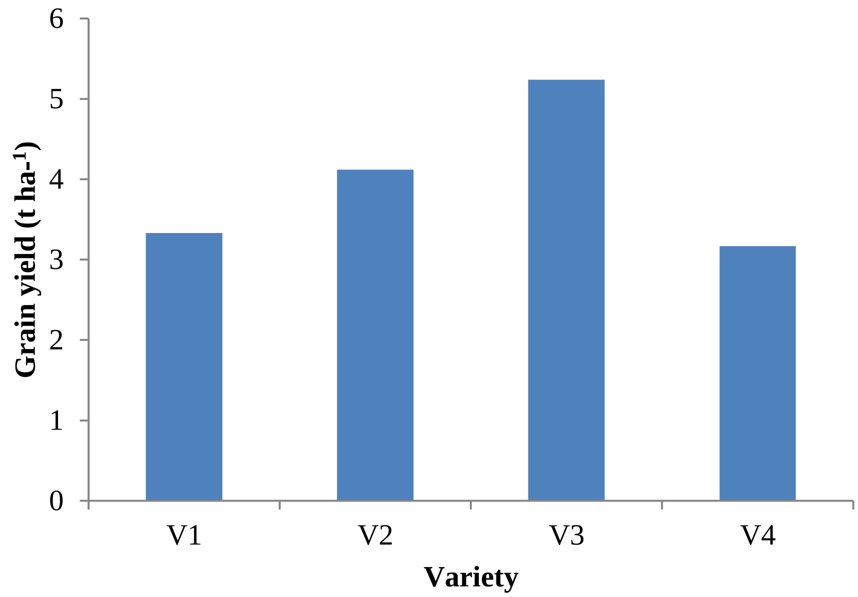


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 27. Effect of nitrogen on grain yield of transplanted aman rice ($LSD_{(0.05)}$= 0.25).

4.2.9.2 Effect of variety

Grain yield is a function of inter play of various yield components such as number of productive tillers, panicle length, percentage of grain filling and 1000-grains weight (Hassan *et al.*, 2009). Grain yield varied significantly from cultivar to cultivar (Figure 28 and Appendix XII). Among the studied materials, the highest grain yield (5.24 t ha^{-1}) was obtained from BRRI hybrid dhan6 followed by BRRI dhan70 (4.12 t ha^{-1}). The lowest grain yield (3.17 t ha^{-1}) was obtained from SAU ADL11 which was statistically similar with SAU ADL1 (3.33 t ha^{-1}). More number of grains panicle^{-1}, less number of non-effective tillers of BRRI hybrid dhan6 may have resulted in higher yield. Poor tillering, less number of grains panicle^{-1}, lodging tendency and more straw yield may be the reasons for such lower yield in SAU ADL1 and SAU ADL11. Islam *et al*. (2013) reported that the varieties which produced higher number of effective tillers hill^{-1} and higher number of filled grains panicle^{-1} also showed higher grain yield ha^{-1}. Varietal differences of grain yield were reported by Biswas *et al.* (1998) and Dwivedi (1997). The genotypes, which produced higher number of effective tillers hill^{-1} and higher number of grains panicle^{-1} also showed higher grain yield in rice (Dutta *et al.* 2002). Yield differences due to varieties were recorded by Chowhan *et al*. (2017) , Sarkar *et al*. (2016), Islam *et al.* (2014), Jisan *et al.* (2014) and Tyeb *et al* (2013) and Islam *et al.* (2013) and Tayefe *et al*. (2014) who observed variable grain yield among varieties.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 28. Effect of variety on grain yield of transplanted aman rice ($LSD_{(0.05)}$= 0.20).

4.2.9.3 Interaction effect of nitrogen and variety

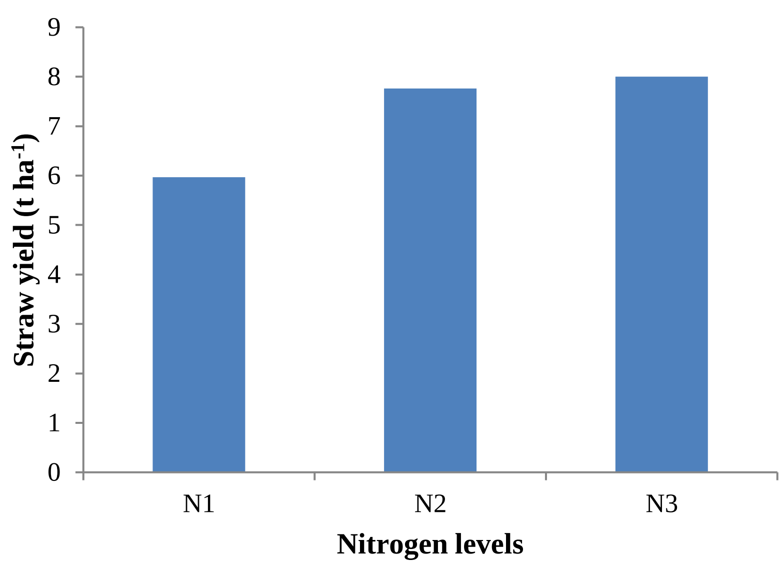
Combined effect of nitrogen and variety had significant influence on grain yield (Table 9 and Appendix XII). Grain yield increased with the increase of nitrogen level among all the varieties but sometimes not statistically significant. The highest grain yield (6.22 t ha^{-1}) was obtained from the combination N_3V_3 followed by N_2V_3 (5.70 t ha^{-1}). The lowest grain yield (2.52 t ha^{-1}) was recorded in N_1V_1 which was statistically similar with N_1V_4 (2.53 t ha^{-1}). These findings were in conformity with the results of Hossain *et al.* (2018), Saha *et al.* (2017), Fageria and Santos (2015), Shukla *et al.* (2015), Jisan *et al.* (2014), Abou-Khalifa (2012) and Hossain *et al*. (2008).

4.2.10 Straw yield

Straw yield is the amount of rest photosynthates after partitioned to economic yield (Kumar, 2016).

4.2.10.1 Effect of nitrogen

Nitrogen levels influenced straw yield but not statistically significant always (Figure 29 and Appendix XII). The maximum straw yield (8.00 t ha^{-1}) was obtained from 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1} (7.76 t ha^{-1}). The minimum straw yield (5.97 t ha^{-1}) was recorded at 50 kg N ha^{-1}. Siddique *et al.* (2014) also reported the similar trend of straw yield that beyond 90 kg N ha^{-1}, the increase in straw yield was not significant. These results were in accordance with the results of Shah *et al*. (2013), Das (2011), Mahajan *et al*. (2011), Thind *et al.* (2010), Sathiya and Ramesh (2009) Mhaskar *et al.* (2005b), Chopra and Chopra (2000) and Islam *et al.* (1997). Application of nitrogenous fertilizer encouraged vegetative growth of rice in terms of plant height and number of total tillers $hill^{-1}$, which ultimately resulted in the increase of straw yield (Mishra *et al.*, 2003).

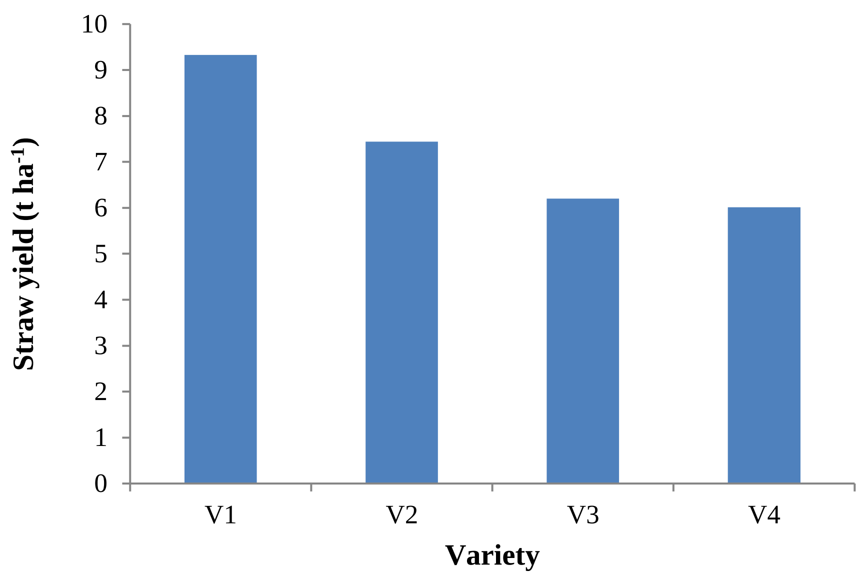


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 29. Effect of nitrogen on straw yield of transplanted aman rice ($LSD_{(0.05)}$= 0.72).

4.2.10.2 Effect of variety

Variety had significant effect on straw yield but straw yield of all studied materials did not differ significantly (Figure 30 and Appendix XII). The maximum straw yield (9.33 t ha^{-1}) was obtained from SAU ADL1 followed by BRRI dhan70 (7.44 t ha^{-1}). The minimum straw yield (6.01 t ha^{-1}) was obtained from SAU ADL11 which was statistically at par with BRRI hybrid dhan6 (6.20 t ha^{-1}). Delayed maturity and long duration may have caused in higher straw weight in SAU ADL1. Medium plant height, short duration and high yield may be the reason of low straw weight in BRRI hybrid dhan6. Plant height is a growth character of rice which contribution is more efficient to enhancing the straw yield incase of the tallest plant produce the higher yield of straw (Howlader *et al.*, 2017). The results were in accordance with the findings of Chowhan *et al.* (2017), Sarkar *et al.* (2016) and Hossain (2002). Pheloung and Siddique (1991) reported that straw yield could be assigned to plant height. Sarkar (2014) reported that straw weight differed significantly due to varieties. Mahmud *et al.* (2013) found that significant variation in straw yield due to the variation in genetic make up.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 30. Effect of variety on straw yield of transplanted aman rice ($LSD_{(0.05)}$= 0.42).

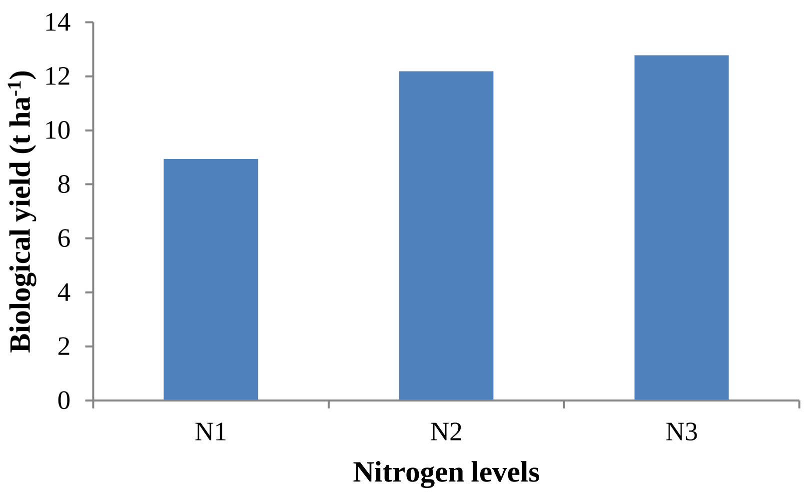
4.2.10.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant influence on straw yield (Table 9 and Appendix XII). Straw yield increased with the increase of nitrogen levels among all the varieties but not statistically significant always. The highest straw yield (9.99 t ha^{-1}) was recorded from N_3V_1 which was statistically at par with N_2V_1 (9.90 t ha^{-1}). The lowest straw yield (4.98 t ha^{-1}) was obtained from N_1V_4 which was statistically similar with N_1V_3 (5.01 t ha^{-1}). Saha *et al*. (2017), Shukla *et al.* (2015), Jisan *et al.* (2014) Hossain *et al.* (2008) also documented similar findings.

4.2.11 Biological yield

4.2.11.1 Effect of nitrogen

Nitrogen significantly influenced biological yield (Figure 31 and Appendix XII). The highest biological yield (12.78 t ha^{-1}) was obtained when 150 kg N ha^{-1} was applied which was statistically similar with 100 kg N ha^{-1}. The lowest biological yield (8.94 t ha^{-1}) was recorded for 50 kg N ha^{-1}. Adhikari *et al.* (2018) and Moro *et al.* (2015) also reported that biological yield was significantly affected due to application of nitrogenous fertilizer.

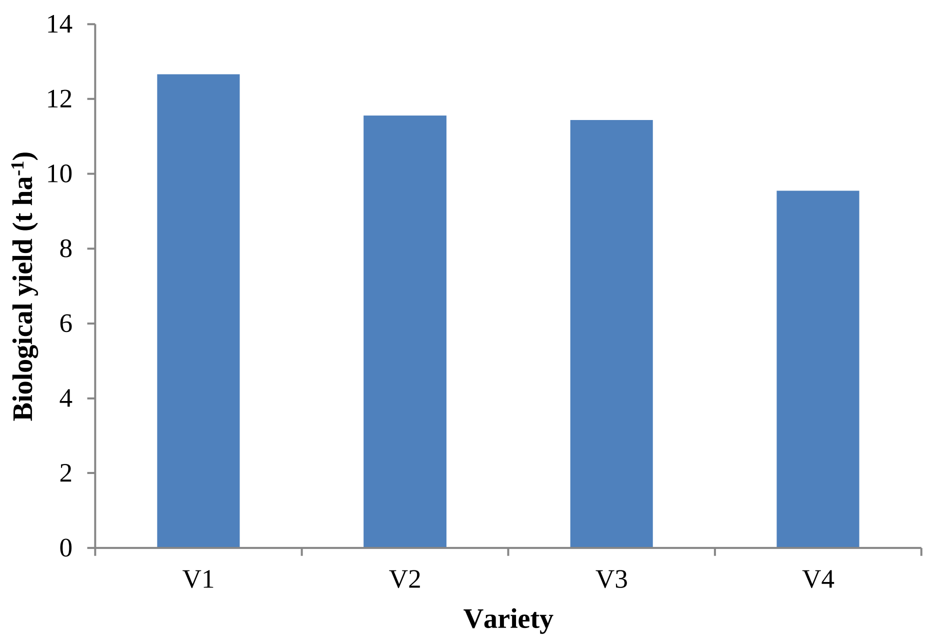


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 31. Effect of nitrogen on biological yield of transplanted aman rice ($LSD_{(0.05)}$= 0.95).

4.2.11.2 Effect of variety

Variety had significant influence on biological yield (Figure 32 and Appendix XII). The highest biological yield (12.66 t ha^{-1}) was recorded in SAU ADL1. The second highest biological yield (11.56 t ha^{-1}) was obtained from BRRI dhan70 which was statistically similar with BRRI hybrid dhan6 (11.44 t ha^{-1}). The lowest biological yield (9.55 t ha^{-1}) was recorded in SAU ADL11. Variation in maturity and duration may be the reason for differences in biological yield (Chowhan *et al.* (2017). Munshi (2005) reported that grain yield was positively correlated with biological yield in rice. Howlader *et al.* (2017) and Sarkar *et al.* (2016) reported varied biological yield among different rice varieties. Murshida *et al.* (2017), Hossain *et al*. (2014) and Islam *et al*. (2013) found that the variation in biological yield was also found due to the variation in grain and straw yield.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 32. Effect of variety on biological yield of transplanted aman rice ($LSD_{(0.05)}$= 0.75).

4.2.11.3 Interaction effect of nitrogen and variety

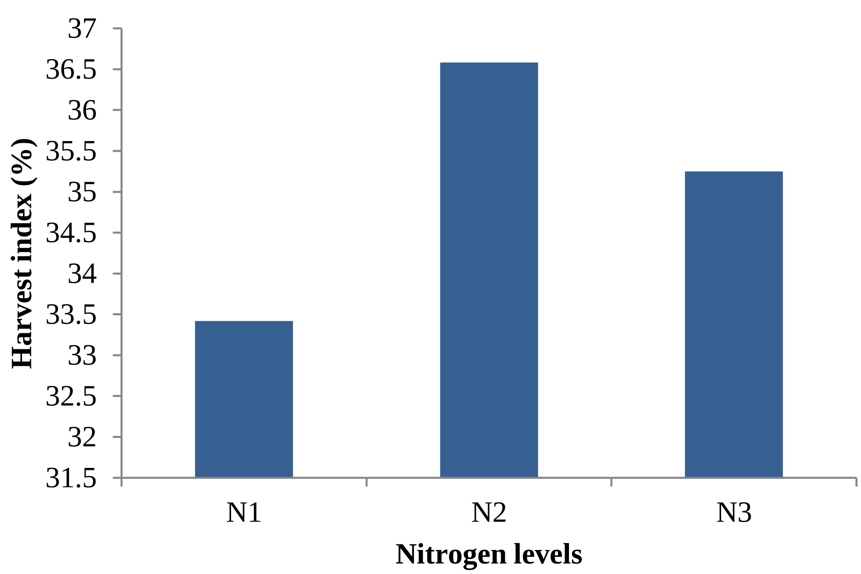
Interaction effect of nitrogen and variety influenced significantly the biological yield (Table 9 and Appendix XII). The highest biological yield (13.73 t ha^{-1}) was obtained from N_2V_1 which was statistically at par with N_3V_1 (13.64 t ha^{-1}), N_3V_3 (13.37 t ha^{-1}), N_3V_2 (13.04 t ha^{-1}) and N_2V_2 (12.84 t ha^{-1}) and. The lowest biological yield (7.52 t ha^{-1}) was recorded in N_1V_4 which was statistically similar with N_1V_2 (8.78 t ha^{-1}). Hossain *et al.* (2008) documented similar results.

4.2.12 Harvest index

Harvest index is also a measure of efficiency of crop production which indicates percentage of total photosynthates converted into economic yield (Kumar, 2016).

4.2.12.1 Effect of nitrogen

Nitrogen significantly influenced harvest index (Figure 33 and Appendix XII). The highest harvest index (36.58%) was recorded for 100 kg N ha^{-1} followed by 150 kg N ha^{-1} (35.25%). The lowest harvest index (33.42%) was obtained when 50 kg N ha^{-1} was



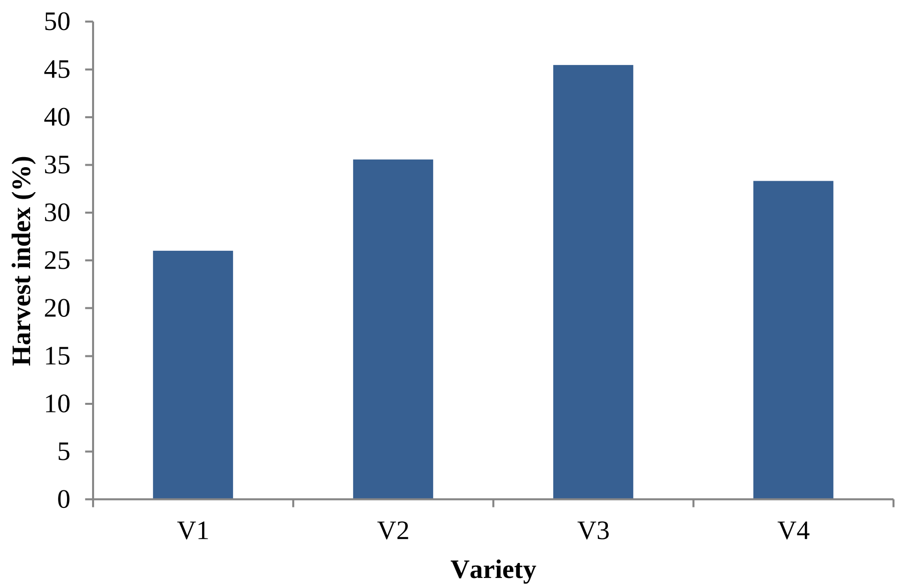
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 33. Effect of nitrogen on harvest index of transplanted aman rice ($LSD_{(0.05)}$=1.25).

applied. The findings were in agreement with those of Adhikari *et al.* (2018) and Siddique *et al.* (2014). Fageria *et al*. (2006) and Mae *et al*. (2006) explained that the HI represents partitioning of photosynthate between grain and vegetative plant parts. But Tayefe *et al.* (2014) did not observe any significant effect of nitrogen on harvest index.

4.2.12.3 Effect of variety

Harvest index varied significantly among different varieties (Figure 34 and Appendix XII). The highest harvest index (45.44%) was obtained from BRRI hybrid dhan6 followed by BRRI dhan70 (35.56%) and SAU ADL11 (33.33%). The lowest harvest index (26.00%) was obtained from SAU ADL1. Harvest index is a vital character having physiological importance. It reflects translocation on alternatively dry matter partitioning of a given genotype to the economic parts (Chowhan *et al.* 2017). Kusutani *et al.* (2000) highlighted the contribution of high harvest index to yields. High yield is determined by physiological process leading to a high net accumulation of photosynthates and their partitioning (Miah *et al.* 1990).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 34. Effect of variety on harvest index of transplanted aman rice ($LSD_{(0.05)}$= 2.38).

Murshida *et al.* (2017), Sarkar *et al*. (2016), Jisan *et al.* (2014) and Tyeb *et al.* (2013) reported that variety had significant influence on harvest index. Uddin *et al*. (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. But Islam *et al.* (2013) reported no significant effect of variety on harvest index.

4.2.12.3 Interaction effect of nitrogen and variety

Nitrogen and variety combinedly influenced harvest index significantly (Table 9 and Appendix XII). The highest harvest index (47%) was recorded for N_3V_3 which was statistically similar with N_2V_3 (46.33%). The lowest harvest index (23.67%) was recorded for N_1V_1 which was statistically similar with N_3V_1 (26.67%) and N_2V_1 (27.67%). Saha *et al.* (2017), Shukla *et al.* (2015), Fageria and Santos (2015) Hossain *et al*. (2008) also observed that harvest index was significantly influenced by N and genotype treatments.

4.3 Quality characters

4.3.1 Physical properties

Rice grain quality largely depends on the physicochemical properties which are greatly influenced by the genotype (Kishine *et al.,* 2008).

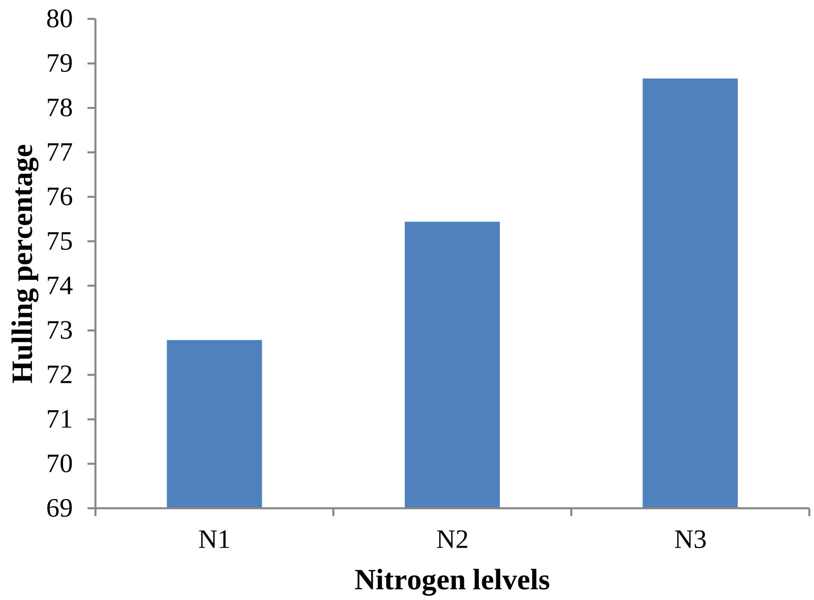
4.3.1.1 Hulling percentage

The dehulling of rice is one of the important post harvest processes. If the hulling percentage is high, then the recovery of rice also increases.

4.3.1.1.1 Effect of nitrogen

Nitrogen had significant effect on hulling percentage (Figure 35 and Appendix XIII). The highest hulling percentage (78.66) was recorded at 150 kg N ha^{-1} followed by 100 kg N ha^{-1} (75.44). The lowest hulling percentage (72.78) was recorded at 50 kg N ha^{-1}. Gharieb *et al.* (2016) also reported that hulling percentage (HP) significantly increased with increasing nitrogen levels and opined that this increase could be attributed due to the application of nitrogen increased grain filling rate consequently decreased the hull thickness. These findings were in close agreement with those reported by Kaur (2016), Murthy *et al.* (2015), Subudhi *et al.* (2012), Metwally *et al.* (2011a), Srivastava *et al.* (2009) and Kandil *et al.*

(2010) who obtained marked increase in hulling percentage with increased nitrogen level. Significant increase in hulling percentage and head rice recovery due to increase of N dose from 40 to 80 kg ha^{-1} was also reported by Adhikari *et al*. (2005).

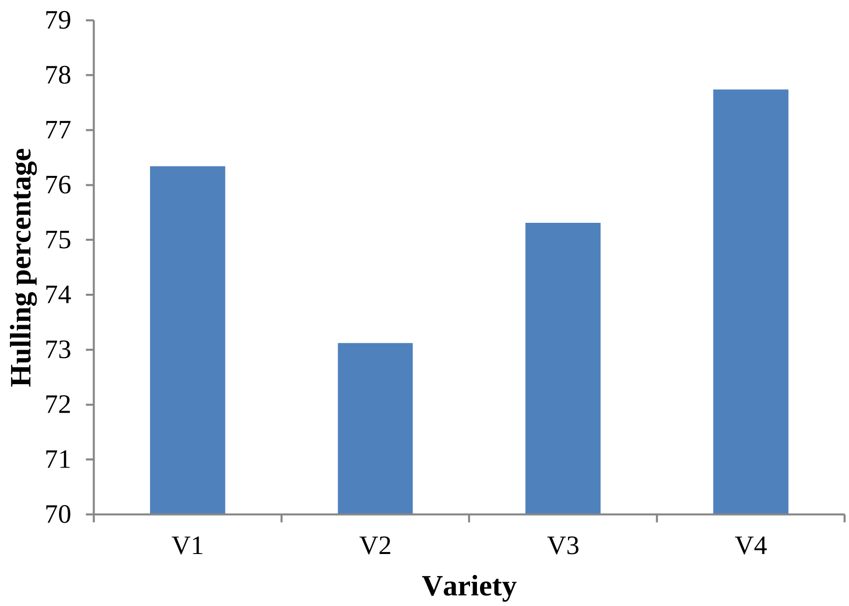


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 35. Effect of nitrogen on hulling percentage of transplanted aman rice ($LSD_{(0.05)}$= 2.51).

4.3.1.1.2 Effect of variety

Varietal difference had significant impact on hulling percentage (Figure 36 and Appendix XIII). The highest hulling percentage (77.74) was obtained from SAU ADL11 which was statistically similar with SAU ADL1 (76.34). The lowest hulling percentage (73.12) was obtained from BRRI dhan70. Paul (2016) also found hulling percentage (76.97) in SAU ADL1. This finding was in conformity with the results of Vikram *et al.* (2018) who opined that variation in hulling percentage was due to differences in genetic potential and moisture content. Similar findings had also been reported by Khaled *et al.* (2014) and Subudhi *et al.* (2012).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 36. Effect of variety on hulling percentage of transplanted aman rice ($LSD_{(0.05)}$= 1.72).

4.3.1.1.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant impact on hulling percentage (Table 10 and Appendix XIII). The highest hulling percentage (82.67) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4) followed by N_3V_3 (78.82). The lowest hulling percentage (71.31) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} which was statistically similar with N_1V_3 (72.48), N_1V_4 (72.48), N_2V_2 (78.28), N_2V_3 (74.85). Ebaid and El-Hissewy (2000) indicated that increasing nitrogen fertilizer levels from 0 up to 165 kg N ha^{-1} significantly increased hulling percentage in Sakha 101 rice cultivar. Kaur (2016) and Khaled *et al.* (2014) also found significant effect of nitrogen and variety on hulling percentage.

Table 10. Interaction effect of nitrogen and variety on physical properties of transplanted aman rice

Treatment combinations	Hulling percentage	Milling outturn (%)
N_1V_1	74.85 cd	67.33 ef
N_1V_2	71.31 f	63.67 f
N_1V_3	72.48 ef	70.27 de
N_1V_4	72.48 ef	72.15 b-e
N_2V_1	76.77 bcd	72.79 a-d
N_2V_2	72.28 ef	71.78 cde
N_2V_3	74.63 de	74.89 a-d
N_2V_4	78.08 bc	76.68 abc
N_3V_1	77.40 bcd	75.52 a-d
N_3V_2	75.77 cd	72.91 a-d
N_3V_3	78.82 b	77.18 ab
N_3V_4	82.67 a	77.63 a
LSD $_{(0.05)}$	2.99	5.27
CV (%)	2.30	4.22

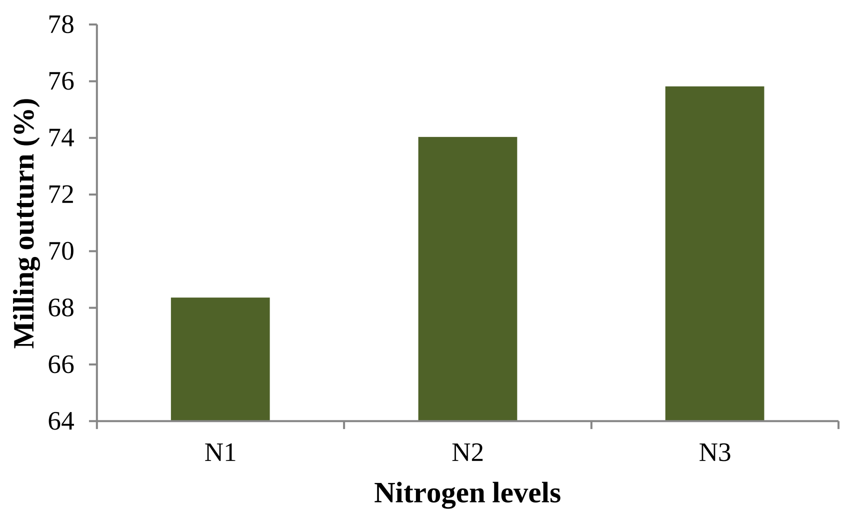
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

4.3.1.2 Milling outturn (MOT)

Milling outturn (MOT) is one of the key parameters of the rice grain quality as it increases the shelf life and provides the consumer with more whiteness that they desire (Hosen *et al.,* 2017). Milling outturn is the total quantity of head rice and broken rice recovered from unit quantity of rough rice. In general milling outturn more than 50% is desirable as the more the value the less the rough rice is discarded as bran. Milling quality was significantly negatively related with cooking/eating quality (Da-wei *et al.,* 2017).

4.3.1.2.1 Effect of nitrogen

Nitrogen had significant influence on milling outturn (Figure 37 and Appendix XIII). The highest milling outturn (75.81%) was recorded at 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1} (74.03%). The lowest milling outturn (68.36%) was obtained when 50 kg N ha^{-1} was applied. Similar results were recorded by Gharieb *et al.* (2016) who concluded that the increase in milling percentage might be due to the increase in metabolite substances in grains, which were attributed with the increasing nitrogen levels. These findings were in close agreement with those of reported by Murthy *et al.* (2015), Metwally *et al.* (2011a), Srivastava *et al.* (2009) and Kandil *et al.* (2010) who obtained marked increase in milling and head rice percentages with increased nitrogen level. Previous study had reported that an increasing nitrogen level could improve the milling quality (Liu *et al*. 2007), which was primarily due to the fact that increasing nitrogen level increased the gliadin content in grains. Da-wei *et al.* (2017) reported that the milling quality was significantly negatively related with eating/cooking quality, which was primarily due to the significant increase in protein content due to the application of nitrogen. Although an increase in protein content is beneficial to milling quality, it hampers the eating/cooking quality.

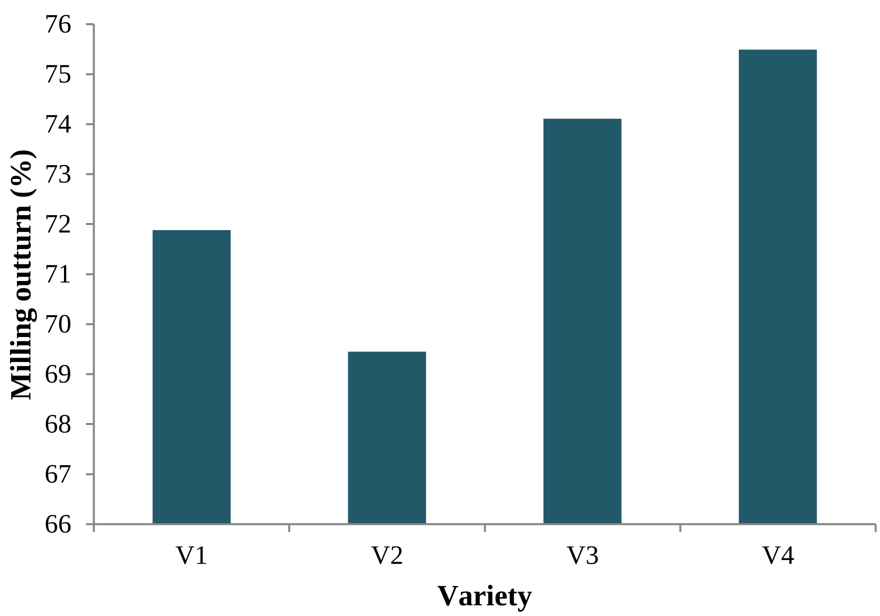


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 37. Effect of nitrogen on milling outturn of transplanted aman rice ($LSD_{(0.05)}$= 2.08).

4.3.1.2.2 Effect of variety

Variety had significant effect on milling outturn (Figure 38 and Appendix XIII). Milling outturn (MOT) ranged from 69.45% to 75.49% among the tested materials. The highest milling outturn (75.49%) was obtained from SAU ADL11 which was statistically similar with BRRI hybrid dhan6 (74.11%). The lowest milling outturn (69.45%) was obtained from BRRI dhan70 which was statistically similar with SAU ADL1 (71.88%). Among the tested cultivars, three cultivars showed milling outturn more than 70 %. Similar findings were scrutinized by Khaled *et al.* (2014), Shozib *et al.* (2017), Hosen *et al.* (2017), Subudhi *et al.* (2012) and Babu *et al.* (2013), Dipti *et al.* (2002). This result was in agreement with Vikram *et al.* (2018) who reported that variation in milling outturn might be due to variations in genetic characteristics and moisture percentage.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 38. Effect of variety on milling outturn of transplanted aman rice ($LSD_{(0.05)}$= 3.04).

4.3.1.2.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly affected milling outturn (Table 10 and Appendix XIII). The highest milling outturn (77.63%) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4) which was statistically similar with N_3V_3 (77.18%), N_2V_4 (76.68%), N_2V_3 (74.89%) and N_2V_1 (72.79%). The lowest milling outturn (63.67%) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with N_1V_1 (67.33%). These findings were in close agreement with those reported by Kaur (2016) and Ebaid and El-Hissewy (2000). Khaled *et al*. (2014) found no significant effect of interaction on milling percentage.

4.3.2 Chemical properties

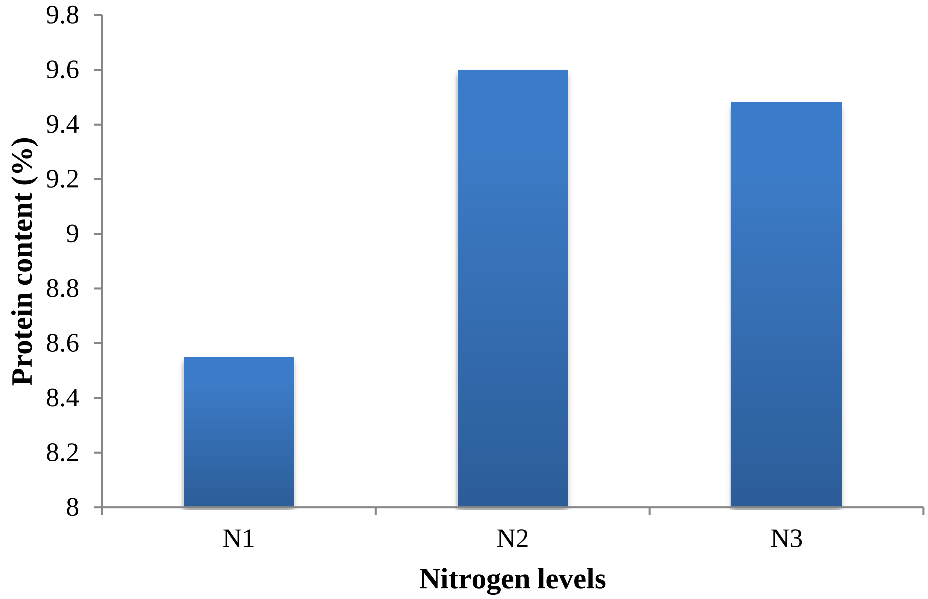
Nutritive quality is largely determined by physicochemical characteristics of rice, such as amylose content (AC), gel consistency (GC), and protein content (PC) (Da-wei *et al.*, 2017).

4.3.2.1 Protein content

Protein content of rice is important from nutritional point of view. Several factors such as variety, environmental and cultural practices may influence the protein content of the grain.

4.3.2.1.1 Effect of nitrogen

Nitrogen had significant effect on protein content (Figure 39 and Appendix XIV). The highest protein (9.60%) was obtained from 100 kg N ha^{-1} which was statistically similar with 150 kg N ha^{-1} (9.48%). The lowest protein (8.55%) was obtained from 50 kg N ha^{-1}. Murthy *et al.* (2015), Maqsood *et al.* (2013) and Hao *et al.* (2007) recorded that nitrogen rate had a significant effects on protein content. Increased grain protein makes brown rice more resistant to cracking and breaking during abrasive milling (Sandhu *et al.,* 2015)

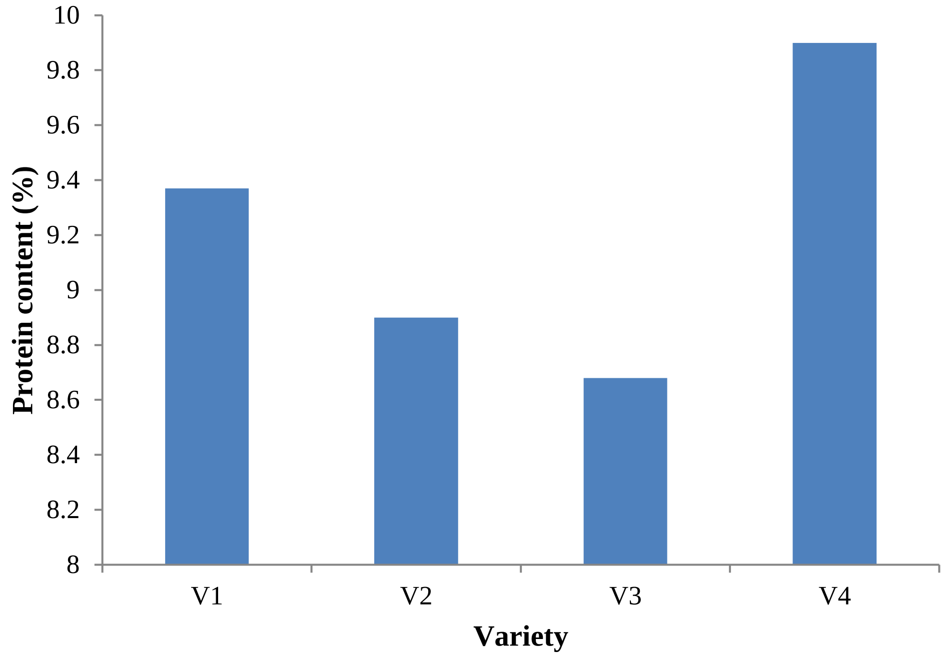


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 39. Effect of nitrogen on protein content of transplanted aman rice ($LSD_{(0.05)}$= 0.33).

4.3.2.1.2 Effect of variety

Variety had significant effect on protein content (Figure 40 and Appendix XIV). Protein content ranged from 9.90% to 8.68% among the cultivars. The highest protein (9.90%) was recorded in SAU ADL11 followed by SAU ADL1 (9.37%). The lowest protein (8.68%) was obtained from BRRI hybrid dhan6 which was statistically similar with BRRI dhan70 (8.9%). Shozib *et al.* (2017), Matin *et al.* (2017), Hosen *et al.* (2017), Dipti *et al.* (2002) also reported variable protein content among varieties. This result was consistent to Dutta *et al.* (1998) and Alam (2002) who recorded variable protein percentage among varieties. But Khaled *et al.* (2014) found no significant effect of variety on protein content. Varietal differences regarding grain protein content and aroma might be due to their difference in genetic make-up (Sarker *et al.*, 2014). The protein content of fine grain rice is usually lower (Kaul *et al.*, 1982; Dutta *et al.*, 1998) which was consistent with the findings of present study. Increased grain protein content increases its hardness and thus increases the milling recovery (Leesawatwong *et al.*, 2003).



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 40. Effect of variety on protein content of transplanted aman rice ($LSD_{(0.05)}$= 0.36).

4.3.2.1.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly influenced protein content (Table 11 and Appendix XIV). The highest protein (10.36%) was obtained from SAU ADL11 fertilized with 100 kg N ha^{-1} (N_2V_4) which was statistically similar with N_3V_4 (9.93%). The lowest protein (7.51%) was obtained from BRRI hybrid dhan6 fertilized with 50 kg N ha^{-1} (N_1V_3) which was statistically similar with N_1V_2 (7.81%). Sarkar *et al.* (2014), Khaled *et al.* (2014) documented similar findings of interaction effect of nitrogen and variety.

Table 11. Interaction effect of nitrogen and variety on chemical properties of transplanted aman rice

Treatment combinations	Protein content (%)	AAC %	Alkali spreading value
N_1V_1	9.50 bcd	25.67 a	3.50 e
N_1V_2	7.81 e	24.84 a	5.50 c
N_1V_3	7.51 e	21.85 cd	7.00 a
N_1V_4	9.40 bcd	24.37 ab	5.50 c
N_2V_1	9.60 bc	24.00 abc	4.50 d
N_2V_2	9.52 bcd	21.50 d	4.50 d
N_2V_3	8.93 d	21.43 d	7.00 a
N_2V_4	10.36 a	22.23 bcd	5.17 c
N_3V_1	9.00 cd	24.15 abc	4.50 d
N_3V_2	9.37 bcd	18.86 e	3.50 e
N_3V_3	9.60 bc	20.58 de	7.00 a
N_3V_4	9.93 ab	21.49 d	6.50 b
$LSD_{(0.05)}$	0.62	2.45	0.38
CV (%)	3.95	6.33	0.92

N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

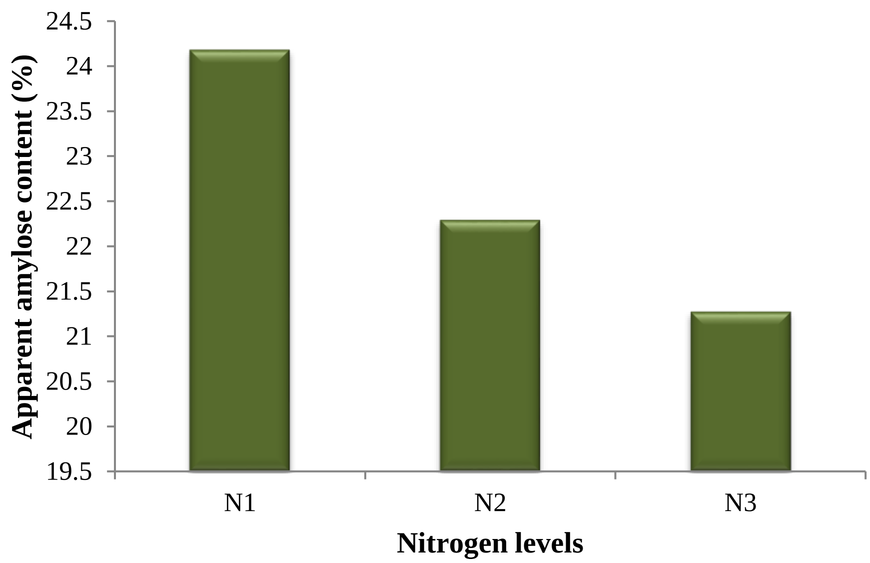
4.3.2.2 Apparent amylase content (AAC)

The apparent amylase content (AAC) of rice is considered as the main parameter of cooking and eating quality (Juliano, 1972). Amylose content of rice determines the hardness and stickiness of cooked rice (Hosen *et al.,* 2017). Da-wei *et al.* (2017) opined that AAC were significantly positively related with cooking/ eating quality.

4.3.2.2.1 Effect of nitrogen

Nitrogen had significant effect on apparent amylose content (Figure 41 and Appendix XIV). The highest apparent amylose content (24.18%) was recorded at 50 kg N ha^{-1}

followed by 100 kg N ha^{-1} (22.29%). The lowest apparent amylose content (21.27%) was recorded at 150 kg N ha^{-1}. Maqsood *et al.* (2013) recorded that nitrogen rate had a significant effect on amylose content. Similar findings were scrutinized by Da-wei *et al.* (2017) and Tayefe *et al*. (2014) who opined that AAC was decreased with the increase in nitrogen level. Ju-Young, (2006) showed that there was a negative correlation between nitrogen rate and AAC. Dong *et al*. (2007) confirmed with the above results when he showed that with an increase in the amount of nitrogen fertilizer from zero to 120 kg ha^{-1} in Japan's varieties under their studies, activation of starch branching enzymes increased and as a result amylopectin percentage increased while in contrast AC decreased. But Gharieb *et al.* (2016) found the existence of positive relation between nitrogen amount and amylose content.



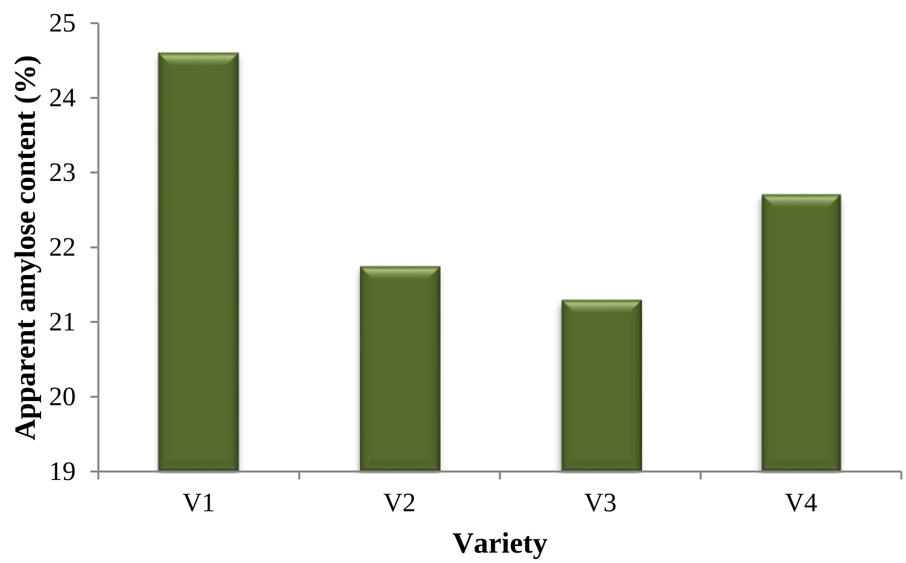
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 41. Effect of nitrogen on apparent amylose content of transplanted aman rice ($LSD_{(0.05)}$=0.88).

4.3.2.2.2 Effect of variety

Variety had significant effect on apparent amylose content. AAC ranged from 21.74% to 24.60% among the tested cultivars (Figure 42 and Appendix XIV). The highest AAC (24.60%) was obtained from SAU ADL1. The lowest AAC (21.29%) was obtained from

BRRI hybrid dhan6 which was statistically similar with BRRI dhan70 (21.74%) and SAU ADL11 (22.70%). Hosen *et al.* (2017), Shozib *et al.* (2017), Matin *et al*. (2017), Subudhi *et al.* (2012) and Dipti *et al.* (2002) also reported difference in amylose content among varieties. Rice having intermediate AAC (20-25%) gives soft and relatively sticky cooked rice (Hosen *et al.*, 2017). Shozib *et al.* (2017) opined that in Bangladesh, consumers preference is high amylose containing rice which become non sticky after cooking but intermediate amylose containing rice gradually popularizes in Bangladeshi population in recent days specially for formulation of baby foods and consuming by senior citizens of Bangladesh. Zhu *et al.* (2004) opined that rice varieties with high amylose content have bad eating/cooking quality while those with low amylose content usually have good eating/cooking quality.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 42. Effect of variety on apparent amylose content of transplanted aman rice ($LSD_{(0.05)}$= 1.42).

4.3.2.2.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant influence on apparent amylose content (Table 11 and Appendix XIV). The highest AAC (25.67%) was obtained from

SAU ADL1 fertilized with 50 kg N ha^{-1} which was statistically similar with N_1V_2 (24.84%), N_1V_4 (24.37%), N_3V_1 (24.15%) and N_2V_1 (24.00%). The lowest apparent amylose content (18.86%) was obtained from BRRI dhan70 fertilized with 150 kg N ha^{-1} (N_3V_2) which was statistically similar with N_3V_3 (20.58%). Da-wei *et al*. (2017) also reported that amylose content decreased among varieties with the increase of nitrogen levels. Kaur (2016) also reported that amylose content in rice grain in general decreased with nitrogen fertilization levels in both non-basmati and basmati varieties. Khaled *et al.* (2014), Maqsood *et al.* (2013) also confirmed these results. Tayefe *et al.* (2014) found that interaction effect of nitrogen and variety had significant influence on AAC. Ebaid and El-Hissewy (2000) indicated that increasing nitrogen fertilizer levels from 0 up to 165 kg N ha^{-1} significantly increased amylose content in Sakha101 rice cultivar.

4.3.2.3 Alkali spreading value (ASV)

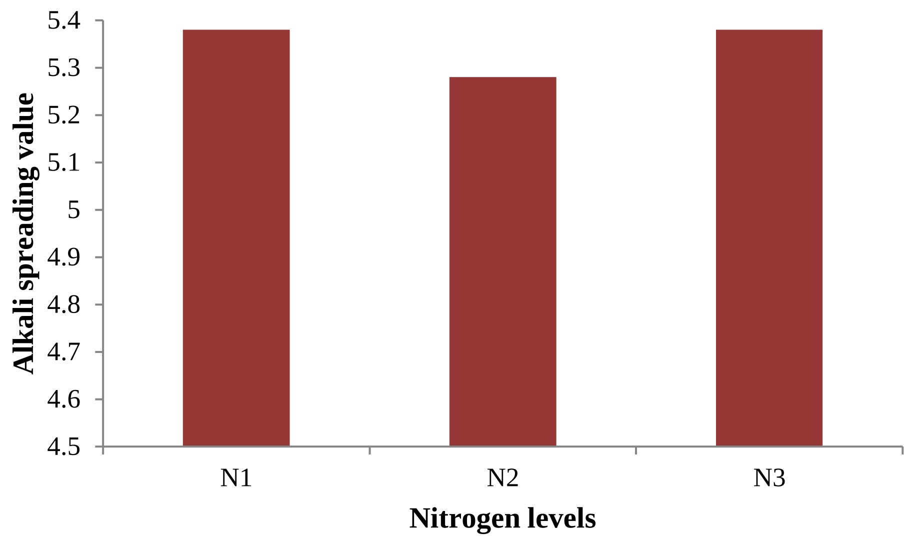
Alkali spreading value (ASV) gives an idea for gelatinization temperature. The quality and quantity of starch and gelatinization temperature strongly influence the cooking quality and cooking time. A low ASV correspond to a high gelatinization temperature; conversely, a high ASV indicates a low GT (Oko *et al*., 2012)

4.3.2.3.1 Effect of nitrogen

Nitrogen had no significant influence on alkali spreading value (Figure 43 and Appendix XIV). Alkali spreading value ranged from 5.38 to 5.28 due to different nitrogen levels which was statistically similar with one another. Kaur (2016) also found no significant effect of nitrogen on ASV.

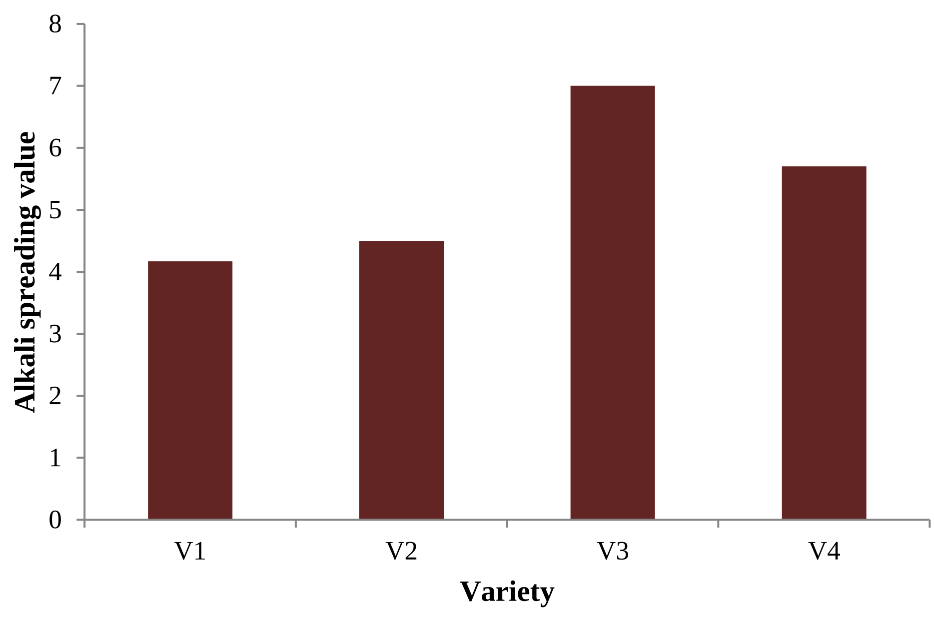
4.3.2.3.2 Effect of variety

Variety had significant effect on alkali spreading value (Figure 44 and Appendix XIV). The highest alkali spreading value (7.00) was obtained from BRRI hybrid dhan6 followed by SAU ADL11 (5.70). The lowest alkali spreading value (4.17) was obtained from SAU ADL1. Hosen *et al*. (2017), Matin *et al.* (2017), Subudhi *et al*. (2012) and Dipti *et al.* (2002) also reported similar findings. Matin *et al.* (2017) reported that alkali spreading value was negatively correlated with the cooking time which indicates that cooking time was higher for those varieties which had low alkali spreading value.



N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 43. Effect of nitrogen on alkali spreading value of transplanted aman rice



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 44. Effect of variety on alkali spreading value of transplanted aman rice ($LSD_{(0.05)}$= 0.22).

4.3.2.3.3 Interaction effect of nitrogen and variety

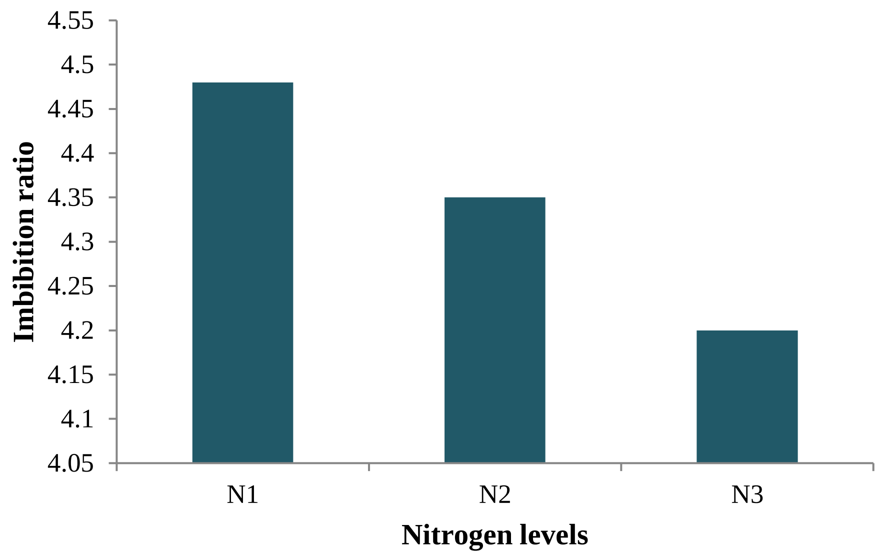
Interaction effect of nitrogen and variety had significant influence on alkali spreading value (Table 11 and Appendix XIV). The highest alkali spreading value (7.00) was recorded in BRRI hybrid dhan6 fertilized with 50, 100 and 150 kg N ha^{-1} (N_1V_3, N_2V_3 and N_3V_3). The lowest alkali spreading value (3.50) was obtained from SAU ADL1 fertilized with 50 kg N ha^{-1} (N_1V_1) and BRRI dhan70 fertilized with 150 kg N ha^{-1} (N_3V_2). But Kaur (2016) found no significant effect for interaction between nitrogen and variety on ASV.

4.3.3 Cooking properties

4.3.3.1 Imbibition ratio (IR)

4.3.3.1.1 Effect of nitrogen

Nitrogen had significant effect on imbibition ratio (Figure 45 and Appendix XV). The highest imbibition ratio (4.48) was obtained from 50 kg N ha^{-1} followed by 100 kg N ha^{-1} (4.35). The lowest imbibition ratio (4.20) was recorded when 150 kg N ha^{-1} was applied.

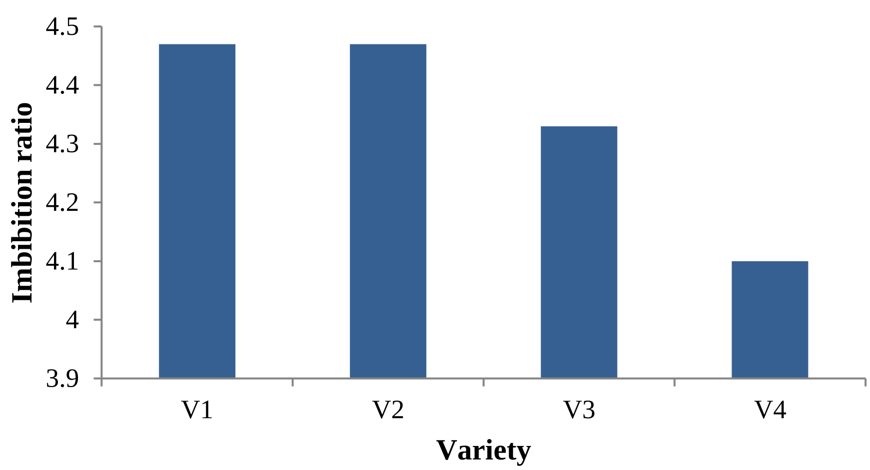


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 45. Effect of nitrogen on imbibition ratio of transplanted aman rice ($LSD_{(0.05)}$= 0.03).

4.3.3.1.2 Effect of variety

Variety had significant effect on imbibition ratio (Figure 46 and Appendix XV). The highest imbibition ratio (4.47) was obtained from SAU ADL1 and BRRI dhan70 followed by BRRI hybrid dhan6 (4.33). The lowest imbibition ratio (4.10) was obtained from SAU ADL11. Hosen *et al.* (2017) and Matin *et al.* (2017) also found the similar results. Shozib *et al.* (2017) found a positive correlation between AAC and IR. It resembles that higher AAC containing rice will absorb higher amount of water while cooking and it will eventually increase cooked rice volume accordingly. High volume expansion of cooking is still considered as the good quality by the lower income people who want to fill up their belly without considering how much energy they will get from it (Dipti *et al.*, 2002). The imbibition ratio of BRRI dhan28 is 4.3 which means 1 kg rice will produce 4.3 kg cooked rice. This is one of the reason to become BRRI dhan28, a mega variety in Boro season in Bangladesh (Shozib *et al.* 2017). As, SAU ADL1 has higher IR (4.47) than BRRI dhan28, so this character can be explored in HYV for mega variety release. Again, lower the imbibition ratio, higher will be the energy content per unit volume or weight of cooked rice as they have less water and more solid materials (Dipti *et al.*, 2002). So SAU ADL11 has more energy content that other tested cultivars.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 46. Effect of variety on imbibition ratio of transplanted aman rice ($LSD_{(0.05)}$= 0.03).

4.3.3.1.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety significantly influenced imbibition ratio (Table 12 and Appendix XV). The highest imbibition ratio (4.8) was obtained from SAU ADL1 and BRRI dhan70 both fertilized with 50 kg N ha^{-1} (N_1V_1 and N_1V_2). The lowest imbibition ratio (3.50) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4). Kaur (2016) found significant effect of interaction between nitrogen and variety.

Table 12. Interaction effect of nitrogen and variety on cooking properties of transplanted aman rice

Treatment combinations	Imbibition ratio	Gel consistency (mm)
N_1V_1	4.80 a	80.00 e
N_1V_2	4.80 a	92.00 cd
N_1V_3	4.30 c	89.63 d
N_1V_4	4.50 b	94.00 bc
N_2V_1	4.30 c	96.00 ab
N_2V_2	4.30 c	96.00 ab
N_2V_3	4.50 b	95.11 ab
N_2V_4	4.30 c	97.63 a
N_3V_1	4.30 c	90.00 d
N_3V_2	4.30 c	80.00 e
N_3V_3	4.2 d	91.83 cd
N_3V_4	3.50 e	97.32 a
LSD $_{(0.05)}$	0.06	2.66
CV (%)	0.78	1.69

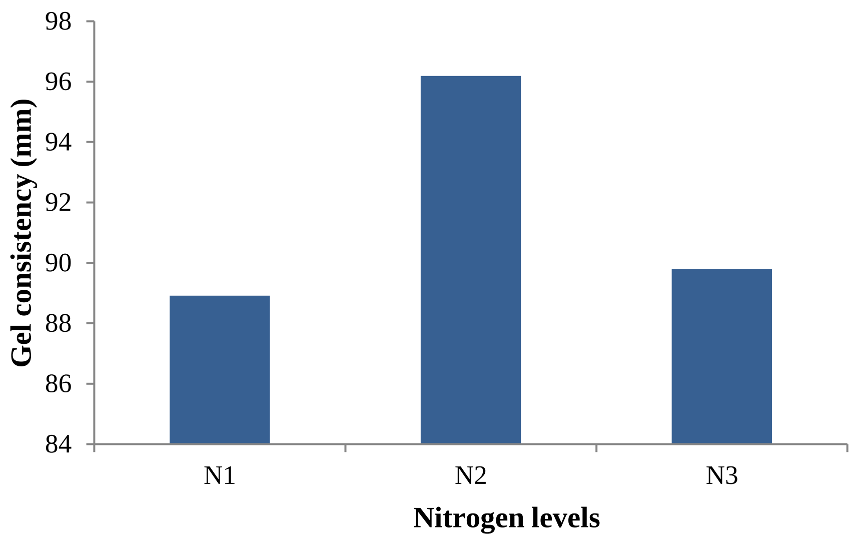
N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}, V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11.

4.3.3.2 Gel consistency (GC)

Gel consistency was significantly positively related with cooking/ eating quality (Da-wei *et al.*, 2017).

4.3.3.2.1 Effect of nitrogen

Nitrogen had significant effect on gel consistency (Figure 47 and Appendix XV). The highest gel consistency (96.16 mm) was obtained from 100 kg N ha^{-1}. The lowest gel consistency (88.91 mm) was found at 50 kg N ha^{-1} which was statistically similar with 150 kg N ha^{-1} (89.79 mm). Similar findings was reported by Tayefe *et al.* (2014) who opined that with an increase in the used amount of nitrogen fertilizer to a certain point, an increase in GC and then a lowering trend resulted. Ju-Young *et al.* (2006) showed that with an increase in nitrogen fertilizer amount, GC decreased.

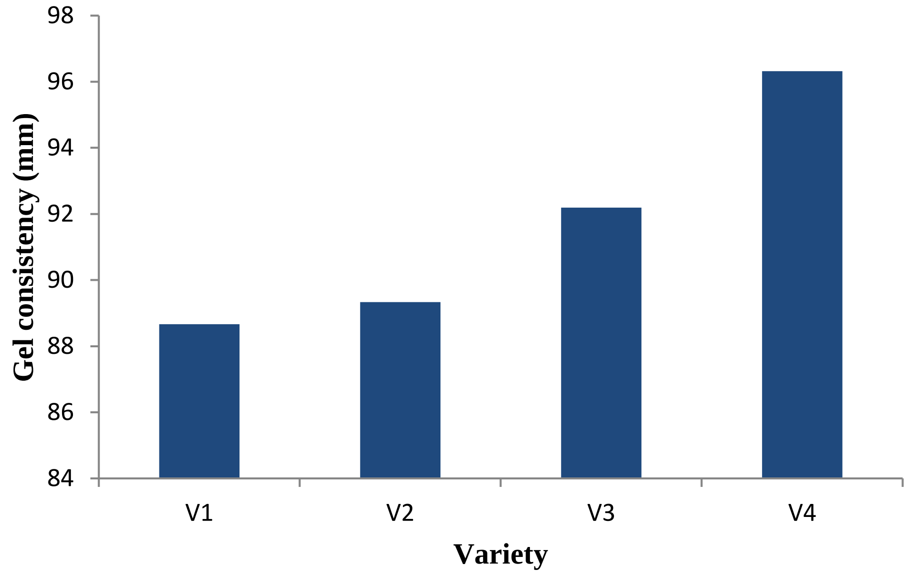


N_1= 50 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 47. Effect of nitrogen on gel consistency of transplanted aman rice ($LSD_{(0.05)}$= 3.75).

4.3.3.2.2 Effect of variety

Variety had significant effect on gel consistency (Figure 48 and Appendix XV). The highest gel consistency (96.32 mm) was observed in SAU ADL11 followed by BRRI hybrid dhan6 (92.19 mm). The lowest gel consistency (88.67 mm) was recorded in SAU ADL1 which was statistically similar with BRRI dhan70 (89.33 mm). Kaur (2016), Tayefe *et al.* (2014) and Ju-Young *et al* (2006) also reported the variation in gel consistency due to varietal variation.



V_1= SAU ADL1, V_2= BRRI dhan70, V_3= BRRI hybrid dhan6, V_4= SAU ADL11

Figure 48. Effect of variety on gel consistency of transplanted aman rice ($LSD_{(0.05)}$= 1.54).

4.3.3.2.3 Interaction effect of nitrogen and variety

Interaction effect of nitrogen and variety had significant effect on gel consistency (Table 12 and Appendix XV). The highest gel consistency (97.63 mm) was obtained from SAU ADL11 fertilized with 100 kg N ha^{-1} (N_2V_4) which was statistically similar with N_3V_4 (97.32 mm), N_2V_1 (96.00 mm), N_2V_2 (96.00 mm) and N_2V_3 (95.11 mm). The lowest gel consistency (80.00 mm) was obtained from N_1V_1 and N_3V_2. Kaur (2016) and Tayefe *et al.* (2014) found that interaction effect of nitrogen and variety had significant influence on gel consistency.

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from July 2017 to December 2017 to evaluate the effect of different nitrogen levels on growth, yield and quality of transplanted aman rice under the Modhupur Tract (AEZ-28).

The factors under study comprised of (A) Nitrogen (3 levels): N_1- 50 kg N ha^{-1}, N_2-100 kg N ha^{-1} and N_3- 150 kg N ha^{-1} which were kept in main plots and (B) Variety/ line (4): V_1- SAU ADL1, V_2- BRRI dhan70, V_3- BRRI hybrid dhan6 and V_4- SAU ADL11 which were kept in sub plots. The experiment was conducted in split plot design which was replicated thrice. Twenty five days old seedlings were transplanted following line to line distance 20 cm and hill to hill distance 20 cm with 2 seedlings $hill^{-1}$.

Crop management practices were performed as per standard package of practices as per main plot treatment. Nitrogen was applied as per treatment. Whereas, full dose of P_2O_5, K_2O and S were applied as basal dose at the time of field preparation.

The data on crop growth parameters like plant height, number of tillers $hill^{-1}$, leaf area index, SPAD reading and dry matter $hill^{-1}$ at different growth stages were recorded. Yield parameters like number of effective and ineffective tillers $hill^{-1}$, panicle length, rachis branches $panicle^{-1}$, number of grains $panicle^{-1}$, filled and unfilled grains $panicle^{-1}$, 1000-grains weight, grain and straw yield, biological yield and harvest index were recorded after harvest. Quality data on hulling percentage, milling outturn percentage, protein content, apparent amylose content, alkali spreading value, imbibition ratio, gel consistency were recorded. Data were analyzed using Statistix 10 package. The mean differences among the treatments were compared by least significant difference test (LSD) at 5% level of significance.

Results revealed that nitrogen had significant effect on growth parameters. The plant height, number of tillers $hill^{-1}$, leaf area index, SPAD value, dry matter $hill^{-1}$ were, in general, augmented steadily in all the treatments with the successive growth and development stages. These vegetative growth parameters were, in general, enhanced very fast between 20 to 80 days period, thereafter was normally slow beyond 80 days and up to harvest. Higher plant height was recorded at 150 kg N ha^{-1} at all sampling dates. Plant height reached its maximum at harvest and highest plant height (146.48 cm) was obtained from 150 kg N ha^{-1} which was statistically similar with the plant height (140.52 cm) obtained from 100 kg N ha^{-1}. The shortest plant (133.79 cm) was produced by 50 kg N ha^{-1} at harvest. Number of tillers hill^{-1} of rice increased significantly over time by gradual elevation of nitrogen fertilizer and 150 kg N ha^{-1} produced maximum number of tillers hill^{-1} at all observations compared to other nitrogen levels. The lowest number of tiller hill^{-1} was observed at all sampling dates when the crop is fertilized with 50 kg N ha^{-1}. Maximum number of tillers hill^{-1} was observed at 80 DAT and at harvest it was reduced due to tiller mortality. At 80 DAT, the maximum number of tillers hill^{-1} (14.38) was obtained from 150 kg N ha^{-1} and minimum number of tillers hill^{-1} (11.62) was produced by 50 kg N ha^{-1}. The LAI increased progressively with increase in the level of nitrogen from 50 kg N ha^{-1} to 150 kg N ha^{-1}. Leaf area index progressively increased and achieved its maximum value (7.93) at 80 days after transplanting when fertilized with 150 kg N ha$^{–1}$. At same planting date, the lowest value (5.68) was recorded at 50 kg N ha^{-1}. SPAD value increased with the increase of nitrogen level at all sampling dates. At 50 and 70 DAT, maximum SPAD value (44.14 and 45.01 respectively) was recorded from 150 kg N ha^{-1} followed by 100 kg N ha^{-1} (42.57 and 40.31, respectively). Minimum SPAD value (41.01 and 35.46, respectively) was recorded at 50 kg N ha^{-1}. Dry matter production hill^{-1} was found to be positive and significant at all growth stages due to nitrogen. Dry matter hill^{-1} increased with the increase of nitrogen throughout the growth period and at harvest. The maximum dry matter hill^{-1} was obtained at all sampling date when 150 kg N ha^{-1} was applied (37.85 g, 56.99 g, 86.98 g and 101.14 g at 50, 70, 90 DAT and at harvest, respectively). The minimum dry matter hill^{-1} was recorded when fertilized with 50 kg N ha^{-1} (22.30 g, 35.54 g, 60.15 g, 74.87 g at 50, 70, 90 DAT and at harvest, respectively).

Nitrogen had significant effect on yield and yield contributing characters except panicle length, rachis branch panicle^{-1}. Number of effective tillers hill^{-1} progressively increased with the increase of nitrogen levels and achieved its maximum value (11.9) when fertilized with 150 kg N ha^{-1}. The minimum number of effective tillers $hill^{-1}$ (9.17) was recorded at 50 kg N ha^{-1}. Number of ineffective tillers $hill^{-1}$ decreased with the increase of nitrogen level. The maximum number of ineffective tillers $hill^{-1}$ (1.47) was obtained from 50 kg N ha^{-1} and the minimum number of ineffective tillers $hill^{-1}$ (0.58) obtained from 150 kg N ha^{-1}. Nitrogen has no significant effect on panicle length. The panicle length ranged from 28.74 cm to 29.47 cm due to different nitrogen doses which was statistically similar with one another. The maximum number of filled grains $panicle^{-1}$ (184.13) was produced by 150 kg N ha^{-1} followed by 100 kg N ha^{-1}. The minimum number of filled grains $panicle^{-1}$ (136.66) was produced from 50 kg N ha^{-1}. The maximum number of unfilled grain $panicle^{-1}$ (43.09) was produced by 50 kg N ha^{-1}. The minimum number of unfilled grain $panicle^{-1}$ (33.66) was recorded when 150 kg N ha^{-1} was applied which was statistically at par with 100 kg N ha^{-1}. The maximum number of total grains $panicle^{-1}$ (217.81) was obtained from 150 kg N ha^{-1} and minimum number of total grains $panicle^{-1}$ (179.74) was recorded in 50 kg N ha^{-1}. Among the nitrogen doses, lowest one produced minimum 1000 grain weight and other two produced 1000 grain weight statistically at par with each other. Grain yield increased significantly with the increase of nitrogen doses up to 100 kg N ha^{-1} and then the increase for 150 kg N ha^{-1} was not statistically significant. The highest grain yield (4.50 t ha^{-1}) was recorded for 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1}. The lowest grain yield (2.96 t ha^{-1}) was obtained when 50 kg N ha^{-1} was applied. The maximum straw yield (8.00 t ha^{-1}) was obtained from 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1} (7.76 t ha^{-1}). The minimum straw yield (5.97 t ha^{-1}) was recorded at 50 kg N ha^{-1}. The highest biological yield (12.78 t ha^{-1}) was obtained when 150 kg N ha^{-1} was applied which was statistically similar with 100 kg N ha^{-1}. The lowest biological yield (8.94 t ha^{-1}) was recorded for 50 kg N ha^{-1}. The highest harvest index (36.58%) was recorded for 100 kg N ha^{-1} followed by 150 kg N ha^{-1} (35.25%) and the lowest harvest index (33.42%) for 50 kg N ha^{-1}.

Nitrogen had significant effect on quality characters except alkali spreading value. The highest hulling percentage (78.66) was recorded at 150 kg N ha^{-1} followed by 100 kg N ha^{-1} (75.44). The lowest hulling percentage (72.78) was recorded at 50 kg N ha^{-1}. The highest milling outturn (75.81%) was recorded at 150 kg N ha^{-1} which was statistically similar with 100 kg N ha^{-1} (74.03%). The lowest milling outturn (68.36%) was obtained when 50 kg N ha^{-1} was applied.

The highest protein (9.60%) was obtained from 100 kg N ha^{-1} which was statistically similar with 150 kg N ha^{-1} (9.48%). The lowest protein (8.55%) was obtained from 50 kg N ha^{-1}. Apparent amylose content was decreased with the increase in nitrogen level. The highest apparent amylose content (24.18%) was recorded at 50 kg N ha^{-1} followed by 100 kg N ha^{-1} (22.29%). The lowest apparent amylose content (21.27%) was recorded at 150 kg N ha^{-1}. The highest imbibition ratio (4.48) was obtained from 50 kg N ha^{-1} followed by 100 kg N ha^{-1} (4.35). The lowest imbibition ratio (4.20) was recorded when 150 kg N ha^{-1} was applied. The highest gel consistency (96.16 mm) was obtained from 100 kg N ha^{-1}. The lowest gel consistency (88.91 mm) was found at 50 kg N ha^{-1} which was statistically similar with 150 kg N ha^{-1} (89.79 mm).

Significant variation was recorded for all data (crop growth parameters, yield and yield contributing parameters and) due to varietal difference. Varietal variation also significantly influenced qualitative parameters. The plant height of transplanted aman rice significantly varied among varieties at 20, 40 60, 80 DAT and at harvest. The results showed that SAU ADL1 produced the tallest plant (191.28 cm) and BRRI hybrid dhan6 produced the shortest plant (113.12 cm) at harvest. BRRI hybrid dhan6 produced maximum number of tillers hill^{-1} and SAU ADL1 produced minimum number of tillers hill^{-1} at all sampling dates. SAU ADL1 produced higher leaf area index compared to other varieties at all the dates of taking observation. Both at 50 and 70 DAT, highest SPAD value (44.55 and 47.53, respectively) was observed in SAU ADL11 and lowest SPAD value (41.75, 29.99, respectively) was observed in BRRI hybrid dhan6. At harvest, maximum dry matter hill^{-1} (99.85 g) was produced by SAU ADL1 followed by BRRI hybrid dhan6 (92.36 g) and minimum dry matter hill^{-1} (85.64 g) was recorded in SAU ADL11 which was statistically similar with BRRI dhan70 (86.25 g). BRRI hybrid dhan6 produced maximum number of effective tillers hill^{-1} (12.53) followed by BRRI dhan70 (10.47). SAU ADL1 produced minimum number of effective tillers hill^{-1} (9.09) which was statistically at par with SAU ADL11 (9.58). The highest number of ineffective tillers hill^{-1} (1.16) was produced by BRRI dhan70 which was statistically similar with SAU

ADL1 and BRRI hybrid dhan6. The lowest number of ineffective tillers hill^{-1} (0.98) was produced by SAU ADL11. The panicle length varied from 27.78 cm to 31.65 cm among the cultivars. Among the cultivars, SAU ADL1 produced longest panicle (31.65 cm) followed by BRRI dhan70 (29.27). BRRI hybrid dhan6 produced shortest panicle (27.78 cm) which was statistically similar with SAU ADL11. The maximum number of rachis branch panicle^{-1} was observed in SAU ADL11 which was significantly superior to BRRI hybrid dhan6 (11.75) while statistically at par with rest of the varieties. BRRI hybrid dhan6 produced highest number of filled grains panicle^{-1} (184.72) which was statistically at par with BRRI dhan70. The lowest number of filled grains panicle^{-1} (137.69) was produced by SAU ADL11 which was statistically similar with SAU ADL1. The maximum number of unfilled grains panicle^{-1} (47.24) was observed in SAU ADL1 which was statistically similar with SAU ADL11. The minimum number of unfilled grains panicle^{-1} (19.33) was observed in BRRI hybrid dhan6. The highest number of total grains panicle^{-1} (210.04) was recorded in BRRI dhan70 which was statistically similar with BRRI hybrid dhan6 (204.06). The lowest number of total grains panicle^{-1} (186.32) was obtained from SAU ADL1 which was statistically similar with SAU ADL11 (184.60). The maximum 1000-grains weight (31.49 g) was obtained from SAU ADL1 followed by SAU ADL11 (30.80 g). The minimum 1000-grains weight (20.50 g) was recorded in BRRI dhan70. The highest grain yield (5.24 t ha^{-1}) was obtained from BRRI hybrid dhan6 followed by BRRI dhan70 (4.12 t ha^{-1}). The lowest grain yield (3.17 t ha^{-1}) was obtained from SAU ADL11 which was statistically similar with SAU ADL1 (3.33 t ha^{-1}). The maximum straw yield (9.33 t ha^{-1}) was obtained from SAU ADL1 followed by BRRI dhan70 (7.44 t ha^{-1}). The minimum straw yield (6.01 t ha^{-1}) was obtained from SAU ADL11 which was statistically at par with BRRI hybrid dhan6 (6.20 t ha^{-1}). The highest biological yield (12.66 t ha^{-1}) was recorded in SAU ADL1 and the lowest biological yield (9.55 t ha^{-1}) was recorded in SAU ADL11. The highest harvest index (45.44 %) was obtained from BRRI hybrid dhan6 where the lowest harvest index (26%) was obtained from SAU ADL1. SAU ADL11 gave the highest hulling percentage (77.74) and milling outturn (75.49%) where BRRI dhan70 gave the lowest hulling percentage (73.12) and milling outturn (69.45%). The highest protein (9.90%) was recorded in SAU ADL11 followed by SAU ADL1 (9.37%). The lowest protein (8.68%) was obtained from BRRI hybrid dhan6 which was statistically similar with BRRI dhan70 (8.9%). The highest apparent amylose content (24.60%) was obtained from SAU ADL1. The lowest apparent amylose content (21.29%) was obtained from BRRI hybrid dhan6 which was statistically similar with BRRI dhan70 (21.74%) and SAU ADL11 (22.70%). The highest alkali spreading value (7.00) was obtained from BRRI hybrid dhan6 followed by SAU ADL11 (5.70) and the lowest alkali spreading value (4.17) was obtained from SAU ADL1. The highest imbibition ratio (4.47) was obtained from SAU ADL1 and BRRI dhan70 where the lowest imbibition ratio (4.10) was obtained from SAU ADL11. The highest gel consistency (96.32 mm) was observed in SAU ADL11 followed by BRRI hybrid dhan6 (92.19 mm). The lowest gel consistency (88.67 mm) was recorded in SAU ADL1 which was statistically similar with BRRI dhan70 (89.33 mm).

Interaction effect of nitrogen and variety also significantly affected growth, yield and yield contributing characters and quality parameters of transplanted aman rice. At harvest, the highest plant height (193.18 cm) was recorded from the treatment combination N_3V_1 which was statistically similar with N_2V_1 (192.33 cm) and N_1V_1 (187.34 cm). The lowest plant height (100.07 cm) was obtained from N_1V_3 which was statistically similar with N_2V_3 (111.40 cm), N_2V_4 (112.33 cm) and N_1V_4 (113.31 cm). The interaction of 150 kg N ha^{-1} with BRRI hybrid dhan6 (N_3V_3) produced maximum number of tillers $hill^{-1}$ at all sampling dates. A trend of increase in the value of LAI, SPAD reading and dry matter $hill^{-1}$ was observed in each variety with the increasing levels of nitrogen. The maximum number of effective tillers $hill^{-1}$ (14.47) was recorded from BRRI hybrid dhan6 when fertilized with 150 kg N ha^{-1} (N_3V_3) and minimum number of effective tillers $hill^{-1}$ (7.93) was recorded from SAU ADL11 fertilized with 50 kg N ha^{-1} (N_1V_4) which was statistically similar with N_1V_1 (8.67) and N_2V_1 (8.80). Number of ineffective tillers $hill^{-1}$ decreased with the increase in nitrogen level among the varieties. SAU ADL1 with 100 kg N ha^{-1} (N_2V_1) produced longest panicle (32.92 cm) which was statistically similar with the panicle length produced by SAU ADL1 and 150 kg N ha^{-1} (N_3V_1). SAU ADL11 with 150 kg N ha^{-1} (N_3V_4) produced the shortest panicle (27.01 cm) which was statistically at par with N_2V_3 (27.12 cm), N_1V_3 (27.58 cm), N_1V_4 (27.52 cm), N_2V_2 (27.76 cm) and N_3V_3 (28.63 cm). The highest number of filled grains panicle^{-1} (237.00) was recorded in N_3V_3. The lowest number of filled grains panicle^{-1} (116.73) was recorded in N_1V_4 which was statistically similar with N_1V_1 (128.07), N_1V_3 (129.15) and N_2V_1 (134.87). The number of unfilled grains panicle^{-1} decreased with the increase in nitrogen level in all the varieties. The highest number of total grains panicle^{-1} (253.23) was produced by BRRI hybrid dhan6 fertilized with 150 kg N ha^{-1} (N_3V_3) followed by N_2V_2 (221.20) and N_3V_2 (220.80). The lowest number of total grains panicle^{-1} (147.60) was recorded from N_1V_3 which was statistically similar with N_1V_4 (170.50). The maximum 1000-grains weight (32.22 g) was recorded from N_2V_4 which was statistically at par with N_3V_4, N_2V_4 and N_2V_1. The minimum 1000-grains weight (19.19 g) was obtained from the interaction N_1V_2 which is statistically similar with N_1V_3 (20.04 g). The highest grain yield (6.22 t ha^{-1}) was obtained from the combination N_3V_3 followed by N_2V_3 (5.70 t ha^{-1}). The lowest grain yield (2.52 t ha^{-1}) was recorded in N_1V_1 which was statistically similar with N_1V_4 (2.53 t ha^{-1}). The highest straw yield (9.99 t ha^{-1}) was recorded from N_3V_1 which was statistically at par with N_2V_1 (9.90 t ha^{-1}). The lowest straw yield (4.98 t ha^{-1}) was obtained from N_1V_4 which was statistically similar with N_1V_3 (5.01 t ha^{-1}). The highest biological yield (13.73 t ha^{-1}) was obtained from N_2V_1 which was statistically at par with N_3V_1 (13.64 t ha^{-1}), N_3V_3 (13.37 t ha^{-1}), N_3V_2 (13.04 t ha^{-1}) and N_2V_2 (12.84 t ha^{-1}). The lowest biological yield (7.52 t ha^{-1}) was recorded in N_1V_4 which was statistically similar with N_1V_2 (8.78 t ha^{-1}). The highest harvest index (47%) was recorded for N_3V_3 which was statistically similar with N_2V_3 (46.33%). The lowest harvest index (23.67%) was recorded for N_1V_1 which was statistically similar with N_3V_1 (26.67%) and N_2V_1 (27.67%). The highest hulling percentage (82.67) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4). The lowest hulling percentage (71.31) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} which was statistically similar with N_1V_3 (72.48), N_1V_4 (72.48), N_2V_2 (78.28) and N_2V_3 (74.85). The highest milling outturn (77.63%) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4) which was statistically similar with N_3V_3 (77.18%), N_2V_4 (76.68%), N_2V_3 (74.89%) and N_2V_1 (72.79%). The lowest milling outturn (63.67%) was obtained from BRRI dhan70 fertilized with 50 kg N ha^{-1} (N_1V_2) which was statistically similar with N_1V_1 (67.33%). The highest protein (10.36%) was obtained from SAU ADL11 fertilized with 100 kg N ha^{-1} (N_2V_4) which was statistically similar with N_3V_4 (9.93%). The lowest protein (7.51%) was obtained from BRRI hybrid dhan6 fertilized with 50 kg N ha^{-1} (N_1V_3) which was statistically similar with N_1V_2

(7.81%). The highest apparent amylose content (25.67%) was obtained from SAU ADL1 fertilized with 50 kg N ha^{-1} which was statistically similar with N_1V_2 (24.84%), N_1V_4 (24.87%), N_3V_1 (24.45%) and N_2V_1 (24.00%). The lowest apparent amylose content (18.86%) was obtained from BRRI dhan70 fertilized with 150 kg N ha^{-1} (N_3V_2) which was statistically similar with N_3V_3 (20.58%). The highest alkali spreading value (7.00) was recorded in BRRI hybrid dhan6 fertilized with 50, 100 and 150 kg N ha^{-1} (N_1V_3, N_2V_3 and N_3V_3). The lowest alkali spreading value (3.50) was obtained from SAU ADL1 fertilized with 50 kg N ha^{-1} (N_1V_1) and BRRI dhan70 fertilized with 150 kg N ha^{-1} (N_3V_2). The highest imbibition ratio (4.8) was obtained from SAU ADL1 and BRRI dhan70 both fertilized with 50 kg N ha^{-1} (N_1V_1 and N_1V_2). The lowest imbibition ratio (3.50) was obtained from SAU ADL11 fertilized with 150 kg N ha^{-1} (N_3V_4). The highest gel consistency (97.63 mm) was obtained from SAU ADL11 fertilized with 100 kg N ha^{-1} (N_2V_4) which was statistically similar with N_3V_4 (97.32 mm). The lowest gel consistency (80.00 mm) was obtained from N_1V_1 and N_3V_2.

Keeping in view the limitations of present investigation that it was conducted only for one crop season. The following broad conclusion can be drawn.

- Among different nitrogen levels, 150 kg N ha^{-1} performs better in case of all growth parameter and yield and yield contributing characters but grain yield, straw yield and biological yield produced by 150 kg N ha^{-1} was statistically similar with 100 kg N ha^{-1}. Maximum hulling percentage, milling outturn was recorded for 150 kg N ha^{-1} but highest protein content, gel consistency and satisfactory level of all quality contributing characters was recorded at 100 kg N ha^{-1}.

- BRRI hybrid dhan6 showed higher yield potential than other studied materials. SAU ADL11 gave maximum hulling percentage, milling outturn. It had highest amount of protein, maximum gel consistency, lowest imbibition ratio, intermediate amylose content. So considering nutritive value and quality purpose, SAU ADL11 has a great potential. Again SAU ADL1 had highest amylose content and imbibition ratio. So, it can be a better option for poor people as it fills the belly with relatively small amount compared with other cultivars.

- Interaction of 150 kg N ha^{-1} with BRRI hybrid dhan6 gave maximum value of all studied parameters but BRRI dhan70, SAU ADL1 and SAU ADL11 were more responsive to 100 kg N ha^{-1} to produce better yield and quality rice.

However, SAU ADL11 has been found promising for quality rice production. So, SAU ADL11 with 100 kg N ha^{-1} can be suggested for further research under different agro-ecological zones to reach a specific conclusion and recommendation.

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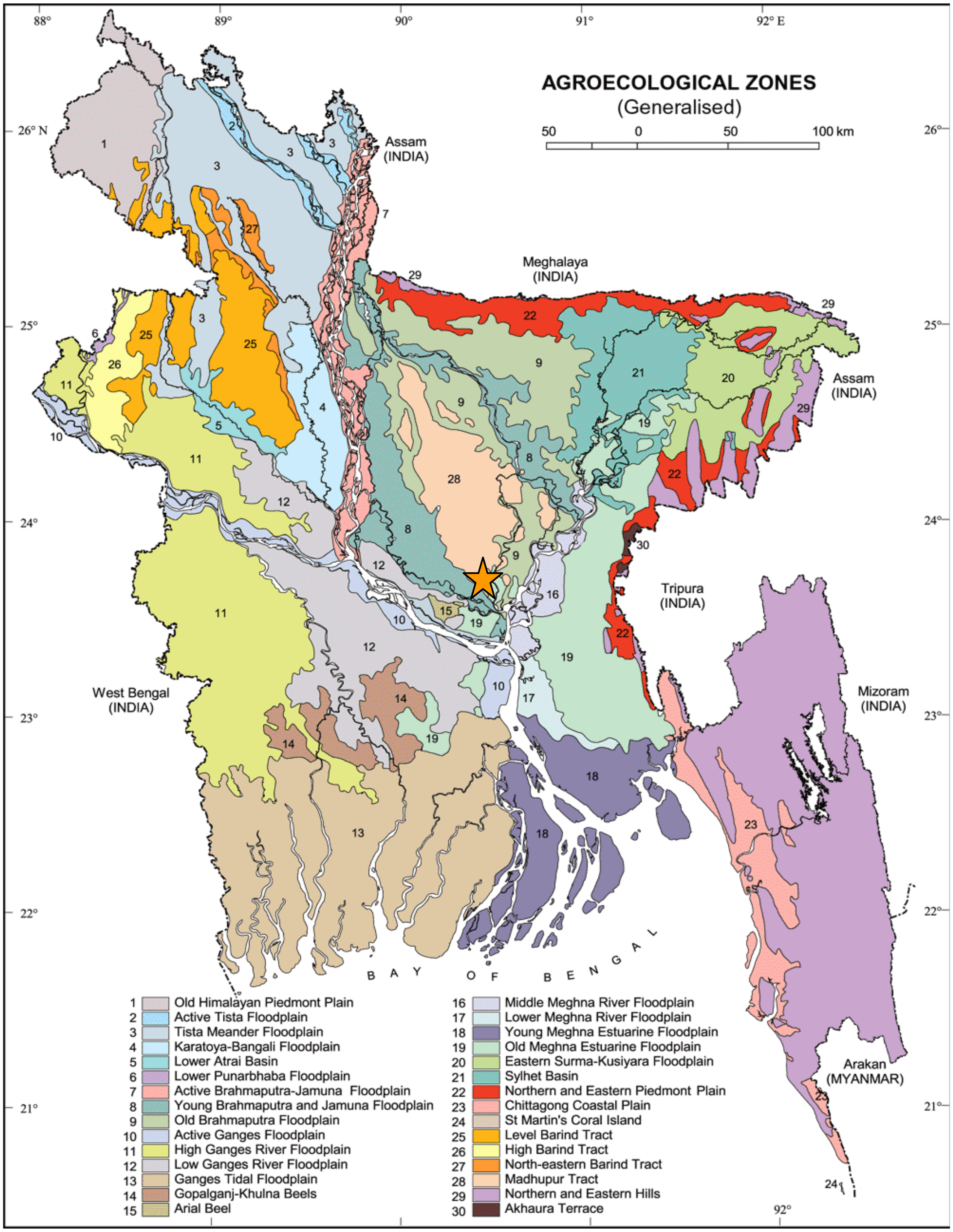
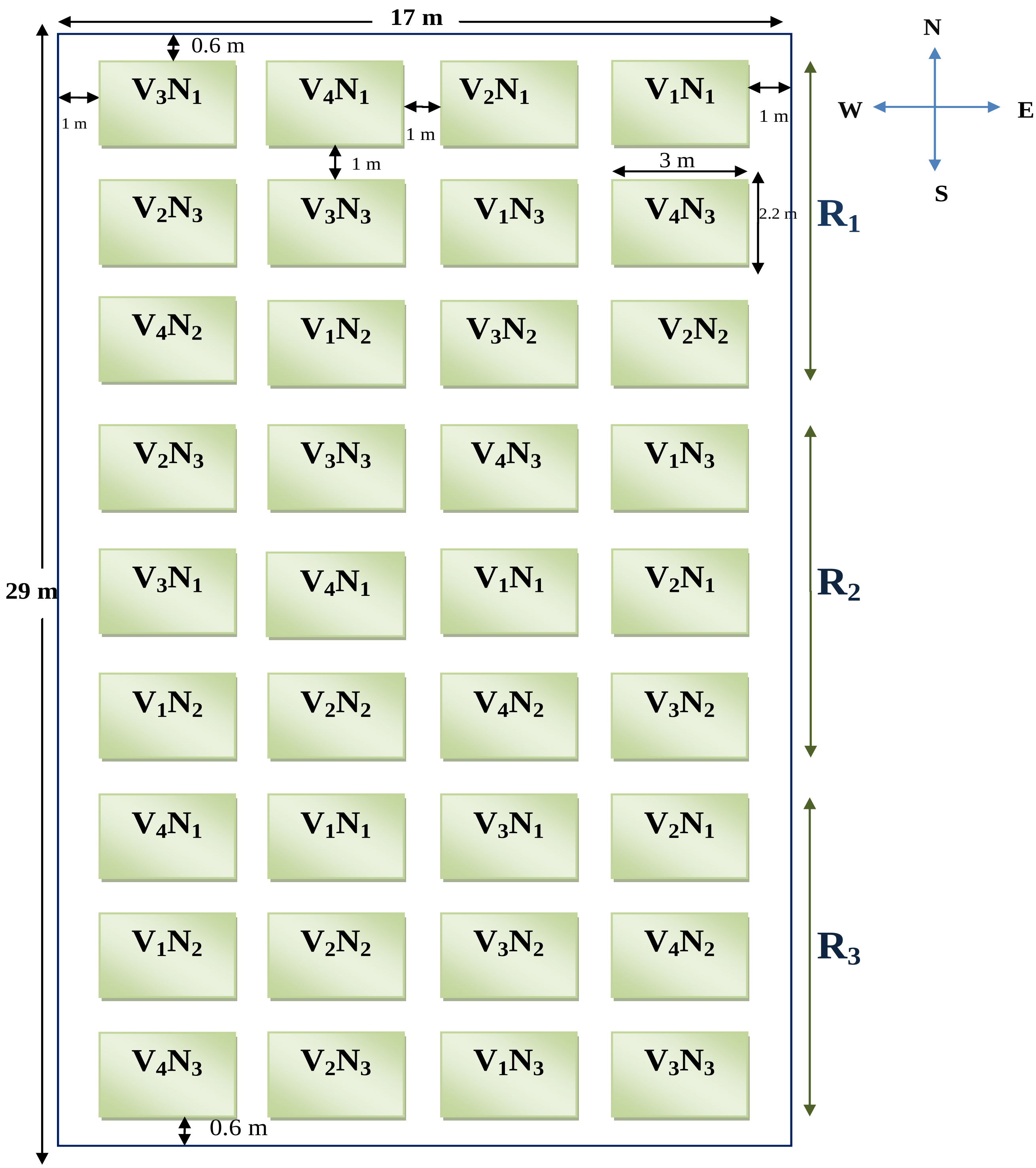
APPENDICES

Appendix I. Map showing the experimental sites under study

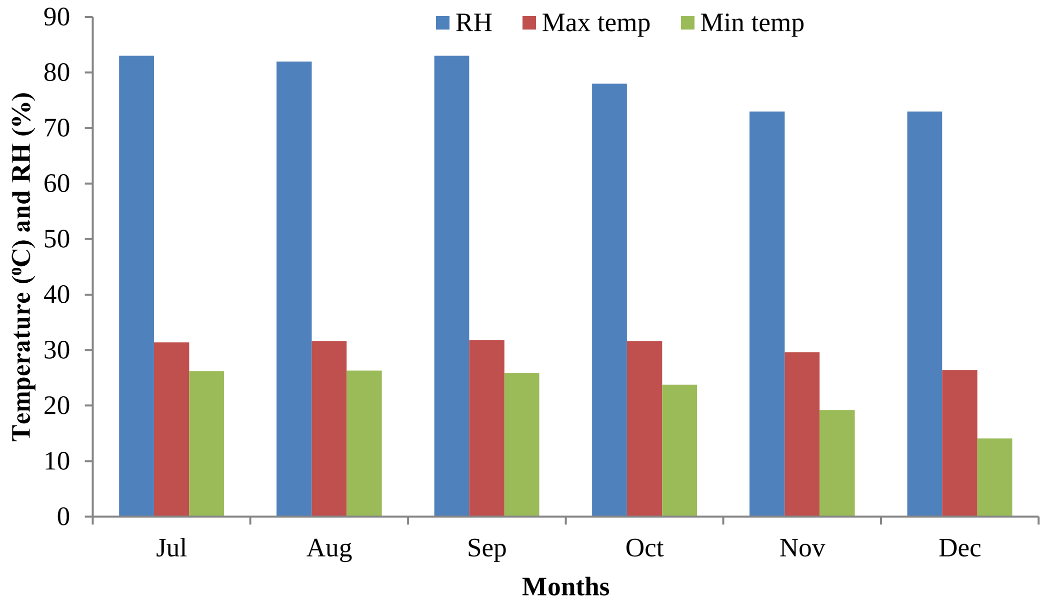


★ **The experimental site under study**

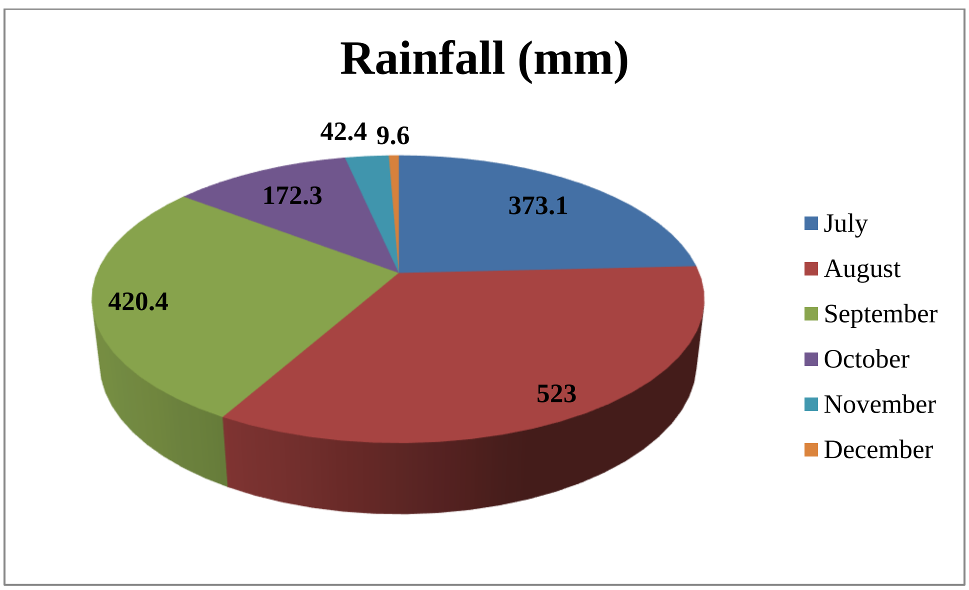
Appendix II. Layout of experimental field



Appendix III. Monthly average maximum and minimum temperature, relative humidity of the experimental site during the period from July to December, 2017 [Source: Bangladesh Meteorological Department, Agargoan, Dhaka-1212]



Appendix IV. Monthly total rainfall (mm) of the experimental site during the period from July to December, 2017 [Source: Bangladesh Meteorological Department, Agargoan, Dhaka-1212]



Appendix V. Mean square values for plant height of transplanted aman rice at different crop growth stages

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting (DAT)				
		20	40	60	80	At harvest
Replication	2	13.87	113.24	334.40	755.0	121.8
Nitrogen	2	501.81**	1453.13**	509.03	1309.5**	483.8*
Error (a)	4	2.31	8.29	91.48	67.2	30.7
Variety	3	161.85**	543.81**	2220.25**	10444.3**	12054.5**
Nitrogen × Variety	6	22.59*	41.62*	69.08*	62.6*	111.7*
Error (b)	18	6.11	11.01	40.24	28.5	76.8

* Significant at 5% level
** Significant at 1% level

Appendix VI. Mean square values for number of tillers hill^{-1} of transplanted aman rice at different crop growth stages

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting (DAT)				
		20	40	60	80	At harvest
Replication	2	1.51	3.23	1.04	3.54	0.03
Nitrogen	2	6.77**	25.40**	21.98**	23.58**	10.53**
Error (a)	4	0.13	0.50	0.71	0.09	0.15
Variety	3	8.06**	46.80**	11.16**	21.97**	21.73**
Nitrogen × Variety	6	1.12*	2.54*	0.79*	0.97*	1.03*
Error (b)	18	0.40	0.73	1.04	0.45	0.31

* Significant at 5% level
** Significant at 1% level

Appendix VII. Mean square values for leaf area index of transplanted aman rice at different crop growth stages

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting (DAT)		
		40	60	80
Replication	2	0.002	0.03	0.02
Nitrogen	2	7.15**	10.04**	16.18**
Error (a)	4	0.05	0.28	0.12
Variety	3	2.14**	1.36**	2.58**
Nitrogen × Variety	6	0.53**	0.23*	0.32**
Error (b)	18	0.03	0.11	0.07

* Significant at 5% level

** Significant at 1% level

Appendix VIII. Mean square values for SPAD value of transplanted aman rice at different crop growth stages

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting (DAT)	
		50	70
Replication	2	0.05	10.31
Nitrogen	2	29.36**	273.92**
Error (a)	4	1.50	2.36
Variety	3	15.82**	505.57**
Nitrogen × Variety	6	2.00*	26.35*
Error (b)	18	0.86	10.46

* Significant at 5% level

** Significant at 1% level

Appendix IX. Mean square values for dry matter hill^{-1} of transplanted aman rice at different crop growth stages

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting (DAT)			
		50	70	90	At harvest
Replication	2	10.21	1.08	77.11	39.09
Nitrogen	2	727.78**	1379.91**	2232.93**	2399.24**
Error (a)	4	18.36	60.66	53.28	18.54
Variety	3	57.02*	170.27**	1633.91**	394.17**
Nitrogen × Variety	6	6.90*	9.58*	43.31*	34.15*
Error (b)	18	16.004	30.35	20.19	10.47

* Significant at 5% level

** Significant at 1% level

Appendix X. Mean square values for effective and ineffective tillers hill^{-1} of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values	
		Effective tillers hill^{-1}	Ineffective tillers hill^{-1}
Replication	2	0.06	0.03
Nitrogen	2	22.90**	2.37**
Error (a)	4	0.12	0.01
Variety	3	20.85**	0.05*
Nitrogen × Variety	6	1.03*	0.06*
Error (b)	18	0.31	0.02

* Significant at 5% level

** Significant at 1% level

Appendix XI. Mean square values for yield contributing characters of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values				
		Panicle length	Rachis branch panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains Panicle^{-1}	Total grains panicle^{-1}
Replication	2	2.19	0.97	8.51	49.65	25.53
Nitrogen	2	1.63	3.48	6819.44**	321.97**	4575.73**
Error (a)	4	0.57	2.40	131.09	8.59	147.19
Variety	3	29.77**	17.37**	5303.10**	1556.85**	1456.49**
Nitrogen × Variety	6	4.69*	0.35*	1401.29**	98.51**	1976.67**
Error (b)	18	1.07	2.03	169.28	24.45	266.46

* Significant at 5% level

** Significant at 1% level

Appendix XII. Mean square values for weight of 1000-grains, yield and harvest index of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values				
		1000 grains weight	Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.03	0.01	0.75	0.06	3.00
Nitrogen	2	26.03**	9.07**	14.76**	51.48**	30.33**
Error (a)	4	0.45	0.04	0.40	0.69	1.21
Variety	3	309.25**	8.07**	20.96**	14.99**	579.44**
Nitrogen × Variety	6	1.77**	0.35**	0.23**	0.63*	5.52*
Error (b)	18	0.37	0.04	0.18	0.57	5.77

* Significant at 5% level

** Significant at 1% level

Appendix XIII. Mean square values for physical properties of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values	
		Hulling percentage	Milling outturn
Replication	2	24.57	24.57
Nitrogen	2	104.13**	181.95**
Error (a)	4	4.91	3.37
Variety	3	34.11**	62.97**
Nitrogen × Variety	6	8.96*	3.10*
Error (b)	18	3.03	9.44

* Significant at 5% level

** Significant at 1% level

Appendix XIV. Mean square values for chemical properties of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values		
		Protein content	AAC	Alkali spreading value
Replication	2	0.08	4.66	0.06
Nitrogen	2	3.93**	26.21**	0.04
Error (a)	4	0.08	0.61	0.05
Variety	3	2.62**	19.48**	14.90**
Nitrogen × Variety	6	1.06**	3.75*	1.84**
Error (b)	18	0.13	2.04	0.04

* Significant at 5% level

** Significant at 1% level

Appendix XV. Mean square values for cooking properties of transplanted aman rice

Sources of variation	Degrees of freedom	Mean square values	
		Imbibition ratio	Gel consistency
Replication	2	0.01	22.77
Nitrogen	2	0.23^{**}	189.44^{*}
Error (a)	4	0.0006	10.94
Variety	3	0.27^{**}	108.97^{**}
Nitrogen × Variety	6	0.39^{**}	83.19^{**}
Error (b)	18	0.001	2.41

* Significant at 5% level

** Significant at 1% level