MINIMIZATION OF NITROGEN ON YIELD AND GRAIN QUALITY OF SCENTED RICE

MST. EFAT AFROZ ARIN

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2018

MINIMIZATION OF NITROGEN ON YIELD AND GRAIN QUALITY OF SCENTED RICE

BY

MST. EFAT AFROZ ARIN

REGISTRATION NO. : 17-08204

A Thesis
Submitted to the Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)

IN

SEED TECHNOLOGY

SEMESTER: JANUARY-JUNE, 2018

Approved by:

Prof. Dr. Tuhin Suvra Roy
Supervisor
Department of Agronomy
SAU, Dhaka

Dr. Muhammad Ali Siddique
Co-supervisor
Chief Scientific Officer and Head
Grain Quality and Nutrition Division
BRRI, Joydevpur, Gazipur

Prof. Dr. Mohammad Ali
Director
Institute of Seed Technology
Sher-e-Bangla Agricultural University

INSTITUTE OF SEED TECHNOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled '**Minimization of Nitrogen on Yield and Grain Quality of Scented Rice'** submitted to the Department of Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SEED TECHNOLOGY**, embodies the results of a piece of bona fide research work carried out by **MST. EFAT AFROZ ARIN**, Registration No. **17-08204** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2018
Dhaka, Bangladesh

Prof. Dr. Tuhin Suvra Roy
Supervisor
Department of Agronomy
SAU, Dhaka

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, the Supreme Ruler of the universe Who enables the author to complete this present piece of work.

The author feels proud to express her heartiest sence of gratitude, sincere appreciation and immense indebtedness to her Supervisor ***Dr. Tuhin Suvra Roy****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of thesis, without his intense co-operation this work would not have been possible.*

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her Co-supervisor ***Dr. Muhammad Ali Siddique****, Chief Scientific Officer and Head, Grain Quality and Nutrition Division, BRRI, Joydevpur, Gazipur, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.*

The author expresses her sincere respect and sence of gratitude to ***Dr. Mohammad Ali****, Director, Institute of Seed Technology, SAU, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses her heartfelt thanks to all the teachers of the Department of Agronomy, SAU, for their valuable teaching, suggestions and encouragement during the period of study.*

The author deems it a great pleasure to express her profound gratefulness to her respected parents, for their inspiring for prosecuting her studies and also receiving proper education.

The author expresses her sincere appreciation to her relatives, well wishers and friends for their inspiration, help and encouragement throughout the study.

The Author

MINIMIZATION OF NITROGEN ON YIELD AND GRAIN QUALITY OF SCENTED RICE

ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to December 2017 to assess the minimization of nitrogen on yield and grain quality of scented rice. Scented rice cultivars Kalizira, BRRI dhan34, Begun Bichi and Sada Sanne were used as the test crops in this experiment. The experiment consisted of two factors: Factor A: Levels of nitrogen (4 levels) as- N_1: 37.5 kg N ha^{-1}, N_2: 40.0 kg N ha^{-1}, N_3: 42.5 kg N ha^{-1}, N_4: 45 kg N ha^{-1}; and Factor B: Scented rice variety (4 varieties) as- V_1: Kalizira, V_2: BRRI dhan34, V_3: Begun Bichi and V_4: Sada Sanne. The two factors experiment was laid out in split-plot design with three replications. The four levels of N were assigned in the main plot and 4 scented rice varieties in the sub-plot. Data were recorded on yield contributing characters, yield and quality of scented rice and statistically significant variation was recorded for most of the studied characters for different treatments. Results revealed that nitrogen and/or different varieties had significant effect on most of the yield and quality contributing parameters. Effective tillers, filled grains, weight of milled rice, protein content, proline content and grain 2-AP content increased with increasing nitrogen level upto a certain level. But N level had no significant effect on 1000 grains weight, harvest index and amylose content among the four scented rice varieties. Among the treatment combinations, the highest number of effective tillers $hill^{-1}$ (15.40) was found from N_3V_2 and the lowest number (8.40) from N_1V_3 treatment combination. The highest grain yield (3.47 t ha^{-1}) was found from N_3V_2, whereas the lowest (1.43 t ha^{-1}) was recorded from N_1V_3 treatment combination. The highest protein content (9.20%) was recorded from N_3V_4 and the lowest (7.04%) was observed from N_3V_3 treatment combination. The highest proline content (25.54 mg g^{-1}) was observed from N_3V_2, while the lowest (18.08 mg g^{-1}) was found from N_3V_3 treatment combination. The highest grain 2-AP content (1.06 µg g^{-1}) was recorded from N_3V_3 and the lowest (0.78 µg g^{-1}) was observed from N_3V_1 treatment combination. Data revealed that 40.0 kg N ha^{-1} and scented rice variety BRRI dhan34 showed best performance when considered yield with protein, amylose, proline and 2-AP content. So, Bangladeshi rice growers can produce high quality aromatic rice through 11.11% minimization of nitrogen without sacrificing its yield.

TABLE OF CONTENTS

CHAPTER	TITLE	Page

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDICES

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Gramineae, is second most widely grown cereal and primary source of food for more than half of the world population. About 90% of the world rice grown in Asia which is carrying about 60% of world population (Haque *et al*., 2015). It is grown in more than a hundred countries of the world and in the year 2014-15, worldwide total 474.86 million metric tons of rice has been produced from 159.64 million hectares of land (USDA, 2015). Rice contributes on an average 20% of apparent calorie intake of the world and also 30% of Asian populations (Hien *et al.*, 2006). In Bangladesh, annual production of rice is 34.71 million tons from the cultivation of 11.42 million hectares of land which is about 72.24% of total cropped area (BBS, 2015). Bangladesh ranks 4th in both area and production of rice and also 6th in per hectare production of rice yield (Sarkar *et al*., 2016).

In Bangladesh, the average production of rice is about 2.92 t ha^{-1} (FAO, 2014) which is very low compared to other rice growing countries of the world, like Japan (6.60 t ha^{-1}), China (6.30 t ha^{-1}) and Korea (6.30 t ha^{-1}). The population will swell progressively to 223 million by the year 2030 which will demand additional 48 million tons of food grains (Julfiquar *et al*., 2008). Increasing food demand to meet the global rice demand in the world is becoming challenged in terms of food security. It is generally estimated that about 114 million tonnes of additional milled rice will be produce by 2035 which is equivalent to overall increase of 26 percent in the next 25 years (Kumar and Ladha, 2011). Population growth of Bangladesh required continuous increase of rice production and the highest priority has been given to produce more rice in same land by increasing per hectare yield (Bhuiyan, 2004). Yearly increment of rice production in Bangladesh needs to be sustained to feed her ever increasing population although there are very little scope to increase rice area (Sarkar *et al*., 2016) rather agricultural land is declining @ 0.7% per annum (BBS, 2015).

Scented rice is globally appreciated among consumers and is in high demand because of its potent aromatic flavor and good quality (Hashemi *et al*., 2013; Ashraf and Tang, 2017). Scented rice, such as Basmati and Jasmine, has a characteristic fragrance and good grain quality (Ashraf *et al*., 2017; Ashraf and Tang, 2017) and the grains valued at a higher market price than non-aromatic rice varieties (Zhang *et al*., 2008). Despite a huge market demand at present area of Scented rice cultivation is less than 2% of the national rice coverage of Bangladesh (Ashrafuzzaman *et al*., 2009). The production of scented rice in Bangladesh during 2013 is approximately 0.30 million tons from 0.16 million ha of land which is so far from the national average, and hence the yield needs to be increased by 53.3% (Mahamud *et al*., 2013). Most of the well-off people preferred long, slender scented fine grain rice (Mannan *et al*., 2012; Sarkar *et al*., 2014). The demand for scented fine grain rice has been increased due to economic development of the people of Bangladesh (Ali *et al*., 2016).

Among the essential nutrients nitrogen (N) is the main nutrient that determines rice yield, due to its role in the photosynthesis and dry matter accumulation in plant (Yoshida *et al.*, 2006). Significant improvement in crop yields is attributed to the increase in fertilizer use, especially nitrogen fertilizer (Cassman *et al*., 2003). At farmer's level, the rate of applied N fertilizer is usually greater than the recommendation for maximum crop growth and maximum yields (Fan *et al*., 2012). However, excessive N input could increase the rice production cost and reduce paddy yield (Peng *et al*., 2009; Pen *et al*., 2010; Guo *et al*., 2010; Fan *et al*., 2012). Imbalanced nitrogen fertilizer applied rate in soils is the most important variable that limits the quality and yields in rice (Wang *et al*., 2008). N level at 80 kg ha^{-1} improved grain quality and soil fertility (Sikdar *et al*., 2008). However, high nitrogen can lead to lodging in rice (Mahajan *et al*., 2010). High aroma content in grains was associated to high total nitrogen in soil (Yang *et al*., 2012) and 2-AP content in grains was increased with increasing nitrogen application (Zhong and Tang (2014). The 2-AP content in brown rice was highest when the N supply was 60 kg ha^{-1} (Li *et al*., 2014).

Depending upon the differences in genotypic characters, input requirements and of course the prevailing environmental conditions during the entire growing season variety is the key component for producing higher yield of rice. Growth process of rice under a given agro-climatic condition differs due to specific rice variety (Alam *et al*., 2012). Improving and increasing the world's supply will also depend upon the development and improvement of rice varieties with better yield potential, and to adopt various conventional and biotechnological approaches for the development of high yielding varieties that having resistance against biotic and abiotic stresses (Khush, 2005). In Bangladesh high yielding rice variety has been introduced through BRRI, BINA, IRRI and different seed companies and it gains positive monumentaion in rice production in three distinct growing seasons (Haque and Biswas, 2011). Depending on the aroma and fineness, two types of rice varieties viz. aromatic (fine) and nonaromatic (coarse) rice are producing in Bangladesh. The most important aromatic rice varieties in Bangladesh are Chinisagara, Badshabhog, Kataribhog, Kalizira, Tulsimla, Dulabhog, Basmati, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and BRRI dhan38 (Sarkar *et al*., 2014). Production of aromatic rice can be increased by the selection of appropriate variety and nutrient management especially nitrogenous fertilizer (Zhaowen *et al*., 2018). It is important to preserve the content and maintain flavor of scented rice. Under the above mentioned perspective the present study was conducted with fulfilling the following objectives-

- To study the effect of nitrogen minimization on yield and the grain quality of scented rice.
- To find out the optimum value of nitrogen and suitable variety for producing good quality scented rice.

Chapter II
Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rice has remarkable adaptability to different environmental conditions as is evident from its worldwide distribution. Many researchers at home and abroad investigated various aspects of successful rice production. Nitrogen fertilizer is one of the major elements which greatly influence the vegetative growth and yield of rice. Judicious application of nitrogenous fertilizer is a key factor in rice based production system which can increase yield and reduce production cost. BRRI, BINA and IRRI developed different rice varieties of both aromatic and non-aromatic. Different researcher reported the effect of nitrogenous fertilizer on yield attributes and yield of both aromatic and non-aromatic rice but the findings is not adequate and conclusive in agro-climatic condition of Bangladesh. An attempt was taken to review the available important and informative research findings that are related to nitrogenous fertilizer on yield and yield attributes of both aromatic and non-aromatic rice have been reviewed under the following headings:

2.1 Effect of nitrogen on growth and yield of rice

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October 1997 to determine the best split application of 150 kg N ha^{-1} for rice cv. IR20. They found that applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the highest grain (6189.4 kg ha^{-1}) and straw (8649.6 kg ha^{-1}) yields, response ratio (23.40) and agronomic efficiency (41.26).

Munnujan *et al*. (2001) treated 4 levels of nitrogen fertilizer (0, 40, 80, and 160 kg ha^{-1}) application at three levels each planting density (20, 40 and 80 hill m^{-1}) and conducted that the highest grain yield (3.8 t ha^{-1}) was obtained with 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

Duhan and Singh (2002) conducted an experiment and reported that the rice yield and uptake of nutrients increased significantly with increasing N levels. Moreover, the application along with various green manures (GM) showed additive effect on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg ha^{-1} than with lower level of nitrogen.

Sidhu *et al*. (2004) reported that nitrogen fertilizers substantially increased the mean grain yield of Basmati up to 40 kg ha^{-1} N in the fallow Basmati-wheat sequence, while 60 kg ha^{-1} N reduced Basmati yield. Compared to 0 kg N ha^{-1}, the mean grain yield of Basmati was increased by 0.31, 0.40 t ha^{-1} at doses of 20 and 40 kg N ha^{-1}.

Hossain *et al*. (2005) carried out an experiment to assess the effects of nitrogen (30, 60, 90 and 120 kg ha^{-1} N) and phosphorus on the growth and yield of rice and reported that application of nitrogen up to 90 kg ha^{-1} enhanced the growth and yield of rice crop.

Muhammad *et al*. (2005) reported that the highest number of plant height (116.55 cm), number of spikelets panicle^{-1} (118.85) and straw yield (11.00 t ha^{-1}) were obtained from 150 kg ha^{-1} urea

Naik and Paryani (2005) reported that the plant height and grain yield were increased with application of N up to 150 kg ha^{-1}. The highest number of grains panicle^{-1} (157.9), yield of grains (64.4 q ha^{-1}) and straw (94.4 q ha^{-1}) were produced significantly from rice hybrids PHB-71.

Amin *et al*. (2006) found significant variation on growth, tillering and yield of three traditional rice varieties due to variable doses of N fertilizer compared with that of a modern variety at BSMRAU, Salna, Gazipur. Application of 60 kg ha^{-1} N produced more TDM and lesser ineffective tillers. Application of 30 kg ha^{-1} N produced the highest yield (4451 kg ha^{-1}).

Dwivedi *et al*. (2006) conducted a field experiment on growth and yield of rice to evaluate the effect of N level. They found that 184.07 kg ha^{-1} N (urea) was the optimum rate for highest yield.

Manzoor *et al*. (2006) evaluated the nine different nitrogen levels i.e. 0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha^{-1} for observing the field performance of rice. Plant height, productive tillers $hill^{-1}$, panicle length, grains $panicle^{-1}$, 1000 grain weight and paddy yield showed increasing trend from 0 kg ha^{-1} N up to 175 kg ha^{-1} N. The yield parameters including rice yield, grains $panicle^{-1}$ and 1000 grain weight started declining at 200 kg N ha^{-1} level and above. Maximum rice yield (4.24 t ha^{-1}) was obtained from 175 kg ha^{-1} nitrogen application treatment which also produced highest values of grains $panicle^{-1}$ (130.2) along with a maximum 1000 grain weight (22.92 gm). The plant height (139.8 cm) along with productive tillers $hill^{-1}$ (23.42) and panicle length (29.75 cm) was the maximum at 225 kg N ha^{-1}.

Abbasi *et al*. (2007) found that the highest number of fertile tiller was obtained in the fifth and sixth treatments with double and triple split application of 120 kg ha^{-1} N. They suggested that triple split application of 80 kg ha^{-1} N could be best for rice production.

Hossain *et al*. (2007) carried out an experiment and reported that the N levels also exerted significant effect on all the yield parameters, except for panicle length and 1000 grain weight. The highest grain yield was obtained from the application of 75 kg ha^{-1} of the recommended dose of N and the lowest from the control treatment (0 kg ha^{-1}) of rice cv. BRRI dhan32. The greatest plant height and highest number of tillers $hill^{-1}$ were observed with the application of 69 kg ha^{-1} N, which was significantly followed by 51.75, 34.5 and 17.25 kg ha^{-1} N, respectively and the lowest was observed in control treatment (0 kg ha^{-1} N).

Hossain *et al*. (2008) reported that different nitrogen rates also significantly affected the aromatic rice cultivars. All the yield components were significantly increased up to 90 kg ha^{-1} N. Nonetheless, maximum grain yield (3.62 t ha^{-1}) was observed from 60 kg ha^{-1} N.

Islam *et al*. (2008) conducted a field experiment at Bangladesh Agricultural University, Mymensingh to evaluate the effect of nitrogen (N) level on the quality of aromatic rice and fertility status of the post-harvest soil. The experiment comprised of three varieties viz., Kalizira, Badshabhog and Tulshimala and three levels of nitrogen viz., 40, 60 and 80 kg ha^{-1}. Among three N levels, 80 kg ha^{-1} performs the best to quality of aromatic rice.

Nori *et al*. (2008) studied to assess the grain yield and straw nutritive quality of MR 211 and MR 219 rice varieties due to five nitrogen rates (0, 120, 160, 200 and 240 kg ha^{-1} N). Increases in nitrogen application was found increase ($P<0.01$) the grain yield, total spikelets m^{-2}, spikelets $panicle^{-1}$ and straw crude protein from 4.56% to a maximum level of 8.45%.

Salahuddin *et al*. (2009) found gradual increase in panicle length (24.50 cm), grains $panicle^{-1}$ (110) and grain yield (4.91 t ha^{-1}) due to the increase in nitrogen levels up to 150 kg ha^{-1} and declined thereafter. 1000 grain weight was not significantly influenced by application of different levels of nitrogen.

Islam *et al*. (2009) found significant variation on morphophysiological attributes of BINA dhan5, Tainan 3 and BINA dhan6 due to four N levels. Plant height, tillers $hill^{-1}$, leaf area $hill^{-1}$ (cm^2) were increased with the split application of N. Among the treatments, T_4 (full doze of urea at three equal splits, 1/3 at 15 DAT + 1/3 at 30 DAT + 1/3 at 55 DAT showed the best performance and grain yield (45.25 g $hill^{-1}$) compared to control (30.61 g $hill^{-1}$). Full dose of urea (215 kg ha^{-1} urea) applied at three equal split at 15, 30 and 55 DAT was found to be the most beneficial one for the all the rice genotypes.

Hoshain (2010) observed that number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield and straw yield were significantly increased with the increasing rates of N 120 Kg ha^{-1} as urea where harvest index increased from up to N 80 Kg ha^{-1} application.

Kandil *et al*. (2010) found that the increasing nitrogen fertilizer levels up to 80 kg ha^{-1} N resulted in marked increases in number of tillers m^{-2} , panicle length, panicle weight, filled grains $panicles^{-1}$, 1000 grain weight, grain and straw yields ha^{-2} and harvest index in both seasons. The addition of 144 or 192 kg ha^{-1} N recorded the tallest plants and the highest number of panicles m^{-2} without significant differences.

Mannan *et al*. (2010) carried out an experiment to determine the optimum N level as well as to find out the genotype having high yield potential. The plant height, tiller number, number of panicles, panicle length, spikelet sterility and straw yield increased with the increase of nitrogen levels up to 75 kg ha^{-1} N. Maximum plant growth at the highest level of N caused lodging of plant which increased spikelet sterility and lower grains $panicle^{-1}$ and ultimately decreased grain yield.

Fageria *et al*. (2011) reported that yield and yield components were significantly increased in a quadratic fashion with increasing N rate. Based on regression equation, maximum grain yield was achieved with the application of 380 mg kg^{-1} N by ammonium sulfate and 271 mg kg^{-1} N by urea. Grain yield and yield components were reduced at higher rates of urea (>300 mg kg^{-1} N) but these plant parameters' responses to ammonium sulfate at higher rates was constant. In the intermediate N rate range (125 to 275 mg kg^{-1}) urea was slightly better compared to ammonium sulfate for grain yield.

Karim (2011) studied on the effect of nitrogen fertilizer (0, 20, 40, 60, 80.100 120 kg ha^{-1} N) in respect to high yield and better seed quality. Growth parameters like plant height (114.37 cm) and tillers $hill^{-1}$ (15.1) had higher at higher level of nitrogen. However, plants with moderate level of applied nitrogen showed better yield component of the variety where the highest panicle $hill^{-1}$ (11.8), grains $panicle^{-1}$ (140.5) and filled grains $panicle^{-1}$ (130.33) were found with 60 kg ha^{-1} N. Better yield components of the variety obtained at 60 kg N ha^{-1} attributed to the highest yield (4.43 t ha^{-1}) of the variety.

Khorshidi *et al*. (2011) reported that the effect of nitrogen fertilizer had no significant difference on 1000 seeds weight and number of grains panicle^{-1}. The effect of fertilizers on rice yield showed that application of 100 kg of nitrogen had the highest yield of 5733 kg ha^{-1}. Data also indicated that yield had the highest positive correlation with panicle and harvest index.

Metwally *et al*. (2011) studied to evaluate the response of Egyptian hybrid rice 1 'H_1' to nitrogen fertilizer. Nitrogen levels were 0, 50, 100, 150, 200, 250, 300, 350, and 400 kg N ha^{-1}. Nitrogen fertilization significantly increased grain yield. The maximum grain yield was obtained with the application of 200 kg N ha^{-1}. Yield components were also significantly affected by N treatments.

Mohaddesi *et al*. (2011) found that the effect of nitrogen fertilizer rates had not significant effects on traits except 1000 grain weight in both seasons. Increasing N fertilizer levels up to 300 kg N ha^{-1} resulted in increases in plant height, grain yield, biological yield but these increases were not significant.

Salem *et al*. (2011) reported that the number of tillers hill^{-1}, days from sowing up to panicle initiation, heading dates, leaf area index, leaf area ratio, chlorophyll content, 1000 grain weight, panicles length, agronomic efficiency, utilization efficiency and grain yield (t ha^{-1}) were increased by increasing nitrogen levels up to 165 kg ha^{-1} N.

Abou-Khalifa (2012) evaluated the 5 rice varieties under different N levels (0, 55, 111, 165 and 220 Kg ha^{-1}). Main results induced that maximum tillering, panicle initiation, roots length, heading dates, grains filling rates at five stages, number of tillers m^{-2} , 1000 grain weight, number of grains panicle^{-1}, panicle length (cm) and grain yield (t ha^{-1}) were the highest value at 220 kg ha^{-1} N.

Hasanuzzaman *et al*. (2012) conducted an experiment on growth and yield of rice due to evaluate the effect of N fertilizer (0, 80, 120, 160, 200 kg ha^{-1} N, USG @ 75 kg ha^{-1} N). Results indicated that N had a significant effect on effective tillers hill^{-1}, filled grains panicle^{-1} and 1000 grain weight. USG gave the highest effective tillers hill^{-1} 18 (13.63) followed by 120 kg ha^{-1} N (12.11). The highest filled grains panicle^{-1} (154.7) was found from N_2 (USG) which was at par with 160 kg ha^{-1} N (145.8), 120 kg ha^{-1} N (145.4) and 200 kg ha^{-1} N (144.1). Application of N created significantly variation in grain, straw and biological yield and also harvest index.

Sharma *et al*. (2012) carried out a field experiment and found that the highest grain yield of 70.60 q ha^{-1} was attained with an application of 180 kg ha^{-1} N and the lowest yield (44.12 q ha^{-1}) was recorded in the control plot.

Yoseftabar *et al*. (2012) showed that yield and yield components increased significantly with nitrogen fertilizer. Interesting in comparison to 100 and 200 kg ha^{-1} level application of higher N fertilizer 300 kg ha^{-1} showed a positive respond to application of high nitrogen on hybrid cultivar. Effect of different split application N fertilizer was significantly on parameter of above.

Maqsood *et al*. (2013) reported that the nitrogen application at 100 kg ha^{-1} N provided a maximum paddy yield (4.39 and 4.67 t ha^{-1}) in both years under the climatic conditions of Faisalabad, Pakistan, higher paddy yield and yield components, as well as greater economic benefits, can be obtained at 100 kg ha^{-1} nitrogen application.

Naznin *et al*. (2013) investigate the effects of prilled urea (PU), urea super granule (USG) and NPK briquette on NH4-N concentration in field water, yield and nitrogen (N) use efficiency (NUE) of BR22 rice under reduced water conditions and reported that the highest grain yield of 3.93 t ha^{-1} from 104 kg N ha^{-1} as USG and the lowest of 2.12 t ha^{-1} from control. The overall results revealed that application of USG and NPK briquette may be practiced for obtaining better yields in addition to increasing the efficiency of N fertilizer.

Yoseftabar (2013) reported that N fertilizer is a major essential plant nutrient and key input for in increasing crop yield. The results showed that panicle number, panicle length, panicle dry matter, number of primary branches, total grain and grain yield increased significantly with nitrogen fertilizer. Application 300 kg N ha^{-1} observed high rate of this parameter.

Azarpour *et al*. (2014) studied on yield and physiological traits of three rice cultivars due to the effect of N fertilizer (0, 30, 60, and 90 Kg N ha^{-1}). Results of growth analysis indicated that, nitrogen increasing rates of fertilizer caused the increment of growth indexes and yield of rice.

Murthy *et al*. (2015) conducted an experiment with an objective to revise the existing fertilizer doses of major nutrients in Krishna Godavari delta regions of Andhra Pradesh. 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%.

Haque *et al*. (2015) conducted an experiment to investigate the effect of five nitrogen levels *viz*. 0, 40, 80, 100 and 140 kg ha^{-1} N and he found the longest plant, highest number of total, effective tillers $hill^{-1}$, grains $panicle^{-1}$, grain and straw yields were observed with 100 kg ha^{-1} N followed by 140 kg ha^{-1} N.

Lukman *et al*. (2016) reported that the growth and yield parameters of rice considered were significantly affected by the combined application of cowdung and NPK fertilizer except one thousand grain weight. Application of 8 t ha^{-1} of cowdung in combination with 400 kg ha^{-1} NPK 20:10:10 gave the highest grain yield (5.77 t ha^{-1}) at Sokoto and it is recommended that application of 12 t ha^{-1} of cowdung in combination with 300 kg ha^{-1} NPK 20:10:10 resulted in the best soil nutrient enrichment and yield of rice in Sokoto and Talata Mafara.

Field experiment was conducted by Rajesh *et al*. (2017) to study the response of rice varieties on morpho-physiological and yield under two nitrogen levels 120 kg N ha^{-1} [N_{120}], 60 kg N ha^{-1} [N_{60}] as main treatments and twenty six rice genotypes as sub treatments. In the present investigation among the nitrogen treatments application of 120 kg N ha^{-1} recorded significantly higher values for morpho-physiological parameters such as number of tillers $hill^{-1}$, maximum number of panicles $hill^{-1}$, number of filled grains $hill^{-1}$, filled grain percentage, 1000 grain weight and grain yield. Spikelet sterility and number of unfilled grains hill^{-1} were lowest in this treatment.

Zhaowen *et al*. (2018) carried out and experiment the South China Agricultural University in Guangzhou, China with three N levels (N_0: 0 kg ha^{-1}, N_1: 30 kg ha^{-1}, and N_2: 60 kg ha^{-1}) at the booting stage were applied to a popular aromatic rice cv. Yungengyou 14, to assess the accumulation pattern of 2-AP, proline, and N as well as relationships among the investigated indices regarding 2-AP accumulation. Among all other plant parts, the highest 2AP contents were found in ear axes and flag leaves, *i.e*., 17.04%-18.26% and 14.37%- 15.05% at 17 as well as 18.41%-22.74% and 14.38%-15.75% at 30 DAF under all N-levels. Interestingly, N application at the booting stage also maintained higher proline and 2-AP contents in different plant tissues during the early grain filling stage. Hence additional N dose at booting stage could improve the grain aroma contents of aroma rice while considering the amount of N fertilizer added.

Hossain *et al*. (2018) conducted an experiment at Patuakhali Science and Technology University, Dumki, Patuakhali under AEZ-13 to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment was consisted of three aromatic rice varieties *viz*., V_1 = BRRI dhan34, V_2 = BRRI dhan38 and V_3 = Sakkorkhora and four fertilizer treatments viz., N_0 = 0 kg ha^{-1} nitrogen (Control), N_1 = 30 kg ha^{-1} nitrogen, N_2 = 45 kg ha^{-1} nitrogen and N_3 = 60 kg ha^{-1} nitrogen. Result revealed that 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 condition.

2.2. Effect of varieties on growth and yield of rice

2.2.1 Plant height of different rice varieties

Ghosh (2001) conduced an experiment with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties.

Murthy *et al.* (2004) carried out an experiment with six varieties of rice genotypes namely Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and the findings revealed that the variety Mukti gave the longest plant compared to the others of their experiment.

Masum *et al*. (2008) observed that plant height of rice affected by varieties in *Aman* season where Nizershail produced the taller plant height than BRRI dhan44 at different days after transplanting (DAT).

Khalifa (2009) conducted a field experiment at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

To study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101 field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height.

Bhuiyan *et al*. (2014) carried out an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety. Based on the findings of the study it was revealed that the different hybrid rice varieties had significant effects on plant height at maturity.

An experiment was conducted by Haque and Biswash (2014) with five varieties of hybrid rice and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties was Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29 and the highest plant height was 101.5 cm was recorded from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the tallest plant (142.7 cm) were recorded in BRRI dhan34.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of nitrogen. Data revealed that among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), whereas the lowest plant height by BRRI dhan57.

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties in main plots and six fertilizer levels in subplots. From the findings they sated that ‘Raniselute’ variety produced the highest plant height.

An experiment was conducted by Hossain *et al*. (2018) at Patuakhali Science and Technology University, Dumki, Patuakhali under AEZ-13 to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment was consisted of three aromatic rice varieties viz., V_1= BRRI dhan34, V_2= BRRI dhan38 and V_3 = Sakkorkhora and four fertilizer treatments. The result revealed that the longest plant height (157.08 cm) was found from Sakkorkhora.

2.2.2 Tillering pattern of different rice varieties

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4/m^2) than other tested varieties.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others. Song *et al.* (2004) found that hybrids produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

Masum *et al.* (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all crop growth stages. Nizersail was achieved maximum (25.63) tiller at 45 DAT, whereas BRRI dhan44 gave the maximum tillers (18.92) around panicle initiation stage at 60 DAT from.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated and results indicated that H_1 hybrid rice variety surpassed other varieties in terms of effective and total tillers hill^{-1}.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Among the varieties, BRRI dhan52 produced the highest number of effective tillers hill^{-1} (11.28), while the lowest were produced by BRRI dhan57.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the highest number of effective tillers hill^{-1} (10.02) was recorded in BRRI dhan34.

Bhuiyan *et al.* (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced more productive tillers.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from BRRI. Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29. In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3).

Sarkar *et al.* (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of tillers hill^{-1} and these hybrid varieties showed higher effective tillers hill^{-1}.

Sumon *et al.* (2018) conducted a study was conducted to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties in main plots and six fertilizer levels in subplots. From the findings they sated that 'BRRI dhan34' gave the maximum number of effective tillers hill^{-1} (12.74).

2.2.3 Dry matter content of different rice varieties

Sharma and Haloi (2001) conducted an experiment in Assam during the kharif season with 12 varieties of scented rice cultivars to assess the yield attributes and yield and observed that cv. Kunkuni Joha consistently maintained a higher rate of dry matter production in compared to the other varieties of this experiment at all the growth stages and the highest dry matter accumulation was observed in cv. Kunkuni Joha at the panicle initiation stage.

Mandavi *et al.* (2004) carried out an experiment to study on the morphological and physiological indicators of rice genotypes, a field experiment was conducted at the Rice Research Institute of Iran. In that study, Onda had the greater total dry matter (TDM) among other genotypes (this genotype also had the highest grain yield). Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering the dry matter weight was higher for Jasesh and was lower for Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively). So the photosynthetic potential of improved genotypes was higher as reflected by their TDM which had positive correlation with the grain yield of these varieties.

Amin *et al*. (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (KK-4). The findings of the study revealed that traditional varieties accumulated higher amount of vegetative dry matter content than the modern rice variety.

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

Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}). Masum *et al.* (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan44 Nizershail significantly varied at different sampling dates.

Shaloie *et al*. (2014) carried out an experiment to evaluate the response to planting date in rice hybrids line dry method of working, at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of total dry matter (TMD) $hill^{-1}$ and the highest TDM $hill^{-1}$ (84.0 g) was observed Tia and lowest TDM $hill^{-1}$ (70.10 g) was observed in BRRI dhan33.

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties in main plots and six fertilizer levels in subplots. From the findings they sated that 'Raniselute' variety produced the highest dry matter weight $hill^{-1}$ compared to the other rice varieties.

2.2.4 Yield attributes of different rice varieties

Guilani *et al*. (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Among cultivars, LD183 had the highest grain weight.

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits in a field experiment. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of spikelets m^{-2}).

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

Islam *et al.* (2009) conducted pot experiments during T. *Aman* season in net house at Bangladesh Rice Research Institute (BRRI). Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 was used in both the seasons. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties for studied characters except for number of days to panicle initiation and heading date.

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components was determined at maturity. Hybrid produced higher spikelets panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

Two field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight.

Forty five aromatic rice genotypes were evaluated by Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *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. Among the varieties, BRRI dhan52 produced the grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g), whereas the lowest values of these parameters was produced by BRRI dhan57.

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the number of grains panicle^{-1} (152.3), panicle length (22.71 cm) and 1000-grain weight (15.55 g) were recorded in BRRI dhan34.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan2 in *Aman* season with an inbred BRRI dhan33 as checked and these hybrid varieties also showed higher 1000-grain over the inbred.

An experiment was conducted by Hossain *et al*. (2018) at Patuakhali Science and Technology University, Dumki, Patuakhali under AEZ-13 to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment was consisted of three aromatic rice varieties viz., V_1= BRRI dhan34, V_2= BRRI dhan38 and V_3 = Sakkorkhora and four fertilizer treatments. The result revealed that the longest panicle (28.89 cm), the maximum 1000-grain weight (16.71 g) were obtained from BRRI dhan38 and maximum filled grains per panicle (145.99) from BRRI dhan34.

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties and six fertilizer levels. From the findings they sated that 'BRRI dhan34' produced the highest panicle length (27.93 cm), number of filled grains panicle^{-1} (192.5), 1,000-grain weight (17.22 g) and grain yield (2.26 t ha^{-1}).

2.2.5 Yield of different rice varieties

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

An experiment was carried out by Alam *et al*. (2012) at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi to study the effect of variety, spacing and number of seedlings $hill^{-1}$ on the yield potentials of transplant *Aman* rice. The experiment consisted of three high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings $hill^{-1}$. Variety had significant effects on yield and BR11 produced the highest grain yield (5.92 t ha^{-1}).

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Findings revealed that different hybrid rice varieties had significant effects on yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield.

Jisan *et al*. (2014) carried out and experiment at, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *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. Data revealed that highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar under low input fertilizer levels. There were significant cultivar effects for all traits. The grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar widely grown in Senegal.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the highest grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

A study was design by Wagan *et al*. (2015) to compare the economic performance of hybrid and conventional rice production and reported that total costs per hectare of hybrid rice was 148992.23 Rs per hectare which was more than conventional rice was 140661.68 Rs ha^{-1}. On an average higher yield (196.14 monds ha^{-1}) was obtained from hybrid rice while conventional rice yield (140.14 monds ha^{-1}) was less then hybrid rice. There was 16.64 percent increase in hybrid rice yield comparing with conventional rice.

A study was conducted by Mandira *et al*. (2016) in South Tripura district of Tripura for three consecutive kharif seasons to evaluate the performance of rice variety gomati at farmers field under rainfed conditions. The gomati variety of rice was found superior over farmers' existing practices with local varieties. Rice variety gomati with improved production technologies followed in FLDs, increased mean grain yield by 41.62% over farmers' existing practices.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The highest grain yield was achieved from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced 24.0% higher yield over the inbred BRRI dhan33.

Huang and Yan (2016) tested of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety, at the farm of University of Arkansas at Pine Bluff (UAPB). Results showed that the yields of 7 hybrids were 25.7%-30.7% higher than check Francis. Hybrid 28s/BP23R had the highest yield, 10846.6 kg ha^{-1} and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg ha^{-1} and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg ha^{-1} and over check by 27.1% and 27.0%, respectively.

Chowdhury *et al*. (2016) conducted an experiment was at Bangladesh Agricultural University, Mymensingh with a view to finding out the effect of variety and level of nitrogen on the yield performance of fine aromatic rice. The experiment consisted of three varieties viz. Kalizira, Binadhan-13 and BRRI dhan34, and six levels of nitrogen. The highest grain yield (3.33 t ha^{-1}) was obtained from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}).

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties and six fertilizer levels. From the findings they sated that 'Raniselute' variety produced the highest straw yield (7.81 t ha^{-1}), biological yield (9.05 t ha^{-1}) and 'BRRI dhan34' gave the maximum grain yield (2.26 t ha^{-1}).

An experiment was conducted by Hossain *et al*. (2018) at Patuakhali Science and Technology University, Dumki, Patuakhali under AEZ-13 to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment was consisted of three aromatic rice varieties viz., V_1= BRRI dhan34, V_2= BRRI dhan38 and V_3 = Sakkorkhora and four fertilizer treatments. The result revealed that the maximum grain yield of 3.38 t ha^{-1}, the maximum biological yield (7.87 t ha^{-1}) and harvest index (42.89%) were obtained from BRRI dhan38.

It was revealed from the above mentioned reviews that application of nitrogenous fertilizer greatly and influences the growth, yield attributes and as well as yield of different rice variety. The literature revealed that the effects of nitrogen on rice and comparative study of different aromatic rice variety have not well articulated and have no definite conclusion in the agro climatic condition of Bangladesh especially for yield and quality of aromatic rice.

.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The study was conducted to assess the minimization of nitrogen on yield and aroma quality of scented rice. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental site, experimental treatment and design, growing of crops, data collection and analysis procedure that followed for the conduction of this experiment has been presented below under the following headings and sub-headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted in the period from June to December 2017.

3.1.2 Experimental location

The present experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 23.74^0N latitude and 90.35^0E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). During the experimental period the maximum temperature (36.8^0C), highest relative humidity (87%) and highest rainfall (573 mm) was recorded for the month of July, 2017, whereas the minimum temperature (22.6^0C), minimum relative humidity (74%) and no rainfall was recorded for the month of December, 2017. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.1.4 Soil characteristics

The soil of the experimental field belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area having available irrigation and drainage system and situated above flood level. The soil having a texture of sandy loam organic matter 1.15% and composed of 26% sand, 43% silt and 31% clay. Details morphological, physical and chemical properties of the experimental field soil are presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

Scented rice cultivars Kalizira, BRRI dhan34, Begun Bichi and Sada Sanne were used as the test crops in this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Levels of nitrogen (4 levels) as

i. N_1: 37.5 kg N ha^{-1}

ii. N_2: 40.0 kg N ha^{-1}

iii. N_3: 42.5 kg N ha^{-1}

iv. N_4: 45.0 kg N ha^{-1} (Recommended Dose)

Urea (46% N) is used for nitrogen requirement

Factor B: Scented rice variety (4 varieties) as

i V_1: Kalizira

ii. V_2: BRRI dhan34

iii. V_3: Begun Bichi

iv. V_4: Sada Sanne

There were total 16 (4×4) treatment combination as a whole and they are N_1V_1, N_1V_2, N_1V_3, N_1V_4, N_2V_1, N_2V_2, N_2V_3, N_2V_4, N_3V_1, N_3V_2, N_3V_3, N_3V_4, N_4V_1, N_4V_2, N_4V_3 and N_4V_4.

3.2.3 Description of cultivars

Among the scented rice cultivars BARI dhan34 was developed by BRRI in 1997 through selection process from a Jashore local variety Khaskani. It is recommended for *Aman* seasons and growth duration is about 135 days. On an average it produced yield of 3.5 t ha^{-1} and plant height is about 117 cm. On the other hand Kalizira, Begun Bichi and Sada Sanne are the locally well known scented rice cultivars.

3.2.4 Experimental design and layout

The two factors experiment was laid out in split-plot design with three replications. An area of 443.45 m^2 (24.5 m × 18.1 m) was divided into 3 blocks. The four levels of N were assigned in the main plot and 4 scented rice varieties in the sub-plot. The size of the each unit plot was 2.0 m × 1.6 m. The space between two blocks, main and two plots and sub plots were 1.0 m, 0.75 m and 0.5 m, respectively. Each plot and sub-plot were separated by raised border. The layout of the experiment presented in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds of different scented rice varieties were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and local market just 20 days ahead of the sowing of seeds in seed bed. For seedlings clean seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in the seed bed in 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible at 18^{th} June, 2017. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed.

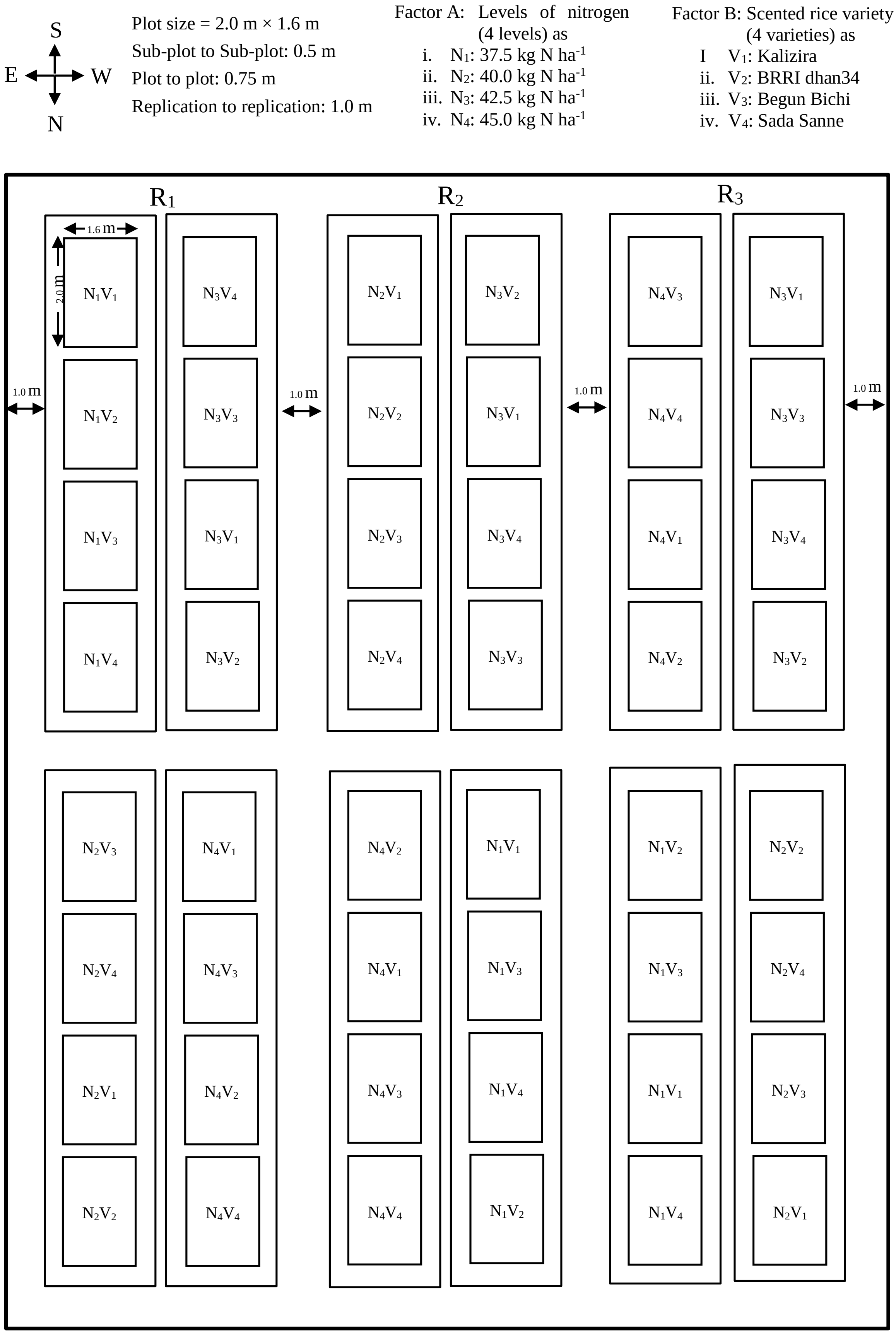


Figure 1. Layout of the experimental plot

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 15th June 2017 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design at 22th June, 2017. Organic and inorganic manures as indicated 3.3.4 were mixed with the soil of each unit plot.

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, Gypsum, zinc sulphate and borax, respectively. TSP, MoP, Gypsum, zinc and borax were applied @ 60, 90, 12, 3.0 and 10 kg ha^{-1} (BRRI, 2016). Vermocompost were applied @ 77.0 kg ha^{-1} in each plot. N were applied as per treatment. The entire amount of Vermocompost, TSP, MoP, gypsum, zinc sulphate and borax were applied during final land preparation. Urea was applied in three equal installments as top dressing at early and maximum tillering and panicle initiation stages.

3.3.5 Transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 26th July, 2017 in well puddled plot with spacing of 20 × 15 cm. Two seedlings was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.6.1 Irrigation and drainage

In the early stages to establishment of the seedlings irrigation was provided to maintain a constant level of standing water upto 6 cm and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development of the seedlings. The weeds were uprooted carefully at 20 DAT (days after transplanting) and 40 DAT by mechanical means.

3.3.6.3 Insect and pest control

Furadan were applied at 15 DAT in the plot. Leaf roller (*Chaphalocrosis medinalis*) was found and used Malathion @ 1.12 L ha^{-1} at 25 DAT using sprayer but no diseases infection was observed in the field.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity based on variety when 80-90% of the grains were turned into straw color. The harvested crop was bundled separately, properly tagged and brought to threshing floor. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to 12% moisture content. Yields of rice grain and straw were recorded from each plot.

3.5 Data recording

3.5.1 Plant height

The height of plant was measured in centimeter (cm) from the ground level to the tip of the plant at 20, 40, 60 DAT and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.2 Number of tillers $hill^{-1}$

Number of tillers $hill^{1}$ was recorded at 20, 40, 60 DAT and at harvest as the average of randomly selected 5 plants from the inner rows of each plot.

3.5.3 Chlorophyll content in flag leaf

Flag leaves were sampled from 5 plants at flowering stage and a segment of 20 mg from middle portion of flag leaf was used for chlorophyll content estimation on fresh weight basis extracting with 80% acetone and for that double beam spectrophotometer (Model: U-2001, Hitachi, Japan) were used according to Witham *et al*. (1986).

3.5.4 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers during harvesting. Data on effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.5 Non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the number of non-panicle bearing tillers during harvesting. Data on non-effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.6 Panicle length

The length of panicle was measured with a meter scale from 5 selected panicle and the average length was recorded as per panicle in cm.

3.5.7 Filled grains panicle^{-1}

The total numbers of filled grains were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.8 Unfilled grains panicle^{-1}

The total numbers of unfilled grains was collected randomly from selected 5 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.9 Total grains panicle^{-1}

The total numbers of grains was calculated by adding filled and unfilled grain selected 5 plants of a plot and average numbers of grains panicle^{-1} was recorded.

3.5.10 Weight of 1000-grains

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.5.11 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. Dry weight of grains of each plot were taken and converted to ton hectare^{-1} (t ha^{-1}).

3.5.12 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. Dry weight of straw of each plot were taken and converted to ton hectare^{-1} (t ha^{-1}).

3.5.13 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.14 Harvest index

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

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

3.5.15 Length of grain rice

Ten (10) milled grain rice was selected from the bulk sample after milling of each entry were measured for their length by slide calipers.

3.5.16 Breadth of grain rice

Ten (10) milled grain rice was selected from the bulk sample after milling of each entry were measured for their breadth by slide calipers.

3.5.17 Weight of milled rice

After milling of 100 g brown rice the milled rice were weighted by digital weighing machine and recorded in gram (g).

3.5.18 Weight of head rice

Unbroken head rice were identified after milling of 100 g brown rice of each entry and weighted by digital weighing machine and recorded in gram (g).

3.5.19 Weight of broken rice

Broken rice were identified after milling of 100 g brown rice of each entry and weighted by digital weighing machine and recorded in gram (g).

3.5.20 Rice and husk ratio

After milling of 100 g brown rice weight of husk was taken and ratio of rick and husk was estimated.

3.5.21 Protein content

The protein content of rice grains was determined by the Micro-Kjeldahl method using automated nitrogen determination system (AOAC, 1990).

3.5.22 Amylose content

The amylose content of the rice samples was carried out using method by Juliano (1971) with some modification. Hundred mg of the powdered rice sample was taken in a volumetric flask. To which 1 ml of 95% ethanol and 9 ml of 1 NaOH was added. It was then heated in boiling water bath to gelatinize starch. Five ml of the starch extract was taken in 100 ml volumetric flask. One ml of 1N acetic acid and 2 ml iodide solution was added to the starch extract and the volume was made up to 100 ml. The solution was shaken and allowed to stand for 20 min. Then the absorbance was measured at 620 nm using Agilent Technologies Cary 60 UV-VIS spectrophotometer. Amylose content of the sample was determined with reference to the standard curve of potato amylose and expressed in % basis.

3.5.23 Proline content

The proline content of rice grains were measured according to the method established by Bates *et al*. (1973). Grains in which the weight was almost 0.3 g, were homogenized in a 4 ml solution of 3% sulfosalicylic acid and cooled after bringing to a boil for 10 min. Samples were filtered and 2 ml of the filtrate was mixed with 3 ml ninhydrin reagent (2.5 g ninhydrin in 60 ml glacial acetic acid and 40 mL 6 M phosphoric acid) and 2 ml glacial acetic acid. For the extraction of proline, the mixture was boiled for 30 min and 4 ml toluene was added to the cooled liquid. The extract was centrifuged at 4000 rpm for 5 min, and proline absorbance was detected at 520 nm and concentration expressed as $\mu g\ g^{-1}$.

3.5.24 Grain-2AP content

The 2-AP content in grain was estimated using the method described by Huang *et al*. (2012), prior to analysis, grains were ground by mortar and pestle. Approximately 10 g grains were mixed homogeneously with 150 ml purified water into a 500 ml round-bottom flask attached to a continuous steam distillation extraction head. The mixture was boiled at 150^0C in an oil pot. A 30 ml aliquot of dichloromethane was used as the extraction solvent and was added to a 500 ml round-bottom flask attached the other head of the continuous steam distillation apparatus, and this flask was boiled in a water pot at 53^0C. The continuous steam distillation extraction was linked with a cold water circulation machine in order to keep temperature at 10^0C. After approximately 35 min, the extraction was complete. Anhydrous sodium sulfite was added to the extract to absorb the water. The dried extract was filtered by organic needle filter and analyzed for 2-AP content by GCMS-QP 2010 Plus. High purity helium gas was used as the carrier gas at flow rate of 2 ml/min. The temperature gradient of the GC oven was as follows: 40^0C (1 min), increased at 2^0C min^{-1} to 65^0C and held at 65^0C for 1 min, and then increased to 220^0C at 10^0C min^{-1}, and held at 220^0C for 10 min. The retention time of 2-AP was confirmed at 7.5 min. Each sample had three replicates, and 2-AP was expressed as μg g^{-1}.

Protein, amylose, proline and 2-AP content were measured at Bangladesh Rice Research Institute (BRRI) and Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka.

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among different treatments. The analysis of variance of all the recorded parameters performed using MSTAT-C software. The difference of the means value was separated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

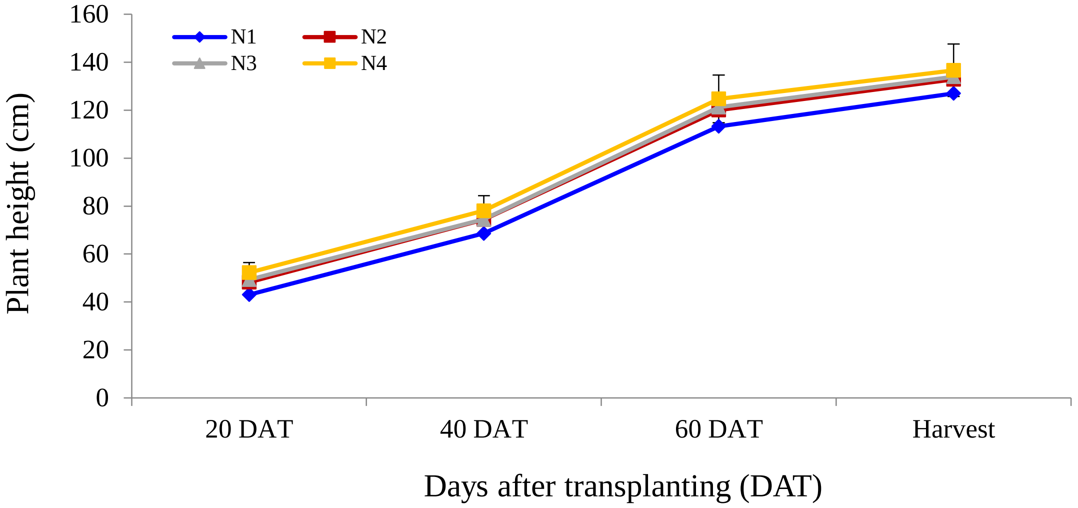
The experiment was conducted to minimization of nitrogen on yield and aroma quality of scented rice. The analyses of variance (ANOVA) of the data on yield contributing characters, yield and quality of scented rice are presented in Appendix IV-X. The results have been presented and discusses with the help of different table and graphs and possible interpretations are provided under the following headings and sub-headings:

4.1 Yield contributing characters and yield of scented rice

4.1.1 Plant height

Plant height of scented rice at 20, 40, 60 DAT (days after transplanting) and at harvest showed statistically significant variations due to different levels of nitrogen (Figure 2). At 20, 40, 60 DAT and harvest, the tallest plant (52.28, 78.10, 124.74 and 136.61 cm, respectively) was observed from N_4 (45.0 kg N ha^{-1}) which was followed (49.35, 74.48, 121.36 and 133.98 cm, respectively) by N_3 (42.5 kg N ha^{-1}) and also (48.28, 74.44, 120.07 and 132.88 cm, respectively) by N_2 (40.0 kg N ha^{-1}), while the shortest plant (43.04, 68.61, 113.29 and 127.01 cm, respectively) was found from N_1 (37.5 kg N ha^{-1}). Cultivars is the key component for producing plant height based on their genotypic characters and off course the prevailing environmental conditions of growing season. Maqsood *et al*. (2013) reported that longest plant height can be obtained at 100 kg ha^{-1} nitrogen application. Haque *et al*. (2015) found the longest plant with 100 kg N ha^{-1}.

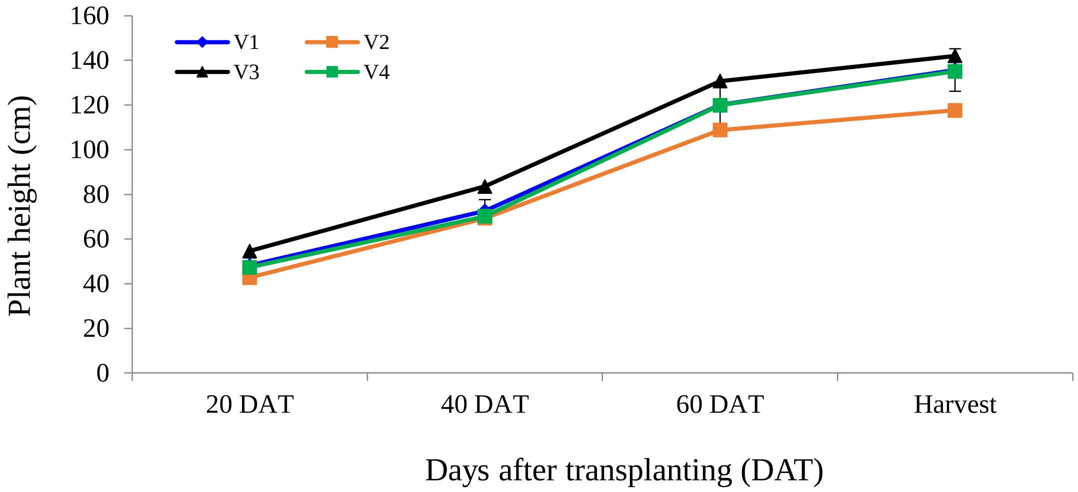
Different rice varieties varied significantly in terms of plant height of scented rice at 20, 40, 60 DAT and at harvest (Figure 3). At 20, 40, 60 DAT and harvest, the tallest plant (54.65, 83.55, 130.72 and 142.03 cm, respectively) was recorded from V_3 (Begun Bichi) which was followed (48.18, 72.53, 120.08 and 135.71 cm, respectively) by V_1 (Kalizira) and also (47.35, 70.20, 119.87 and 135.11 cm, respectively) by V_4 (Sada Sanne) and they were statistically similar, whereas the



N_1: 37.5 kg N ha^{-1} N_2: 40.0 kg N ha^{-1}

N_3: 42.5 kg N ha^{-1} N_4: 45.0 kg N ha^{-1}

Figure 2. Effect of different levels of N on plant height of scented rice. (Vertical bars represent SE value at 5% level of probability)



V_1: Kalizira V_2: BRRI dhan34

V_3: Begun Bichi V_4: Sada Sanne

Figure 3. Effect of different variety on plant height of scented rice. (Vertical bars represent SE value at 5% level of probability)

shortest plant (42.76, 69.33, 108.78 and 117.62 cm, respectively) was found from V_2 (BRRI dhan34). Similarly different researchers recorded different size of plant in earlier for different rice cultivars (Sumon *et al*., 2018; Haque and Biswash, 2014; Khalifa, 2009).

Statistically significant variation was recorded on plant height of scented rice at 20, 40, 60 DAT and at harvest due to the combined effect of different levels of nitrogen and rice varieties (Table 1). At 20, 40, 60 DAT and harvest, the tallest plant (57.41, 87.89, 132.08 and 143.53 cm, respectively) was found from N_4V_3 (45.0 kg N ha^{-1} and Begun Bichi), while the shortest plant (38.21, 64.89, 100.20 and 113.47 cm, respectively) was recorded from N_1V_2 (37.5 kg N ha^{-1} and BRRI dhan34) treatment combination.

4.1.2 Number of tillers hill^{-1}

Different levels of nitrogen showed statistically significant variations in terms of number of tillers hill^{-1} of scented rice at 20, 40, 60 DAT and at harvest (Table 2). At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (4.47, 7.65, 13.70 and 15.43, respectively) was recorded from N_3 which was followed (4.05, 7.25, 13.15 and 13.83, respectively) by N_4 and also (4.00, 7.20, 12.80 and 13.63, respectively) by N_2 and they were statistically similar, while the minimum number (3.42, 6.55, 12.37 and 12.98, respectively) was observed from N_1.

Number of tillers hill^{-1} of scented rice at 20, 40, 60 DAT and harvest showed statistically significant differences due to different rice varieties (Table 2). At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (4.77, 7.65, 14.35 and 15.20, respectively) was found from V_2 which was followed (3.85, 7.25, 13.10 and 14.53, respectively) by V_1 and also (3.80, 7.20, 13.00 and 14.12, respectively) by V_4 and they were statistically similar, whereas the minimum number (3.52, 6.55, 11.57 and 12.03, respectively) was recorded from V_3. Khalifa (2009) reported that modern rice variety surpassed other varieties in case of tillers hill^{-1}. Sumon *et al*. (2018) sated that 'BRRI dhan34' gave the maximum number of effective tillers hill^{-1} (12.74).

Table 1. Combined effect of different levels of nitrogen and scented rice varieties on plant height at different days after transplanting (DAT) and harvest

Treatments	Plant height (cm) at			
	20 DAT	40 DAT	60 DAT	Harvest
N_1V_1	39.74 i	65.72 ef	105.34 e	122.76 c-e
N_1V_2	38.21 i	64.89 f	100.20 e	113.47 e
N_1V_3	44.80 gh	68.98 b-f	117.08 cd	129.05 b-d
N_1V_4	49.39 d-f	74.83 bc	130.55 ab	142.76 a
N_2V_1	51.08 d	73.45 b-e	126.78 a-c	140.29 ab
N_2V_2	41.30 hi	71.00 b-f	109.92 de	117.50 de
N_2V_3	45.65 fg	66.70 d-f	118.52 cd	134.01 a-c
N_2V_4	55.10 a-c	86.58 a	130.23 ab	139.72 ab
N_3V_1	51.66 cd	75.81 b	121.62 a-c	140.88 ab
N_3V_2	46.96 e-g	74.06 b-d	120.95 bc	119.20 de
N_3V_3	53.07 b-d	74.63 bc	124.31 a-c	142.81 a
N_3V_4	45.86 fg	70.49 b-f	119.59 b-d	134.56 a-c
N_4V_1	50.24 de	75.15 bc	126.60 a-c	138.94 ab
N_4V_2	44.58 gh	67.37 c-f	104.06 e	120.30 de
N_4V_3	57.41 a	87.89 a	132.08 a	143.53 a
N_4V_4	56.72 ab	84.92 a	130.04 ab	142.10 ab
SE value	1.263	2.340	3.262	3.901
Level of significance	0.01	0.05	0.01	0.01
CV(%)	4.53	5.48	4.71	5.10

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Table 2. Effect of different levels of nitrogen and scented rice varieties on number of tillers hill^{-1} at different days after transplanting (DAT) and harvest

Treatments	Number of tillers hill^{-1} at			
	20 DAT	40 DAT	60 DAT	Harvest
Levels of nitrogen				
N_1	3.42 c	6.55 c	12.37 b	12.98 c
N_2	4.00 b	7.20 b	12.80 b	13.63 bc
N_3	4.47 a	7.65 a	13.70 a	15.43 a
N_4	4.05 b	7.25 b	13.15 ab	13.83 b
SE value	0.114	0.099	0.229	0.197
Level of significance	0.01	0.01	0.05	0.01
CV(%)	9.88	4.78	6.09	4.88
Scented rice varieties				
V_1	3.85 b	7.25 b	13.10 b	14.53 b
V_2	4.77 a	7.65 a	14.35 a	15.20 a
V_3	3.52 c	6.55 c	11.57 c	12.03 c
V_4	3.80 b	7.20 b	13.00 b	14.12 b
SE value	0.0912	0.104	0.176	0.273
Level of significance	0.01	0.01	0.01	0.01
CV(%)	7.97	5.03%	4.70	6.76

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Combined effect of different levels of nitrogen and rice varieties showed statistically significant differences on number of tillers hill^{-1} of scented rice at 20, 40, 60 DAT and harvest (Table 3). At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (5.47, 8.60, 15.60 and 17.73, respectively) was observed from N_3V_2 and the minimum number (3.07, 5.80, 11.27 and 11.73, respectively) was recorded from N_1V_3 treatment combination.

4.1.3 Chlorophyll content in flag leaf

Statistically significant variations was recorded in terms of chlorophyll content in flag leaf of scented rice due to different levels of nitrogen (Table 4). Data revealed that the highest chlorophyll content in flag leaf (41.14 mg g^{-1}) was found from N_3 which was statistically similar (40.01 mg g^{-1} and 39.74 mg g^{-1}) to N_2 and N_4, whereas the lowest (36.74 mg g^{-1}) was recorded from N_1.

Different rice varieties varied significantly in terms of chlorophyll content in flag leaf of scented rice (Table 4). The highest chlorophyll content in flag leaf (41.31 mg g^{-1}) was recorded from V_2 which was statistically similar (40.55 mg g^{-1}) to V_1. On the other hand, the lowest (37.78 mg g^{-1}) was observed from V_3 which was statistically similar (37.99 mg g^{-1}) to V_3.

Chlorophyll content in flag leaf of scented rice showed statistically significant differences due to the combined effect of different levels of nitrogen and rice varieties (Table 5). The highest chlorophyll content in flag leaf (46.36 mg g^{-1}) was observed from N_3V_2, while the lowest (32.26 mg g^{-1}) was recorded from N_1V_3 treatment combination.

4.1.4 Effective tillers hill^{-1}

Different levels of nitrogen varied significantly variations in terms of effective tillers hill^{-1} of scented rice (Table 4). The highest number of effective tillers hill^{-1} (12.93) was recorded from N_3 which was followed (10.87 and 10.63) by N_4 and N_2 and they were statistically similar, while the lowest number (9.87) from N_1. Haque *et al*. (2015) found the highest effective tillers hill^{-1} with 100 kg N ha^{-1}.

Table 3. Combined effect of different levels of nitrogen and scented rice varieties on number of tillers hill^{-1} at different days after transplanting (DAT) and harvest

Treatments	Number of tillers hill^{-1} at			
	20 DAT	40 DAT	60 DAT	Harvest
N_1V_1	3.60 b-e	6.60 e	12.20 ef	12.40 e-g
N_1V_2	3.60 b-e	7.00 c-e	13.80 b-d	13.20 d-g
N_1V_3	3.07 e	5.80 f	11.27 f	11.73 g
N_1V_4	3.40 c-e	6.80 de	12.20 ef	14.60 b-d
N_2V_1	3.80 b-d	7.40 b-d	13.00 c-e	13.80 c-f
N_2V_2	5.00 a	7.60 bc	13.80 b-d	14.80 b-d
N_2V_3	3.60 b-e	7.00 c-e	11.40 f	11.87 g
N_2V_4	3.60 b-e	7.00 c-e	13.00 c-e	14.07 c-e
N_3V_1	4.00 bc	7.80 b	13.80 b-d	15.93 b
N_3V_2	5.47 a	8.60 a	15.60 a	17.73 a
N_3V_3	4.20 b	6.60 e	11.40 f	12.13 fg
N_3V_4	4.20 b	7.60 bc	14.00 bc	15.93 b
N_4V_1	4.00 bc	7.20 b-e	13.40 b-d	14.33 b-d
N_4V_2	5.00 a	7.40 b-d	14.20 b	15.07 bc
N_4V_3	3.20 de	6.80 de	12.20 ef	12.40 e-g
N_4V_4	4.00 bc	7.40 b-d	12.80 de	13.53 c-g
SE value	0.183	0.208	0.353	0.545
Level of significance	0.01	0.05	0.05	0.05
CV(%)	7.97	5.03%	4.70	6.76

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Table 4. Effect of different levels of nitrogen and scented rice varieties on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1} and panicle length

Treatments	Chlorophyll content in flag leaf (mg g^{-1})	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
Levels of nitrogen				
N_1	36.74 b	9.87 c	3.12 a	21.80 b
N_2	40.01 a	10.63 b	3.00 a	23.36 a
N_3	41.14 a	12.93 a	2.50 b	24.45 a
N_4	39.74 a	10.87 b	2.97 a	23.62 a
SE value	0.762	0.145	0.063	0.354
Level of significance	0.05	0.01	0.01	0.01
CV(%)	6.70	4.53	7.57	5.25
Scented rice varieties				
V_1	40.55 ab	10.93 b	3.18 a	23.37 b
V_2	41.31 a	12.73 a	2.47 c	24.64 a
V_3	37.78 c	9.03 c	3.00 ab	21.52 c
V_4	37.99 bc	11.60 b	2.93 b	23.70 b
SE value	0.887	0.278	0.074	0.314
Level of significance	0.01	0.01	0.01	0.01
CV(%)	7.79	8.68	8.84	4.67

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Table 5. Combined effect of different levels of nitrogen and scented rice varieties on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1} and panicle length

Treatments	Chlorophyll content in flag leaf (mg g^{-1})	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
N_1V_1	39.73 b-f	9.00 h-j	3.40 ab	21.60 f-h
N_1V_2	36.53 e-g	10.67 e-h	2.53 e-h	22.10 e-h
N_1V_3	32.26 g	8.40 j	3.33 a-c	20.70 h
N_1V_4	38.45 d-f	11.40 c-f	3.20 a-d	22.82 d-g
N_2V_1	43.10 a-d	10.27 f-i	3.53 a	23.52 b-f
N_2V_2	40.54 b-e	12.33 b-e	2.47 f-h	24.68 b-d
N_2V_3	44.60 a-c	8.60 ij	3.27 a-c	22.22 e-h
N_2V_4	31.80 g	11.33 c-f	2.73 d-h	23.04 c-f
N_3V_1	38.84 c-f	13.53 b	2.40 gh	25.21 ab
N_3V_2	46.36 a	15.40 a	2.33 h	26.83 a
N_3V_3	33.93 fg	9.73 f-j	2.40 gh	20.78 gh
N_3V_4	45.44 ab	13.07 bc	2.87 c-g	24.97 a-c
N_4V_1	40.54 b-e	10.93 d-g	3.40 ab	23.15 b-f
N_4V_2	41.82 a-e	12.53 b-d	2.53 e-h	24.97 a-c
N_4V_3	40.33 b-e	9.40 g-j	3.00 b-e	22.38 e-h
N_4V_4	36.28 e-g	10.60 e-h	2.93 b-f	23.98 b-e
SE value	1.774	0.555	0.148	0.628
Level of significance	0.01	0.05	0.01	0.05
CV(%)	7.79	8.68	8.84	4.67

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Number of effective tillers hill^{-1} of scented rice varied significantly due to the different rice varieties varied (Table 4). The highest number of effective tillers hill^{-1} (12.73) was found from V_2 which was statistically similar (11.60 and 10.93) to V_4 and V_1, whereas the lowest number (9.03) was observed from V_3. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.

Statistically significant variation was recorded on number of effective tillers hill^{-1} of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 5). The highest number of effective tillers hill^{-1} (15.40) was recorded from N_3V_2 and the lowest number (8.40) was found from N_1V_3 treatment combination.

4.1.5 Non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} of scented rice showed statistically significant variations due to different levels of nitrogen (Table 4). The highest number of non-effective tillers hill^{-1} (3.12) was observed from N_1 which was statistically similar (3.00 and 2.97) by N_2 and N_4, whereas the lowest number (2.50) was recorded from N_3.

Statistically significant variation was recorded due to different rice varieties in terms of number of non-effective tillers hill^{-1} of scented rice (Table 4). The highest number of non-effective tillers hill^{-1} (3.18) was observed from V_1 which was statistically similar (3.00) to V_3 and followed (2.93) by V_4, while the lowest number (2.47) was found from V_2.

Combined effect of different levels of nitrogen and rice varieties showed statistically significant variation in terms of number of non-effective tillers hill^{-1} of scented rice (Table 5). The highest number of non-effective tillers hill^{-1} (3.53) was found from N_2V_1, whereas the lowest number (2.33) was recorded from N_3V_2 treatment combination.

4.1.6 Panicle length

Different levels of nitrogen showed statistically significant differences in terms of panicle length of scented rice (Table 4). The longest panicle (24.45 cm) was observed from N_3 which was statistically similar (23.62 cm and 23.36 cm) to N_4 and N_2, while the shortest panicle (21.80 cm) was found from N_1.

Panicle length of scented rice varied significantly due to different rice varieties (Table 4). The longest panicle (24.64 cm) was recorded from V_2 which was followed (23.70 cm and 23.37 cm) by V_4 and V_1 and they were statistically similar, whereas the shortest panicle (21.52 cm) was found from V_3. Sumon *et al*. (2018) reported from earlier experiment that BRRI dhan34 gave the longest panicle (27.93 cm).

Statistically significant variation was recorded on panicle length of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 5). The longest panicle (26.83 cm) was observed from N_3V_2, while the shortest panicle (20.70 cm) was found from N_1V_3 treatment combination.

4.1.7 Filled grains panicle^{-1}

Statistically significant variations was recorded in terms of filled grains panicle^{-1} of scented rice due to different levels of nitrogen (Table 6). The highest number of filled grains panicle^{-1} (191.80) was found from N_3 which was followed (184.03 and 183.78) by N_2 and N_4 and they were statistically similar, while the lowest number (165.72) was recorded from N_1. Haque *et al*. (2015) found the highest grains panicle^{-1} with 100 kg N ha^{-1}.

Different rice varieties varied significantly in terms of filled grains panicle^{-1} of scented rice (Table 6). The highest number of filled grains panicle^{-1} (200.67) was observed from V_2 which was followed (182.50 and 179.23) by V_4 and V_1 and they were statistically similar, whereas the lowest number (162.93) was recorded from V_3. Sarkar *et al*. (2014) revealed that the number of grains panicle^{-1} (152.3) in BRRI dhan34.

Table 6. Effect of different levels of nitrogen and scented rice varieties on filled, unfilled and total grains panicle^{-1} and weight of 1000-grains

Treatments	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
Levels of nitrogen				
N_1	165.72 c	26.17 a	191.88 c	11.62
N_2	184.03 b	22.28 c	206.32 b	11.83
N_3	191.80 a	21.22 d	213.02 a	11.76
N_4	183.78 b	24.00 b	207.78 ab	11.73
SE value	1.566	0.280	1.569	--
Level of significance	0.01	0.01	0.01	NS
CV(%)	2.99	4.15	2.66	2.96
Scented rice varieties				
V_1	179.23 b	24.17 ab	203.40 b	12.21 a
V_2	200.67 a	21.53 c	222.20 a	12.46 a
V_3	162.93 c	24.73 a	187.67 c	11.60 b
V_4	182.50 b	23.23 b	205.73 b	10.68 c
SE value	2.231	0.331	2.298	0.168
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.26	4.89	3.89	4.95

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Filled grains panicle^{-1} of scented rice showed statistically significant differences due to the combined effect of different levels of nitrogen and rice varieties (Table 7). The highest number of filled grains panicle^{-1} (214.67) was recorded from N_3V_2 and the lowest number (143.00) was observed from N_1V_3 treatment combination.

4.1.8 Unfilled grains panicle^{-1}

Unfilled grains panicle^{-1} of scented rice showed statistically significant variations due to different levels of nitrogen (Table 6). The highest number of unfilled grains panicle^{-1} (26.17) was observed from N_1 which was followed (24.00) by N_4. On the other hand, the lowest number (21.22) was found from N_3 which was followed (22.28) by N_2.

Different rice varieties varied significantly in terms of unfilled grains panicle^{-1} of scented rice (Table 6). The highest number of unfilled grains panicle^{-1} (24.73) was recorded from V_3 which was statistically similar (24.17) to V_1 and followed (23.23) by V_1, while the lowest number (21.53) was found from V_2.

Statistically significant variation was recorded on unfilled grains panicle^{-1} of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 7). The highest number of unfilled grains panicle^{-1} (27.87) was observed from N_1V_3, whereas the lowest number (20.13) was found from N_3V_2 treatment combination.

4.1.9 Total grains panicle^{-1}

Different levels of nitrogen showed statistically significant variations in terms of total grains panicle^{-1} of scented rice (Table 6). The highest number of total grains panicle^{-1} (213.02) was recorded from N_3 which was statistically similar (207.78) to N_4 and followed (206.32) by N_2, while the lowest number (191.88) from N_1.

Different rice varieties varied significantly in terms of total grains panicle^{-1} of scented rice (Table 6). The highest number of total grains panicle^{-1} (222.20) was found from V_2 which was followed (205.73 and 203.40) by V_4 and V_1 and they were statistically similar, whereas the lowest number (187.67) from V_3.

Table 7. Combined effect of different levels of nitrogen and scented rice varieties on filled, unfilled and total grains panicle^{-1} and weight of 1000-grains

Treatments	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
N_1V_1	160.33 i	27.07 ab	187.40 fg	11.05 d-f
N_1V_2	186.60 c-f	23.33 d-f	209.93 cd	12.56 a
N_1V_3	143.00 j	27.87 a	170.87 h	12.77 a
N_1V_4	172.93 f-i	26.40 ab	199.33 d-g	10.11 f
N_2V_1	181.67 d-g	23.33 d-f	205.00 c-e	12.54 ab
N_2V_2	204.53 ab	21.20 fg	225.73 ab	12.14 a-c
N_2V_3	168.20 g-i	23.93 c-e	192.13 e-g	11.75 a-d
N_2V_4	181.73 d-g	20.67 g	202.40 de	10.88 d-f
N_3V_1	192.60 b-e	20.73 g	213.33 b-d	12.67 a
N_3V_2	214.67 a	20.13 g	234.80 a	12.80 a
N_3V_3	164.40 hi	21.80 e-g	186.20 g	10.43 ef
N_3V_4	195.53 b-d	22.20 e-g	217.73 bc	11.15 c-f
N_4V_1	182.33 d-g	25.53 bc	207.87 cd	12.46 ab
N_4V_2	196.87 bc	21.47 fg	218.33 bc	12.46 ab
N_4V_3	176.13 f-h	25.33 b-d	201.47 d-f	11.44 b-e
N_4V_4	179.80 e-g	23.67 c-e	203.47 c-e	10.58 ef
SE value	4.462	0.661	4.596	0.336
Level of significance	0.05	0.05	0.05	0.01
CV(%)	4.26	4.89	3.89	4.95

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Combined effect of different levels of nitrogen and rice varieties showed statistically significant differences in terms of total grains panicle^{-1} of scented rice (Table 7). The highest number of total grains panicle^{-1} (234.80) was found from N_3V_2, while the lowest number (170.87) was observed from N_1V_3 treatment combination.

4.1.10 Weight of 1000-grains

Weight of 1000-grains of scented rice showed statistically non-significant variations due to different levels of nitrogen (Table 6). The highest weight of 1000-grains (11.83 g) was observed from N_2 and the lowest weight (11.62 g) was recorded from N_1.

Different rice varieties varied significantly in terms of weight of 1000-grains (Table 6). The highest weight of 1000-grains of scented rice (12.46 g) was recorded from V_2 which was statistically similar (12.21 g) to V_1 and followed (11.60 g) by V_3, whereas the lowest weight (10.68 g) from V_4. Sumon *et al*. (2018) sated that 'BRRI dhan34' gave the highest 1000-grain weight (17.22 g).

Statistically significant variation was recorded on weight of 1000-grains of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 7). The highest weight of 1000-grains (12.80 g) was observed from N_3V_2 and the lowest weight (10.11 g) was found from N_1V_4 treatment combination.

4.1.11 Grain yield

Statistically significant variation was recorded in terms of grain yield of scented rice due to different levels of nitrogen (Table 8). The highest grain yield (2.48 t ha^{-1}) was found from N_3 which was statistically similar (2.23 t ha^{-1}) to N_2 and N_4, while the lowest grain yield (1.99 t ha^{-1}) was observed from N_1. Maqsood *et al*. (2013) reported that higher paddy yield can be obtained at 100 kg ha^{-1} nitrogen application.

Table 8. Effect of different levels of nitrogen and scented rice varieties on grain, straw, biological yield and harvest index

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Levels of nitrogen				
N_1	1.99 b	3.57 c	5.56 c	35.09
N_2	2.23 ab	3.85 b	6.09 b	36.19
N_3	2.48 a	4.22 a	6.70 a	36.14
N_4	2.23 ab	3.91 b	6.14 b	36.13
SE value	0.085	0.052	0.100	--
Level of significance	0.05	0.01	0.01	NS
CV(%)	13.14	4.60	5.66	8.87
Scented rice varieties				
V_1	2.02 b	3.99 a	6.01 b	33.37 bc
V_2	3.09 a	4.09 a	7.18 a	42.92 a
V_3	1.70 c	3.51 b	5.21 c	32.48 c
V_4	2.13 b	3.95 a	6.08 b	34.79 b
SE value	0.055	0.061	0.091	0.569
Level of significance	0.01	0.01	0.01	0.01
CV(%)	8.46	5.47	5.16	5.49

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Different rice varieties varied significantly in terms of grain yield of scented rice (Table 8). The highest grain yield (3.09 t ha^{-1}) was observed from V_2 which was followed (2.13 t ha^{-1} and 2.02 t ha^{-1}) by V_4 and V_1 and they were statistically similar, while the lowest grain yield (1.70 t ha^{-1}) was recorded from V_3. Chowdhury *et al*. (2016) obtained the highest grain yield (3.33 t ha^{-1}) from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield in Kalizira (2.11 t ha^{-1}).

Grain yield of scented rice showed statistically significant differences due to the combined effect of different levels of nitrogen and rice varieties (Table 9). The highest grain yield (3.47 t ha^{-1}) was found from N_3V_2, whereas the lowest grain yield (1.43 t ha^{-1}) was recorded from N_1V_3 treatment combination.

4.1.12 Straw yield

Straw yield of scented rice showed statistically significant variations due to different levels of nitrogen (Table 8). The highest straw yield (4.22 t ha^{-1}) was observed from N_3 which was followed (3.91 t ha^{-1} and 3.85 t ha^{-1}) by N_4 and N_2 and they were statistically similar, whereas the lowest straw yield (3.57 t ha^{-1}) was recorded from N_1. Haque *et al*. (2015) found the highest straw yields with 100 kg N ha^{-1}.

Different rice varieties varied significantly in terms of straw yield of scented rice (Table 8). The highest straw yield (4.09 t ha^{-1}) was recorded from V_2 which was statistically similar (3.99 t ha^{-1} and 3.95 t ha^{-1}) by V_1 and V_4, while the lowest straw yield (3.51 t ha^{-1}) was observed from V_3.

Statistically significant variation was recorded on straw yield of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 9). The highest straw yield (4.44 t ha^{-1}) was recorded from N_3V_2, whereas the lowest straw yield (3.07 t ha^{-1}) was observed from N_1V_3 treatment combination.

Table 9. Combined effect of different levels of nitrogen and scented rice varieties on grain, straw, biological yield and harvest index

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_1V_1	1.57 gh	3.60 de	5.16 f	30.32 ef
N_1V_2	2.89 bc	3.86 c-e	6.75 bc	42.82 a
N_1V_3	1.43 h	3.07 f	4.54 g	32.29 de
N_1V_4	2.02 f	3.75 c-e	5.77 de	34.94 b-d
N_2V_1	1.99 f	3.94 c-e	5.93 de	33.55 c-e
N_2V_2	3.13 b	4.00 b-d	7.12 b	43.90 a
N_2V_3	1.81 fg	3.57 e	5.38 ef	33.49 c-e
N_2V_4	2.00 f	3.91 c-e	5.91 de	33.82 c-e
N_3V_1	2.39 de	4.34 ab	6.73 bc	35.49 b-d
N_3V_2	3.47 a	4.44 a	7.91 a	43.73 a
N_3V_3	1.47 h	3.72 c-e	5.15 f	27.77 f
N_3V_4	2.64 cd	4.37 ab	7.01 b	37.58 b
N_4V_1	2.12 ef	4.09 a-c	6.21 cd	34.12 b-d
N_4V_2	2.86 bc	4.06 a-c	6.92 b	41.24 a
N_4V_3	2.08 ef	3.70 c-e	5.78 de	36.36 bc
N_4V_4	1.85 fg	3.78 c-e	5.64 d-f	32.82 c-e
SE value	0.109	0.123	0.182	1.138
Level of significance	0.01	0.05	0.01	0.01
CV(%)	8.46	5.47	5.16	5.49

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

4.1.13 Biological yield

Different levels of nitrogen showed statistically significant variations in terms of biological yield of scented rice (Table 8). The highest biological yield (6.70 t ha^{-1}) was found from N_3 which was followed (6.14 t ha^{-1} and 6.09 t ha^{-1}) to N_4 and N_2, while the lowest biological yield (5.56 t ha^{-1}) was observed from N_1.

Biological yield of scented rice showed statistically significant differences due to different rice varieties (Table 8). The highest biological yield (7.18 t ha^{-1}) was recorded from V_2 which was followed (6.08 t ha^{-1} and 6.01 t ha^{-1}) by V_4 and V_1 and they were statistically similar, while the lowest biological yield (5.21 t ha^{-1}) was found from V_3. Sumon *et al*. (2018) revealed that 'Raniselute' variety produced the highest biological yield (9.05 t ha^{-1}).

Statistically significant variation was recorded on biological yield of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 9). The highest biological yield (7.91 t ha^{-1}) was found from N_3V_2 and the lowest biological yield (4.54 t ha^{-1}) was found from N_1V_3 treatment combination.

4.1.14 Harvest index

Harvest index of scented rice showed statistically non-significant variations due to different levels of nitrogen (Table 8). The highest harvest index (36.19%) was found from N_2 and the lowest harvest index (35.09%) was recorded from N_1.

Different rice varieties varied significantly in terms of harvest index of scented rice (Table 8). The highest harvest index (42.92%) was recorded from V_2 which was followed (34.79% and 33.37%) by V_4 and V_1 and they were statistically similar, whereas the lowest harvest index (32.48%) was found from V_3.

Statistically significant variation was recorded on harvest index of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 9). The highest harvest index (43.73%) was observed from N_3V_2 and the lowest harvest index (27.77%) was found from N_3V_3 treatment combination.

4.2 Grain quality of scented rice varieties

4.2.1 Length of grain rice

Different levels of nitrogen showed statistically non-significant variations in terms of length of grain rice (Table 10). The highest length of grain rice (5.30 mm) was recorded from N_4, while the lowest length (5.22 mm) was found from N_2.

Length of grain rice showed statistically significant differences due to different rice varieties (Table 10). The highest length of grain rice (5.43 mm) was recorded from V_2 which was statistically similar (5.36 mm and 5.24 mm) to V_1 and V_4, whereas the lowest length (4.95 mm) was found from V_3.

Combined effect of different levels of nitrogen and rice varieties showed statistically significant differences in terms of length of grain rice (Table 11). The highest length of grain rice (5.97 mm) was observed from N_3V_2, while the lowest length (3.54 mm) was recorded from N_3V_3 treatment combination.

4.2.2 Breadth of grain rice

Breadth of grain rice showed statistically non-significant variations due to different levels of nitrogen (Table 10). The highest breadth of grain rice (2.30 mm) was observed from N_3, whereas the lowest breadth (2.25 mm) was found from N_1.

Different rice varieties varied significantly in terms of breadth of grain rice (Table 10). The highest breadth of grain rice (2.45 mm) was recorded from V_2 which was followed (2.29 mm and 2.28 mm) by V_1 and V_4 and they were statistically similar, while the lowest breadth (2.08 mm) was found from V_3.

Statistically significant variation was recorded on breadth of grain rice due to the combined effect of different levels of nitrogen and rice varieties (Table 11). The highest breadth of grain rice (2.65 mm) was found from N_3V_2, whereas the lowest breadth (2.02 mm) was observed from N_1V_3 treatment combination.

Table 10. Effect of different levels of nitrogen and scented rice varieties on length and breadth of grain rice, weight of milled and broken rice

Treatments	Length of grain rice (mm)	Breadth of grain rice (mm)	Weight of milled rice (g)	Weight of broken rice (g)
Levels of nitrogen				
N_1	5.23	2.25	70.20 c	3.19 a
N_2	5.22	2.28	71.08 bc	2.99 ab
N_3	5.24	2.30	72.54 a	2.73 b
N_4	5.30	2.27	71.34 b	3.28 a
SE value	--	--	0.307	0.088
Level of significance	NS	NS	0.01	0.01
CV(%)	5.46	6.06	1.49	10.01
Scented rice varieties				
V_1	5.36 a	2.29 b	70.09 b	2.96 b
V_2	5.43 a	2.45 a	71.86 a	2.89 c
V_3	4.95 b	2.08 c	70.97 ab	3.07 b
V_4	5.24 ab	2.28 b	72.22 a	3.27 a
SE value	0.118	0.033	0.440	0.061
Level of significance	0.05	0.01	0.01	0.01
CV(%)	7.77	4.96	2.14	6.98

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Table 11. Combined effect of different levels of nitrogen and scented rice varieties on length and breadth of grain rice, weight of milled and broken rice

Treatments	Length of grain rice (mm)	Breadth of grain rice (mm)	Weight of milled rice (g)	Weight of broken rice (g)
N_1V_1	5.12 b-e	2.20 d-g	68.49 d	3.50 a
N_1V_2	4.91 c-e	2.28 b-e	70.39 b-d	2.90 c-e
N_1V_3	5.07 b-e	2.02 g	69.48 cd	2.86 c-e
N_1V_4	5.81 ab	2.49 ab	72.42 a-c	3.51 a
N_2V_1	5.26 a-e	2.38 b-d	69.92 cd	2.58 e
N_2V_2	5.29 a-e	2.40 b-d	71.87 a-c	2.93 b-e
N_2V_3	5.81 ab	2.19 d-g	71.64 a-c	3.20 a-c
N_2V_4	4.51 e	2.14 e-f	70.87 b-d	3.23 a-c
N_3V_1	5.64 a-c	2.22 d-g	71.61 a-c	2.69 de
N_3V_2	5.97 a	2.65 a	74.32 a	2.23 f
N_3V_3	3.54 f	2.04 g	69.74 cd	2.99 b-d
N_3V_4	5.83 ab	2.27 c-f	74.48 a	3.02 b-d
N_4V_1	5.42 a-d	2.35 b-e	70.35 b-d	3.06 b-d
N_4V_2	5.56 a-d	2.47 a-c	70.85 b-d	3.52 a
N_4V_3	5.39 a-d	2.06 fg	73.03 ab	3.22 a-c
N_4V_4	4.82 de	2.22 d-g	71.13 b-d	3.33 ab
SE value	0.235	0.065	0.880	0.123
Level of significance	0.01	0.01	0.05	0.01
CV(%)	7.77	4.96	2.14	6.98

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

N_1: 37.5 kg N ha^{-1}

N_2: 40.0 kg N ha^{-1}

N_3: 42.5 kg N ha^{-1}

N_4: 45.0 kg N ha^{-1}

V_1: Kalizira

V_2: BRRI dhan34

V_3: Begun Bichi

V_4: Sada Sanne

4.2.3 Weight of milled rice

Statistically significant variations was recorded in terms of weight of milled rice due to different levels of nitrogen (Table 10). The highest weight of milled rice (72.54 g) was found from N_3 which was followed (71.34 g and 71.08 g) by N_4 and N_2 and they were statistically similar, while the lowest weight (70.20 g) was recorded from N_1.

Weight of milled rice showed statistically significant differences due to different rice varieties (Table 10). The highest weight of milled rice (72.22 g) was recorded from V_4 which was statistically similar (71.86 g and 70.97 g) to V_2 and V_3, whereas the lowest weight (70.09 g) was observed from V_1.

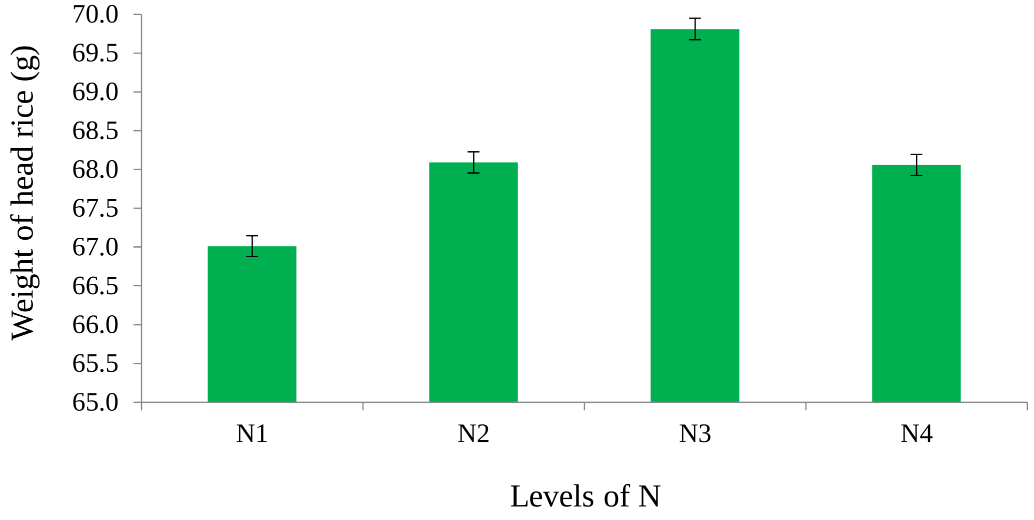
Combined effect of different levels of nitrogen and rice varieties varied significantly in terms of weight of milled rice (Table 11). The highest weight of milled rice (74.48 g) was recorded from N_3V_4 and the lowest weight (68.49 g) was found from N_1V_1 treatment combination.

4.2.4 Weight of head rice

Weight of head rice showed statistically significant variations due to different levels of nitrogen (Figure 4). The highest weight of head rice (69.81 g) was observed from N_3 which was followed by (68.09 g and 68.06 g) by N_2 and N_4 and they were statistically similar, whereas the lowest weight (67.01 g) was found from N_1.

Different rice varieties varied significantly in terms of weight of head rice (Figure 5). The highest weight of head rice (68.97 g) was recorded from V_2 which was statistically similar (68.95 g and 67.91 g) to V_4 and V_3, while the lowest weight (67.13 g) was found from V_1.

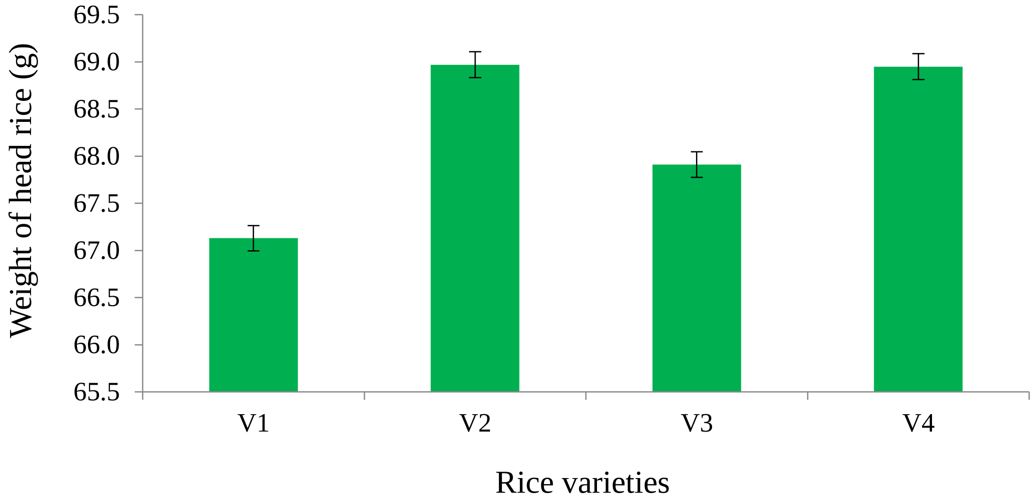
Statistically significant variation was recorded on weight of head rice due to the combined effect of different levels of nitrogen and rice varieties (Figure 6). The highest weight of head rice (72.09 g) was found from N_3V_2, whereas the lowest weight (64.99 g) was found from N_1V_1 treatment combination.



N_1: 37.5 kg N ha^{-1} N_2: 40.0 kg N ha^{-1}

N_3: 42.5 kg N ha^{-1} N_4: 45.0 kg N ha^{-1}

Figure 4. Effect of different levels of N on weight of head rice of scented rice. (Vertical bars represent SE value at 5% level of probability)



V_1: Kalizira V_2: BRRI dhan34

V_3: Begun Bichi V_4: Sada Sanne

Figure 5. Effect of different variety on weight of head rice of scented rice. (Vertical bars represent SE value at 5% level of probability)

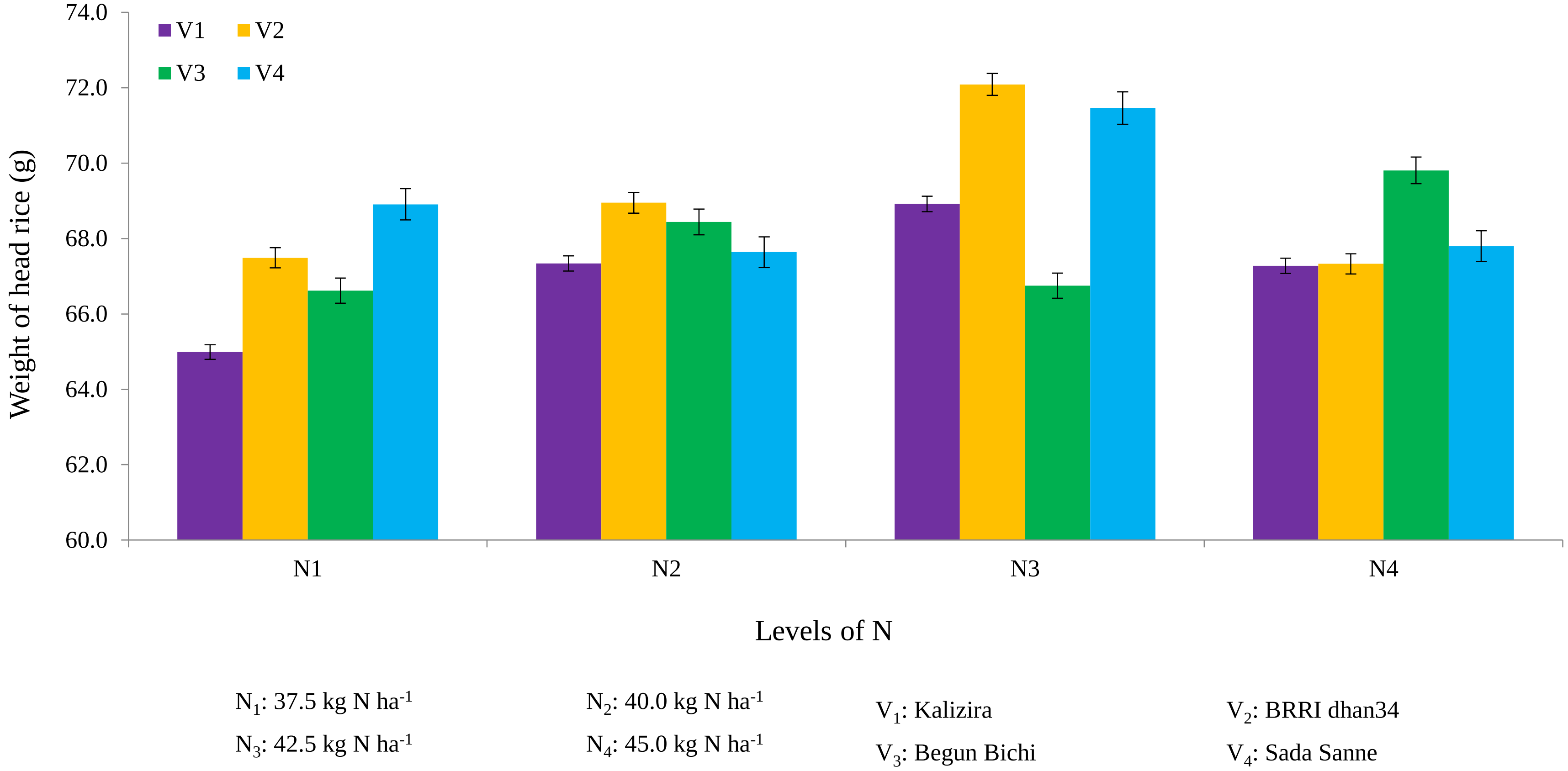


Figure 6. Combined effect of different levels of N and variety on weight of head rice of scented rice. (Vertical bars represent SE value at 5% level of probability

4.2.5 Weight of broken rice

Different levels of nitrogen showed statistically significant differences in terms of weight of broken rice (Table 10). The highest weight of broken rice (3.28 g) was found from N_4 which was statistically similar (3.19 g and 2.99 g) to N_1 and N_2, while the weight (2.73 g) was recorded from N_3.

Statistically significant variation was recorded due to different rice varieties in terms of weight of broken rice (Table 10). The highest weight of broken rice (3.27 g) was observed from V_4 which was followed (3.07 g and 2.96 g) by V_3 and V_1, whereas the lowest weight (2.89 g) was found from V_2.

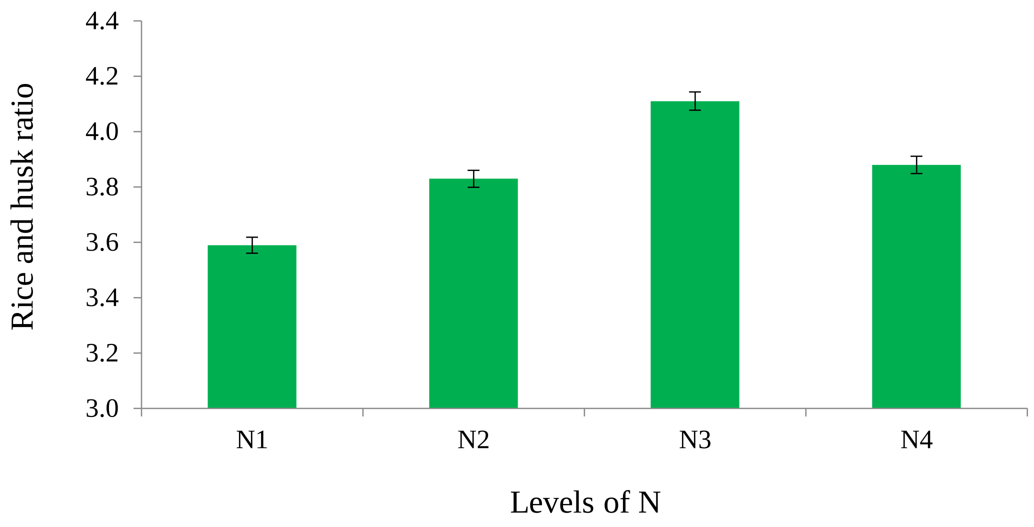
Weight of broken rice showed statistically significant variation due to the combined effect of different levels of nitrogen and rice varieties (Table 11). The highest weight of broken rice (3.50 g) was recorded from N_1V_1 and the lowest weight (2.23 g) was observed from N_3V_2 treatment combination.

4.2.6 Rice and husk ratio

Rice and husk ratio of scented rice showed statistically significant variations due to different levels of nitrogen (Figure 7). The highest rice and husk ratio (3.28 g) was observed from N_4 which was statistically similar (3.19 g and 2.99 g) to N_1 and N_2, whereas the lowest (2.73 g) was found from N_3.

Different rice varieties varied significantly in terms of rice and husk ratio of scented rice (Figure 8). The highest rice and husk ratio (3.27 g) was recorded from V_4 which was followed (3.07 g and 2.96 g) by V_3 and V_1, while the lowest (2.89 g) was found from V_2.

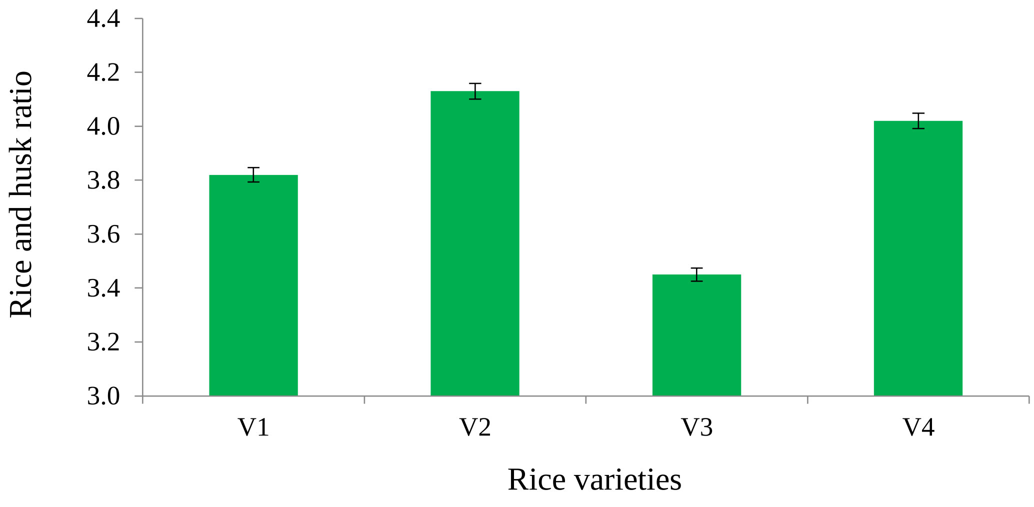
Statistically significant variation was recorded on rice and husk ratio of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Figure 9). The highest rice and husk ratio (4.54) was found from N_3V_2, whereas the lowest (3.31) was found from N_1V_3 treatment combination.



N_1: 37.5 kg N ha^{-1} N_2: 40.0 kg N ha^{-1}

N_3: 42.5 kg N ha^{-1} N_4: 45.0 kg N ha^{-1}

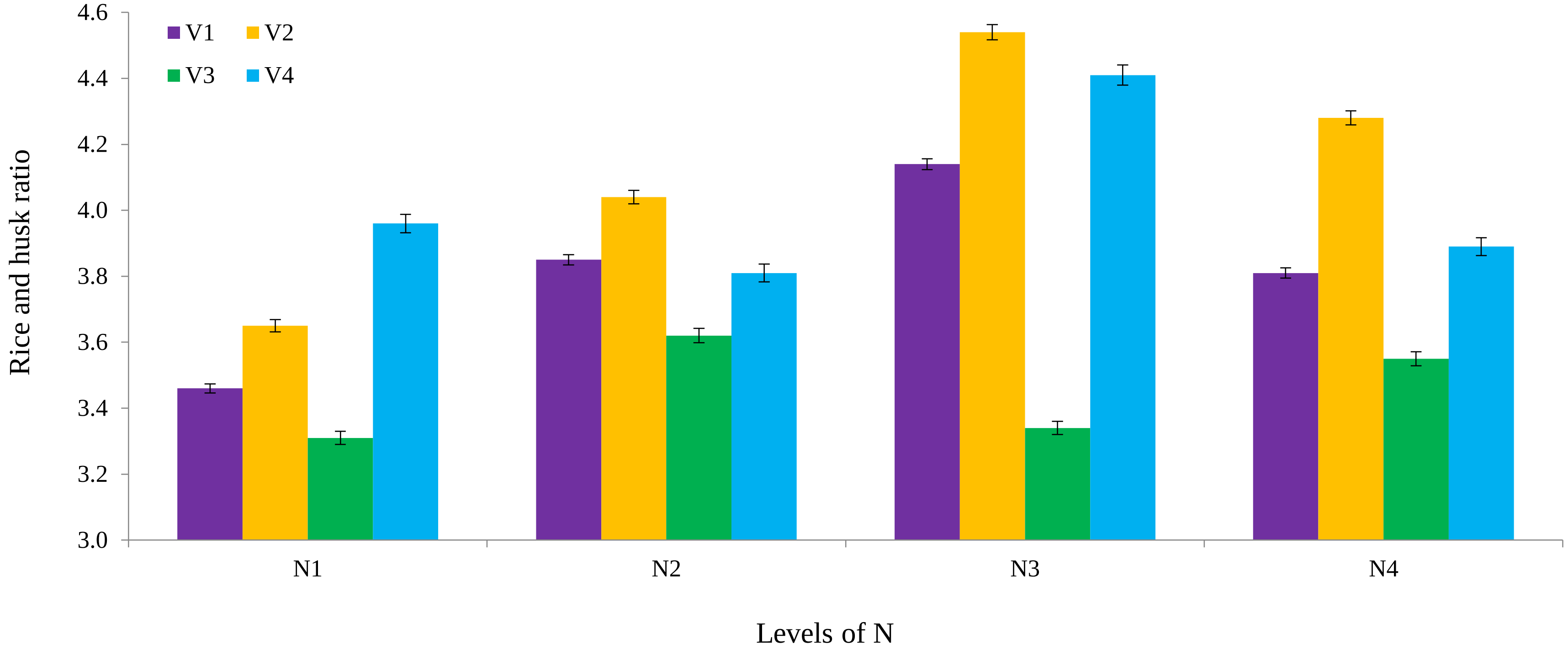
Figure 7. Effect of different levels of N on rice and husk ratio of scented rice. (Vertical bars represent SE value at 5% level of probability)



V_1: Kalizira V_2: BRRI dhan34

V_3: Begun Bichi V_4: Sada Sanne

Figure 8. Effect of different variety on rice and husk ratio of scented rice. (Vertical bars represent SE value at 5% level of probability)



N_1: 37.5 kg N ha^{-1} N_2: 40.0 kg N ha^{-1} V_1: Kalizira V_2: BRRI dhan34

N_3: 42.5 kg N ha^{-1} N_4: 45.0 kg N ha^{-1} V_3: Begun Bichi V_4: Sada Sanne

Figure 9. Combined effect of different levels of N and variety on rice and husk ratio of scented rice. (Vertical bars represent SE value at 5% level of probability

4.2.7 Protein content

Different levels of nitrogen varied significantly in terms of protein content of scented rice (Table 12). The highest protein content (8.56%) was found from N_3 which was followed (8.00% and 7.94%) to N_4 and N_2, while the lowest (7.66%) was observed from N_1.

Statistically significant variation was recorded due to different rice varieties in terms of protein content of scented rice (Table 12). The highest protein content (8.51%) was found from V_2 which was statistically similar (8.44%) to V_4 and followed (7.90%) by V_1, whereas the lowest (7.31%) was observed from V_3.

Combined effect of different levels of nitrogen and rice varieties showed statistically significant variation was recorded in terms of protein content of scented rice (Table 13). The highest protein content (9.20%) was recorded from N_3V_4 and the lowest (7.04%) was observed from N_3V_3 treatment combination.

4.2.8 Amylose content

Amylose content of scented rice showed statistically non-significant variations due to different levels of nitrogen (Table 12). The highest amylose content (23.43%) was found from N_3, whereas the lowest (22.47%) was recorded from N_1.

Different rice varieties varied significantly in terms of amylose content of scented rice (Table 12). The highest amylose content (23.98%) was observed from V_2 which was statistically similar (23.50%) to V_4 and followed (22.72%) by V_1, while the lowest (21.31%) was recorded from V_3.

Statistically significant variation was recorded on amylose content of scented rice due to the combined effect of different levels of nitrogen and rice varieties (Table 13). The highest amylose content (24.92%) was recorded from N_3V_2, whereas the lowest (20.53%) was observed from N_3V_3 treatment combination.

Table 12. Effect of different levels of nitrogen and scented rice varieties on protein, amylose, proline and 2-AP content in grain

Treatments	Protein content (%)	Amylose content (%)	Proline content (mg g^{-1})	Grain-2AP (µg g^{-1})
Levels of nitrogen				
N_1	7.66 c	22.47	21.75 c	0.97 a
N_2	7.94 b	22.70	22.07 b	0.93 ab
N_3	8.56 a	23.43	23.50 a	0.92 bc
N_4	8.00 b	22.91	22.36 b	0.88 c
SE value	0.055	--	0.234	0.013
Level of significance	0.01	NS	0.01	0.01
CV(%)	2.36	3.77	3.61	4.85
Scented rice varieties				
V_1	7.90 b	22.72 b	22.49 a	0.91 b
V_2	8.51 a	23.98 a	23.59 a	0.98 a
V_3	7.31 c	21.31 c	20.15 b	0.83 c
V_4	8.44 a	23.50 a	23.44 a	0.97 a
SE value	0.056	0.237	0.409	0.009
Level of significance	0.01	0.01	0.01	0.01
CV(%)	2.41	3.58	6.32	3.54

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

Table 13. Combined effect of different levels of nitrogen and scented rice varieties on protein, amylose, proline and 2-AP content in grain

Treatments	Protein content (%)	Amylose content (%)	Proline content (mg g^{-1})	Grain-2AP (μg g^{-1})
N_1V_1	7.41 ij	21.93 d-f	20.08 e-g	0.80 hi
N_1V_2	7.93 e-g	23.03 b-d	23.02 a-d	0.96 bc
N_1V_3	7.18 jk	21.26 ef	22.43 b-e	0.90 d-g
N_1V_4	8.12 d-f	23.64 a-c	21.45 c-f	0.85 gh
N_2V_1	7.78 f-h	22.67 c-e	22.53 b-e	0.86 fg
N_2V_2	8.34 cd	23.63 a-c	22.64 b-e	0.92 c-e
N_2V_3	7.49 h-j	21.67 d-f	19.49 fg	0.97 bc
N_2V_4	8.14 c-e	22.82 b-e	23.60 a-c	0.91 c-f
N_3V_1	8.71 b	23.64 a-c	24.91 ab	0.78 i
N_3V_2	9.30 a	24.92 a	25.54 a	1.04 a
N_3V_3	7.04 k	20.53 f	18.08 g	1.06 a
N_3V_4	9.20 a	24.64 a	25.47 a	0.98 b
N_4V_1	7.69 g-i	22.63 c-e	22.42 b-e	0.86 fg
N_4V_2	8.48 bc	24.33 ab	23.16 a-d	0.95 b-d
N_4V_3	7.55 hi	21.78 d-f	20.60 d-g	1.01 ab
N_4V_4	8.30 cd	22.89 b-d	23.26 a-d	0.89 e-g
SE value	0.112	0.473	0.818	0.019
Level of significance	0.01	0.05	0.01	0.01
CV(%)	2.41	3.58	6.32	3.54

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

N_1: 37.5 kg N ha^{-1}
N_2: 40.0 kg N ha^{-1}
N_3: 42.5 kg N ha^{-1}
N_4: 45.0 kg N ha^{-1}

V_1: Kalizira
V_2: BRRI dhan34
V_3: Begun Bichi
V_4: Sada Sanne

4.2.9 Proline content

Different levels of nitrogen varied significantly for proline content of scented rice (Table 12). The highest proline content (23.50 mg g^{-1}) was observed from N_3 which was followed (22.36 mg g^{-1} and 22.07 mg g^{-1}) to N_4 and N_2 and they were statistically similar, while the lowest (21.75 mg g^{-1}) from N_1. Islam *et al*. (2008) reported that N levels, 80 kg ha^{-1} performs the best to quality of aromatic rice.

Proline content of scented rice varied significantly in terms of different rice varieties (Table 12). The highest proline content (23.59 mg g^{-1}) was recorded from V_2 which was statistically similar (22.49 mg g^{-1} and 22.44 mg g^{-1}) by V_1 and V_4, whereas the lowest (20.15 mg g^{-1}) was found from V_3.

Combined effect of different levels of nitrogen and rice varieties showed statistically significant variation in terms of proline content of scented rice (Table 13). The highest proline content (25.54 mg g^{-1}) was observed from N_3V_2, while the lowest (18.08 mg g^{-1}) was found from N_3V_3 treatment combination.

4.2.10 Grain-2AP content

Statistically significant variation was recorded in terms of grain-2AP content of scented rice due to different levels of nitrogen (Table 12). The highest grain 2-AP content (0.97 µg g^{-1}) was recorded from N_1 which was statistically similar (0.93 µg g^{-1}) to N_2 and followed (0.92 µg g^{-1}) by N_3, whereas the lowest (0.88 µg g^{-1}) was observed from N_4. Islam *et al*. (2008) reported that N levels, 80 kg ha^{-1} performs the best to quality of aromatic rice.

Grain 2-AP content of scented rice showed statistically significant differences due to different rice varieties (Table 12). The highest grain 2-AP content (0.98 µg g^{-1}) was found from V_2 which was statistically similar (0.97 µg g^{-1}) to V_4 and followed (0.91 µg g^{-1}) by V_1, while the lowest (0.83 µg g^{-1}) was recorded from V_3.

Combined effect of different levels of nitrogen and rice varieties showed statistically significant differences in terms of grain 2-AP content of scented rice (Table 13). The highest grain 2-AP content (1.06 µg g^{-1}) was recorded from N_3V_3 and the lowest (0.78 µg g^{-1}) was observed from N_3V_1 treatment combination.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to December 2017 to assess the minimization of nitrogen on yield and aroma quality of scented rice. Scented rice cultivars Kalizira, BRRI dhan34, Begun Bichi and Sada Sanne were used as the test crops in this experiment. The experiment consisted of two factors: Factor A: Levels of nitrogen (4 levels) as- N_1: 37.5 kg N ha^{-1}, N_2: 40.0 kg N ha^{-1}, N_3: 42.5 kg N ha^{-1}, N_4: 45.0 kg N ha^{-1}; and Factor B: Scented rice variety (4 varieties) as- V_1: Kalizira, V_2: BRRI dhan34, V_3: Begun Bichi and V_4: Sada Sanne. The two factors experiment was laid out in split-plot design with three replications. The four levels of N were assigned in the main plot and 4 scented rice varieties in the sub-plot. Data were recorded on yield contributing characters, yield and quality of scented rice and statistically significant variation was recorded for most of the studied characters for different treatments.

For different levels of nitrogen, at 20, 40, 60 DAT and harvest, the tallest plant (52.28, 78.10, 124.74 and 136.61 cm, respectively) was observed from N_4, while the shortest plant (43.04, 68.61, 113.29 and 127.01 cm, respectively) was found from N_1. At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (4.47, 7.65, 13.70 and 15.43, respectively) was recorded from N_3, while the minimum number (3.42, 6.55, 12.37 and 12.98, respectively) was observed from N_1. The highest chlorophyll content in flag leaf (41.14 mg g^{-1}) was found from N_3, whereas the lowest (36.74 mg g^{-1}) was recorded from N_1. The highest number of effective tillers hill^{-1} (12.93) was recorded from N_3, while the lowest number (9.87) was observed from N_1. The highest number of non-effective tillers hill^{-1} (3.12) was observed from N_1, whereas the lowest number (2.50) was recorded from N_3. The longest panicle (24.45 cm) was observed from N_3, while the shortest panicle (21.80 cm) was found from N_1. The highest number of filled grains panicle^{-1} (191.80) was found from N_3, while the lowest number (165.72) was recorded from N_1. The highest number of unfilled grains panicle^{-1} (26.17) was observed from N_1 and the lowest number (21.22) was found from N_3. The highest number of total grains panicle^{-1} (213.02) was recorded from N_3, while the lowest number (191.88) was observed from N_1. The highest weight of 1000-grains (11.83 g) was observed from N_2 and the lowest weight (11.62 g) was recorded from N_1. The highest grain yield (2.48 t ha^{-1}) was found from N_3, while the lowest grain yield (1.99 t ha^{-1}) was observed from N_1. The highest straw yield (4.22 t ha^{-1}) was observed from N_3, whereas the lowest straw yield (3.57 t ha^{-1}) was recorded from N_1. The highest biological yield (6.70 t ha^{-1}) was found from N_3, while the lowest biological yield (5.56 t ha^{-1}) from N_1. The highest harvest index (36.19%) was found from N_2 and the lowest harvest index (35.09%) was recorded from N_1.

The highest length of grain rice (5.30 mm) was recorded from N_4, while the lowest length (5.22 mm) was found from N_2. The highest breadth of grain rice (2.30 mm) was observed from N_3, whereas the lowest breadth (2.25 mm) was found from N_1. The highest weight of milled rice (72.54 g) was found from N_3, while the lowest weight (70.20 g) was recorded from N_1. The highest weight of head rice (69.81 g) was observed from N_3, whereas the lowest weight (67.01 g) was found from N_1. The highest weight of broken rice (3.28 g) was found from N_4, while the weight (2.73 g) was recorded from N_3. The highest rice and husk ratio (3.28 g) was observed from N_4, whereas the lowest (2.73 g) was found from N_3. The highest protein content (8.56%) was found from N_3, while the lowest (7.66%) was observed from N_1. The highest amylose content (23.43%) was found from N_3, whereas the lowest (22.47%) was recorded from N_1. The highest proline content (23.50 mg g^{-1}) was observed from N_3, while the lowest (21.75 mg g^{-1}) from N_1. The highest grain 2-AP content (0.97 µg g^{-1}) was recorded from N_1, whereas the lowest (0.88 µg g^{-1}) was observed from N_4.

In case of different rice varieties, at 20, 40, 60 DAT and harvest, the tallest plant (54.65, 83.55, 130.72 and 142.03 cm, respectively) was recorded from V_3, whereas the shortest plant (42.76, 69.33, 108.78 and 117.62 cm, respectively) was found from V_2. At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (4.77, 7.65, 14.35 and 15.20, respectively) was found from V_2, whereas the minimum number (3.52, 6.55, 11.57 and 12.03, respectively) was recorded from V_3. The highest chlorophyll content in flag leaf (41.31 mg g^{-1}) was recorded from V_2 and the lowest (37.78 mg g^{-1}) was observed from V_3. The highest number of effective tillers hill^{-1} (12.73) was found from V_2, whereas the lowest number (9.03) was observed from V_3. The highest number of non-effective tillers hill^{-1} (3.18) was observed from V_1, while the lowest number (2.47) was found from V_2. The longest panicle (24.64 cm) was recorded from V_2, whereas the shortest panicle (21.52 cm) was found from V_3. The highest number of filled grains panicle^{-1} (200.67) was observed from V_2, whereas the lowest number (162.93) was recorded from V_3. The highest number of unfilled grains panicle^{-1} (24.73) was recorded from V_3, while the lowest number (21.53) was found from V_2. The highest number of total grains panicle^{-1} (222.20) was found from V_2, whereas the lowest number (187.67) was recorded from V_3. The highest weight of 1000-grains of scented rice (12.46 g) was recorded from V_2, whereas the lowest weight (10.68 g) was found from V_4. The highest grain yield (3.09 t ha^{-1}) was observed from V_2, while the lowest grain yield (1.70 t ha^{-1}) was recorded from V_3. The highest straw yield (4.09 t ha^{-1}) was recorded from V_2, while the lowest straw yield (3.51 t ha^{-1}) was observed from V_3. The highest biological yield (7.18 t ha^{-1}) was recorded from V_2, whereas the lowest biological yield (5.21 t ha^{-1}) was found from V_3. The highest harvest index (42.92%) was recorded from V_2, whereas the lowest harvest index (32.48%) was found from V_3.

The highest length of grain rice (5.43 mm) was recorded from V_2, whereas the lowest length (4.95 mm) was found from V_3. The highest breadth of grain rice (2.45 mm) was recorded from V_2, while the lowest breadth (2.08 mm) was found from V_3. The highest weight of milled rice (72.22 g) was recorded from V_4, whereas the lowest weight (70.09 g) was observed from V_1. The highest weight of head rice (68.97 g) was recorded from V_2, while the lowest weight (67.13 g) was found from V_1. The highest weight of broken rice (3.27 g) was observed from

V_4, whereas the lowest weight (2.89 g) was found from V_2. The highest rice and husk ratio (3.27 g) was recorded from V_4, while the lowest (2.89 g) was found from V_2. The highest protein content (8.51%) was found from V_2, whereas the lowest (7.31%) was observed from V_3. The highest amylose content (23.98%) was observed from V_2, while the lowest (21.31%) was recorded from V_3. The highest proline content (23.59 mg g^{-1}) was recorded from V_2, whereas the lowest (20.15 mg g^{-1}) was found from V_3. The highest grain 2-AP content (0.98 µg g^{-1}) was found from V_2, while the lowest (0.83 µg g^{-1}) was recorded from V_3.

Due to the combined effect of different levels of nitrogen and rice varieties, at 20, 40, 60 DAT and harvest, the tallest plant (57.41, 87.89, 132.08 and 143.53 cm, respectively) was found from N_4V_3, while the shortest plant (38.21, 64.89, 100.20 and 113.47 cm, respectively) was recorded from N_1V_2. At 20, 40, 60 DAT and harvest, the maximum number of tillers $hill^{-1}$ (5.47, 8.60, 15.60 and 17.73, respectively) was observed from N_3V_2 and the minimum number (3.07, 5.80, 11.27 and 11.73, respectively) was recorded from N_1V_3 treatment combination. The highest chlorophyll content in flag leaf (46.36 mg g^{-1}) was observed from N_3V_2, while the lowest (32.26 mg g^{-1}) was recorded from N_1V_3 treatment combination. The highest number of effective tillers $hill^{-1}$ (15.40) was recorded from N_3V_2 and the lowest number (8.40) was found from N_1V_3 treatment combination. The highest number of non-effective tillers $hill^{-1}$ (3.53) was found from N_2V_1, whereas the lowest number (2.33) was recorded from N_3V_2 treatment combination. The longest panicle (26.83 cm) was observed from N_3V_2, while the shortest panicle (20.70 cm) was found from N_1V_3 treatment combination. The highest number of filled grains $panicle^{-1}$ (214.67) was recorded from N_3V_2 and the lowest number (143.00) was observed from N_1V_3 treatment combination. The highest number of unfilled grains $panicle^{-1}$ (27.87) was observed from N_1V_3, whereas the lowest number (20.13) was found from N_3V_2 treatment combination. The highest number of total grains $panicle^{-1}$ (234.80) was found from N_3V_2, while the lowest number (170.87) was observed from N_1V_3 treatment combination. The highest weight of 1000-grains (12.80 g) was observed from N_3V_2 and the lowest weight (10.11 g) was found from N_1V_4 treatment combination. The highest grain yield (3.47 t ha^{-1}) was found from N_3V_2, whereas the lowest grain yield (1.43 t ha^{-1}) was recorded from N_1V_3 treatment combination. The highest straw yield (4.44 t ha^{-1}) was recorded from N_3V_2, whereas the lowest straw yield (3.07 t ha^{-1}) was observed from N_1V_3 treatment combination. The highest biological yield (7.91 t ha^{-1}) was found from N_3V_2 and the lowest biological yield (4.54 t ha^{-1}) was found from N_1V_3 treatment combination. The highest harvest index (43.73%) was observed from N_3V_2 and the lowest harvest index (27.77%) was found from N_3V_3 treatment combination.

The highest length of grain rice (5.97 mm) was observed from N_3V_2, while the lowest length (3.54 mm) was recorded from N_3V_3 treatment combination. The highest breadth of grain rice (2.65 mm) was found from N_3V_2, whereas the lowest breadth (2.02 mm) was observed from N_1V_3 treatment combination. The highest weight of milled rice (74.48 g) was recorded from N_3V_4 and the lowest weight (68.49 g) was found from N_1V_1 treatment combination. The highest weight of head rice (72.09 g) was found from N_3V_2, whereas the lowest weight (64.99 g) was found from N_1V_1 treatment combination. The highest weight of broken rice (3.50 g) was recorded from N_1V_1 and the lowest weight (2.23 g) was observed from N_3V_2 treatment combination. The highest rice and husk ratio (4.54) was found from N_3V_2, whereas the lowest (3.31) was found from N_1V_3 treatment combination. The highest protein content (9.20%) was recorded from N_3V_4 and the lowest (7.04%) was observed from N_3V_3 treatment combination. The highest amylose content (24.92%) was recorded from N_3V_2, whereas the lowest (20.53%) was observed from N_3V_3 treatment combination. The highest proline content (25.54 mg g^{-1}) was observed from N_3V_2, while the lowest (18.08 mg g^{-1}) was found from N_3V_3 treatment combination. The highest grain 2-AP content (1.06 µg g^{-1}) was recorded from N_3V_3 and the lowest (0.78 µg g^{-1}) was observed from N_3V_1 treatment combination.

Data revealed that 40.0 kg N ha^{-1} and scented rice variety BRRI dhan34 showed best performance when considered yield with protein, amylose, proline and 2-AP content. So, Bangladeshi rice growers can produce high quality aromatic rice through 11.11% minimization of nitrogen without sacrificing its yield.

Considering the results of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability,
2. Other management practices such as supplementation of zinc, sulphur etc. may be used for further study, and
3. Other combination of organic manures and chemicals fertilizer may be used for further study to specify the specific combination.

References

REFERENCES

Abbasi, H.R.A., Esfahani, M., Rabiei, B. and Kavousi, M. (2007). Effect of nitrogen fertilizing management on rice (cv. Khazar) yield and its components in a paddy soil of Guilan Province. *J. Sci. Tec. Agric. Res.* **104**(8): 293-307.

Abou-Khalifa, A.A.B. (2012). Evaluation of some rice varieties under different nitrogen levels. *Adv. Appl. Sci. Res.* **3**(2): 1144-1149.

Alam, M.S., Biswas, B.K., Gaffer, M.A. and Hossain, M.K. (2012). Efficiency of weeding at different stages of seedling emergence in direct-seeded aus rice. *Bangladesh J. Sci. Ind. Res*. **30**(4): 155-167.

Ali, H., Sawar, N., Hasnain, Z., Ahmad, S. and Hussain, A. (2016). Zinc fertilization under optimum soil moisture condition improved the aromatic rice productivity. *Philippine J. Crop Sci*. **41**(2): 71-78.

Amin, M.R., Hamid, A., Choudhury, R.U., Raquibullah, S.M. and Asaduzzaman M. (2006). Nitrogen Fertilizer Effect on Tillering, Dry Matter Production and Yield of Traditional Varieties of Rice. *Intl. J. Suatain*. *Crop Prod*. **1**(1): 17-20.

Angayarkanni, A. and Ravichandran, M. (2001). Judicious fertilizer N split for higher use efficiency in transplanted rice. *Indian J. Agril. Res.* **35**(4):278-280.

AOAC-Association of official Analytical Chemist. (1990). Official Methods of Analysis. Association of official Analytical Chemist (15th edn), AOAC, Washington, DC, USA.

Ashraf, U., and Tang, X. (2017). Yield and quality responses, plant metabolism and metal distribution pattern in aromatic rice under lead (Pb) toxicity. *Chemosphere,* **176**: 141-155.

Ashraf, U., Kanu, A.S., Deng, Q., Mo, Z., Pan, S., Tian, H., Tang, X. (2017). Lead (Pb) toxicity, physio-biochemical mechanisms, grain yield, quality, and pb distribution proportions in scented rice. *Frontiers in Plant Sci*. **8**: 1-17.

Ashrafuzzaman, M., Islam, M.R., Ismail, M.R., Shahidullah, S.M. and Hanafi, M. (2009). Evaluation of six aromatic rice varieties for yield and yield contributing characters. *Intl. J. Agric. Biol*. **11**: 616-620.

Azarpour, E., Moraditochaee, M. and Bozorgi, H.R. (2014). Effect of nitrogen fertilizer management on growth analysis of rice cultivars. *Intl. J. Biosci.* **4**(5): 35-47.

Bates, L., Waldren, R., Teare, I. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil*, **39**(1): 205-207.

BBS (Bangladesh Bureau of Statistics). (2015). Agriculture crop cutting. Estimation of rice production, 2014-2015. Government of the People's Republic of Bangladesh. p. 65.

Bhowmick, N. and Nayak, R.L. (2000). Response of hybrid rice (*Oryza sativa*) varieties to nitrogen, phosphorus and potassium fertilizers during dry (Boro) season in West Bengal. *Indian J. Agron.* **5**(2): 323-326.

Bhuiyan, M.S.H., Zahan, A., Khatun, H., Iqbal, M., Alam, F. and Manir, M.R. (2014). Yield performance of newly developed test crossed hybrid rice variety. *Intl. J. Agron. Agril. Res*. **5**(4): 48-54.

Bhuiyan, N.I. (2004). The Hybrid Rice Program for Bangladesh. **In**: 'Hybrid Rice in Bangladesh: Progress and Future Strategies'. Bangladesh Rice Res. Inst. Publication No. 138. pp. 3-5

BRRI. (2016). Adhunik Dhaner Chash, Joydevpur, Gazipur. P. 34.

Cassman, K.G., Dobermann, A.D., Walters, D. and Yang, H. (2003). Meeting cereal demand while protecting natural resources and improving environmental quality. *Ann. Rev. Environ. Res*. **28**: 315-358.

Chaturvedi, S., Lal, P., Singh, A.P. and Tripathi, M.K. (2004). Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice (*Oryza sativa* L.). *Ann. Biol*. **20**(2): 233-238.

Chowdhury, S.A., Paul, S.K. and Sarkar, M.A.R. (2016). Yield performance of fine aromatic rice in response to variety and level of nitrogen. *J. Environ. Sci. Natural Resources*, **9**(1): 41-45.

Duhan, B.S. and Singh, M. (2002). Effect of green manuring and nitrogen on the yield and nutrient uptake of micronutrient by rice. *J. Indian Soc. Soil Sci*. **50**(2): 178-180.

Dwivedi, A.P., Dixit, R.S. and Singh, G.R. (2006). Effect of nitrogen, phosphorus and potassium levels on growth, yield and quality of hybrid rice (*Oryza sativa* L.). *Oryza*. **43**: 64-66.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p. 112.

Fageria, N.K., Moreira, A. and Coelho, A. M. (2011). Yield and yield components of upland rice as influenced by nitrogen sources. *J. Plant Nutr*. **34**(3): 361-370.

Fan, M., Shen, J., Yuan, L., Jiang, R., Chen, X. and Davies, W.J. (2012). Food security. Improving crop productivity and resource efficiency to ensure food security and environmental quality in China. *J. Exp. Bot*. **63**: 13-24.

FAO (Food and Agriculture Organization). (2014). FAO Production Yearbook, Food and Agriculture Organization, Rome, Italy. pp. 59-78.

Fatema, K., Rasul, M.G., Mian M.A.K. and Rahman, M.M. (2011). Genetic Variability for grain quality traits in aromatic rice (*Oryza sativa* L). *Bangladesh J. Pl. Breed. Genet*. **24**(2): 19-24.

Ghosh, M. (2001). Performance of hybrid and high-yielding rice varieties in Teraj region of West Bengal. *J. Intl. Academicians*. **5**(4): 578-581.

Gomez, K.A. and Gomez, A.A. (1984). Statistically Procedures for Agricultural Research. 2nd edition. An International Rice Research Institute Book. A wiley-Inter science Publication, New York, 28. 1984. pp. 442-443.

Guilani, A.A., Siadat, S.A. and Fathi, G. (2003). Effect of plant density and seedling age on yield and yield components in 3 rice cultivars in Khusestan growth conditions. *Iranian J. Agric. Sci*. **34**(2): 427-438.

Guo, C.H., Gao, Z.Q. and Miao, G.Y. (2010). Effect of shading at post flowering on photosynthetic characteristics of flag leaf and response of grain yield and quality to shading in wheat. *Acta Agron. Sci*. **36**: 673-679.

Haque, M. and Biswash, M.R. (2014). Characterization of commercially cultivated hybrid rice in Bangladesh. *World J. Agric. Sci.* **10**(5): 300-307.

Haque, M.A., Razzaque, A.H.M., Haque, A.N.A. and Ullah, M.A. (2015). Effect of plant spacing and nitrogen on yield of transplant aman rice var. BRRI Dhan52. *J. Biosci. Agric. Res.* **4**(02): 52-59.

Haque, M.M., Pramanik, H.R., Biswas, J.K., Iftekharuddaula, K.M. and Mirza Hasanuzzaman, M. (2015). Comparative performance of hybrid and elite inbred rice varieties with respect to their source-sink relationship. *The Scientific World J*. **15**: 1-11.

Hasanuzzaman, M., Ali, M.H., Karim, M.F., Masum, S.M. and Mahmud, J.A. (2012). Response of hybrid rice to different levels of nitrogen and phosphorus. *Intl. Res. J. App. Basic Sci.* **3**(12): 2522-2528.

Hashemi, F.G., Rafii, M.Y., Ismail, M.R., Mahmud, T.M.M., Rahim, H.A., Asfaliza, R. (2013). Biochemical, genetic and molecular advances of fragrance characteristics in rice. *Critical Reviews in Plant Sci*. **32**(6): 445-457.

Hien, N.L., Yoshihashi, T. and Sarhadi, W.A. (2006). Evaluation of aroma in rice using KOH method, molecular markers and measurement of 2-acetyl-1-pyrroline concentration. *Japanese J. Trop. Agric*. **50**: 190-198.

Hosain, M.T., Ahamed, M.T., Haque, K.U., Islam, M.M., Fazle Bari, M.M. and Mahmud, J.A. (2014). Performance of hybrid rice (*Oryza sativa* L.) varieties at different transplanting dates in *Aus* Season. *App. Sci. Report.* **1**(1): 1-4.

Hossain, M. (2000). Auto-ecology of *Echinochloa crus-galli* and its control in direct seeded aus rice. M. S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 57-62.

Hossain, M.B., Islam, M.O. and Hasanuzzaman, M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice varieties. *Intl. J. Agril. Biol.* 1560-1570.

Hossain, M.E., Ahmed, S., Islam, M.T., Riaj, M.M.R. Haque, K.A. and Hassan, S.M.Z. (2018). Optimization of nitrogen rate for three aromatic rice varieties in Patuakhali region. *Intl. J. Natural and Social Sci*. **5**(4): 65-70.

Hossain, M.F., Bhuiya, M.S.U. and Ahmed, M. (2005). Morphological and agronomic attributes of some local and modern aromatic rice varieties of Bangladesh. *Asian J. Plant. Sci*. **4**(6): 664-666.

Hossain, M.S., Mosaddeque, H.Q.M., Alam, M.A., Moniruzzaman, S.M. and Ahmed, I. (2007). Effect of different organic manures and nitrogen levels on yield and yield attributes of T. aman rice. *Intl. J. Susta. Agri. Tech.* **3**(1): 21-26.

Huang, M. and Yan, K. (2016). Leaf photosynthetic performance related higher radiation use efficiency and grain yield in hybrid rice. *Field Crops Res.* **193**: 87-93.

Huang, Z.L., Tang, X.R., Wang, Y.L., Chen, M.J., Zhao, Z.K., Duan, M.Y. (2012). Effects of increasing aroma cultivation on aroma and grain yield of aromatic rice and their mechanism. *Sci. Agric. Res*. **45**(6): 1054-1065.

Islam, M.S., Akhter, M.M., Rahman, M.S., Banu, M.B. and Khalequzzaman, K.M. (2008). Effect of nitrogen and number of seedlings per hill on the yield and yield components of transplant aman rice (BRRI dhan33). *Intl. J. Sustain. Crop Prod.* **3**(3): 61-65.

Islam, M.S., Bhuiya, M.S.U., Rahman, S. and Hussain, M.M. (2010). Evaluation of SPAD and LCc based nitrogen management in rice (*Oryza sativa* L.),” *Bangladesh J. Agril. Res.* **34**(4): 661-672.

Islam, M.S.H., Bhuiyan, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. (2009). Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net house during transplanted aman season. *Bangladesh J. Agril. Res*. **34**(1): 67-73.

Islam, S., Rahman, M.I., Shohidul, M. Yeasmin, S.M. and Akhter, M. (2008). Effect of nitrogen level on aromatic rice varieties and soil fertility status. *Intl. J. Sustain. Crop Prod*. **3**: 49-54.

Jisan, M.T., Paul, S.K. and Salim, M. (2014). Yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ*. **12**(2): 321-324.

Julfiquar, A.W., Haque, M.M., Haque, A.K.G.M.E. and Rashid, M.A. (2008). Current status of hybrid rice research and future program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh. BARC, Farmgate, Dhaka, 18-19, May.

Juliano. (1971). A simplified assay for milled rice amylose. *Cereal Sci. Today*, **16**: 334-338.

Kandil, A.A., El-Kalla, S.E., Badawi, A.T. and El-Shayb O.M. (2010). Effect of hill spacing, nitrogen levels and harvest date on rice productivity and grain quality. *Crop Environ*. **1**(1): 22-26.

Kanfany, G., El-Namaky, R., Ndiaye, K., Traore, K. and Ortiz, R. (2014). Assessment of rice inbred lines and hybrids under low fertilizer levels in Senegal. *Sustainability*. **6**: 1153-1162.

Karim, M.R. (2011). Effect of nitrogen on growth, productivity and seed quality of long grain rice. MS Thesis, Dept. of Agronomy, BSMRAU, Salna, Gazipur. p. 83.

Khalifa, A.A.B.A. (2009). Physiological evaluation of some hybrid rice varieties under different sowing dates. *Australian J. Crop Sci.* **3**(3):178-183.

Khorshidi, Y.R., Ardakani, M.R., Ramezanpour, M.R., Khavazi, K. and Zargari, K. (2011). Response of yield and yield components of rice (*Oryza sativa* L.) to *Pseudomonas flouresence* and *Azospirillum lipoferum* under different nitrogen levels. *American-Eurasian J. Agric. & Env. Sci*. **10**(3): 387-395.

Khush, G.S. (2005). What it will take to Feed 5.0 Billion Rice consumers in 2030. *Plant Molecular Biol*. **59**: 1-6.

Kumar, V. and Ladha, J.K. (2011). Direct seeding of rice: recent developments and future research needs. **In:** Donald, L.S. (ed.), Advances in Agronomy. Academic Press. pp. 297-413.

Li, Y.H., Tang, X.R., Pan, S.G., Yang, X.J. (2014). Effect of water-nitrogen interaction at tillering stage on aroma, grain yield and quality of aromatic rice. *Acta Agril. Boreali Sci.* **29**(1): 159-164.

Lukman, S., Audu, A.M., Dikko, A.U., Ahmed, H.G., Sauwa, M. M., Haliru, M., Noma, S.S., Yusif1, S.A., Salisu, A. and Hayatu, N.G. (2016). Effects of NPK and Cowdung on the performance of rice (*Oryza sativa*) in the Sudan Savanna Agro-ecological Zone of Nigeria. *Asian Res. J. Agric.* **1**(4): 1-9.

Mahajan, G., Sekhon, N., Singh, N., Kaur, R., Sidhu, A. (2010). Yield and nitrogen-use efficiency of aromatic rice cultivars in response to nitrogen fertilizer. *J. New Seeds*, **11**(4): 356-368.

Mahamud J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. *Intl. J. Sustain. Agric*. **5**(1): 16-24.

Mandavi, F., Eamaili, M.A., Pirdashti, H. and Fallah, A. (2004). Study on the physiological and morphological indices among the modern and old rice (*Oryza sativa* L.) genotypes: New directions for a diverse planet. Proc. 4th Int. Crop Sci. Congress; Brisbane, Australia**.**

Mandira, B., Kumar, S., Chakraborty, D., Kapil, A.C. and Nath, D.J. (2016). Performance of rice variety Gomati in front line demonstration under rainfed condition of south Tripura district. *Intl. J. Agric. Sci*. **8**(63): 3555-3556.

Mannan, M.A., Bhuiya, M.S.U., Akand, M.M. and Rana, M.M. (2012). Influence of date of planting on the growth and yield of locally popular traditional aromatic rice varieties in *Boro* season. *J. Sci. Foundation*. **10**(1): 20-28.

Mannan, M.A., Bhuiya, M.S.U., Hossain, H.M.A. and Akhand, M.I.M. (2010). Optimization of nitrogen rate for aromatic basmati rice (*Oryza sativa* L). *Bangladesh J. Agril. Res.* **35**: 157-165.

Manzoor, Z., Awan, T.H., Zahid, M.A. and Faiz, F.A. (2006). Response of rice crop (super basmati) to different nitrogen levels. *J. Anim. Plant. Sci.* **16**(1-2): 52-55.

Maqsood, M., Shehzad, M.A., Ali, S.N.A., and Iqbal, M. (2013). Rice cultures and nitrogen rate effects on yield and quality of rice (*Oryza sativa* L.). *Turkish J. Agric. Forest*. **37**: 665–673.

Masum, S.M., Ali, M.H. and Ullah, J. (2008). Growth and yield of two T. aman rice varieties as affected by seedling number per hill and urea supper granules. *J. Agric. Educ. Technol*. **11**(1&2): 51-58.

Metwally, T.F., Gewaily, E.E. and Naeem, S.S. (2011). Nitrogen response curve and nitrogen use efficiency of Egyptian hybrid rice. *J. Agric. Res. Kafer El-Sheikh Univ*. **37**(1): 73-81.

Mohaddesi, A., Abbasian, A., Bakhshipour, S. and Aminpanah, H. (2011). Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high–yield rice (number 843). *American-Eurasian J. Agric. Environ. Sci*. **10**(5): 893-900.

Muhammad, M., Babar, M.H. and Muhammad, T. (2005). Effect of nursery transplanting techniques and nitrogen levels of growth and yield of fine rice (Basmati-2000). *Pakistan J. Agril. Sci*. **42**(3/4): 21–24.

Munnujan, K., Hamaid, A., Hashem, A., Hirota, O. and Khanam, M. (2001). Effect of nitrogen fertilizer levels and planting density on growth and yield of long grain rice. *Bull. Inst. Tropic. Agril. Kyushu Univ.* **24**: 1-10.

Murthy, K.M.D., Rao, A.U., Vijay, D. and Sridhar, T.V. (2015). Effect of levels of nitrogen, phosphorus and potassium on performance of rice. *Indian J. Agric. Res*. **49**(1): 83-87.

Murthy, K.N.K., Shankaranarayana, V., Murali, K. and Jayakumar, B.V. (2004). Effect of different dates of planting on spikelet sterility in rice genotypes (*Oryza sativa* L.). *Res. Crops.* **5**(2/3): 143-147.

Naik, K.R. and Paryani, A.K. (2005). Response of rice hybrids to nitrogen and number of seedlings. *Crop Res.* **29**(3) 379-381.

Naznin, A., Afroz, H., Hoque, T.S. and Mian, M.H. (2013). Effects of PU, USG and NPK briquette on nitrogen use efficiency and yield of BR22 rice under reduced water condition. *J. Bangladesh Agril. Univ*. **11**(2): 215-220.

Nori, H., Halim, R.A. and Ramlan, M.F. (2008). Effects of nitrogen fertilization management practice on the yield and straw nutritional quality of commercial rice varieties. *Malaysian J. Math. Sci*. **2**(2): 61-71.

Peng, S., Tang, Q. and Zou, Y. (2009). Current status and challenges of rice production in China. *Plant Prod. Sci*. **12**: 3-8.

Rajesh, K., Thatikunta, R., Naik, D.S. and Arunakumari, J. (2017). Effect of different nitrogen levels on morpho-physiological and yield parameters in rice (*Oryza sativa* L.). *Intl. J. Curr. Microbiol. App. Sci*. **6**(8): 2227-2240.

Roy, S.K.B. (2006). Increasing yield in irrigated boro rice through *indica/japonica* improved lines in West Bengal, India. Proc. Int. Rice Res. Conf. Rice research for food security and poverty alleviation.

Salahuddin, K.M., Chowhdury, S.H., Munira, S., Islam, M.M. and Parvin, S. (2009). Response of nitrogen and plant spacing of transplanted *Aman* rice. *Bangladesh J. Agril. Res.* **34**(2): 279-285.

Salem, A.K.M., ElKhoby, W.M., Abou-Khalifa, A.B. and Ceesay, M. (2011). Effect of nitrogen fertilizer and seedling age on inbred and hybrid rice varieties. *American-Eurasian J. Agric. Environ. Sci.* **11**(5): 640-646.

Salem, A.K.M., Elkhoby, W.M., Abou-Khalifa, A.B. and Ceesay, M. (2011). Effect of nitrogen fertilizer and seedling age on inbred and hybrid rice varieties. *American-Eurasian J. Agric. Environ. Sci*. **11**(5): 640-646**.**

Sarkar, S.C., Akter, M., Islam, M.R. Haque, M.M. (2016). Performance of five selected hybrid rice varieties in *Aman* season. *J. Plant Sci*. **4**(2): 72-79.

Sarkar, S.K., Sarkar, M.A.R., Islam, N. and Paul, S.K. (2014). Yield and quality of aromatic fine rice as affected by variety and nutrient management. *J. Bangladesh Agril. Univ*. **12**(2): 279-284.

Sharma, P., Abrol, V. and Kumar, R. (2012). Effect of water regimes and nitrogen levels on rice crop performance and nitrogen uptake. *Indian J. Soil Conser*. **40**(2): 122-128.

Sharma, S.K. and Haloi, B. (2001). Characterization of crop growth variables in some selected rice cultivars of Assam. *Indian J. Plant Physiol.* **6**(2): 166-171.

Sidhu, M.S., Sikka, R. and Singh, T. (2004). Performance of transplanted Basmati rice in different cropping systems as affected by N application. *Intl. Rice Res. Notes.* **29**(1): 63-65.

Sikdar, M.S.I., Rahman, M.M., Islam, M.S., Yeasmin, M.S., Akhter, M.M. (2008). Effect of nitrogen level on aromatic rice varieties and soil fertility status. *Intl. J. Sus. Crop Prod*. **3**(3): 49-54.

Sumon, M.J.I., Roy, T.S., Haque, M.N., Ahmed, S. and Mondal, K. (2018). Growth, yield and proximate composition of aromatic rice as influenced by inorganic and organic fertilizer management. *Not Sci. Biol.* **10**(2): 211-219.

USDA (United States Department of Agriculture). (2015). World agricultural production, foreign agricultural service, circular series wap. p. 9.

Wagan, S.A., Mustafa, T., Noonari, S., Memon, Q.U. and Wagan, T.A. (2015). Performance of hybrid and conventional rice varieties in Sindh, *Pakistan. J. Econ. Sustain. Dev*. **6**: 114-117.

Wang, J.L., Xu, Z.J. and Yi, X.Z. (2006). Effects of seedling quantity and row spacing on the yields and yield components of hybrid and conventional rice in northern China. *Chinese J. Rice Sci*. **20**(6): 631-637.

Wang, Y.Y., Zhu, B., Shi. Y. and Hu, C.S. (2008). Effect of nitrogen fertilization on upland rice based on pot experiments. *Commun. Soil Sci*. **39**(11-12): 1733-1749.

Witham, H., Blaydes, D.F. and Devlin, R.M. (1986). Exercises in plant physiology. 2nd edition. PWS Publishers, Boston. USA. pp. 128-131.

Xie, W., Wang, G. and Zhang, Q. (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. *J. Zhejiang Univ. Sci*. **8**(7): 486-492.

Yang, S., Zou, Y., Liang, Y., Xia, B., Liu, S., Ibrahim, M. (2012). Role of soil total nitrogen in aroma synthesis of traditional regional aromatic rice in China. *Field Crops Res.* **125**: 151-160.

Yoseftabar, S. (2013). Effect nitrogen management on panicle structure and yield in rice (*Oryza sativa* L). *Intl. J. Agric. Crop Sci.* **5**(11): 1224-1227.

Yoseftabar, S., Fallah. A. and Daneshian, J. (2012). Comparing of yield and yield components of hybrid rice (GRH1) in different application of nitrogen fertilizer. *Intl. J. Biol.* **4**(4): 60-65.

Yoshida, H., Horie, T. and Shiraiwa T. (2006). A model explaining genotypic and environmental variation of rice spikelet number per unit area measured by cross-locational experiments in Asia. *Field Crops Res*. **97**: 337-343.

Zhang, T., Zheng, J., Xu, J., Jiang, K., Wu, X., Wang, X. (2008). Genetic diversity of aromatic rice varieties based on markers of functional genes and SSR. *Agril. Sci*. **41**(3): 625-635.

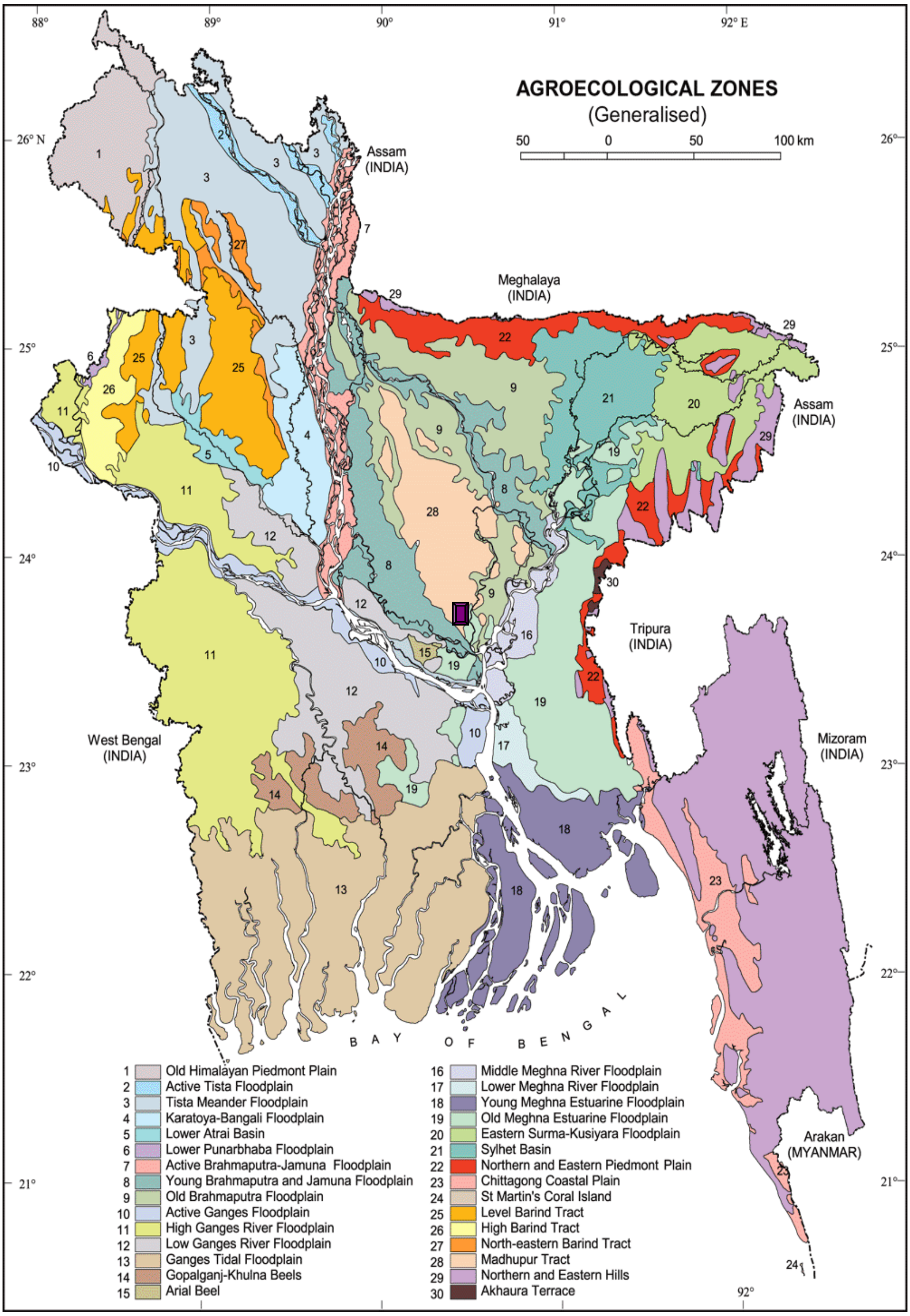
Zhaowen, M, Ashraf, U., Tang, Y., Li, W., Pan, S., Duan, M., Tian, H., and Tang, X. (2018). Nitrogen application at the booting stage affects 2-acetyl-1-pyrroline, proline, and total nitrogen contents in aromatic rice. *Chilean J. Agril. Res*. **78**(2): 165-172.

Zhong, Q., Tang, X.R. (2014). Effects of nitrogen application on aroma of aromatic rice and their mechanism. *Guangdong Agric. Sci*. **41**(4) 85-87.

Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from June to December 2017

Month (2017)	Air temperature (^0C)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
June	32.4	25.5	81	228	5.7
July	36.8	24.9	87	573	5.5
August	35.2	23.3	85	303	6.2
September	33.7	22.6	82	234	6.8
October	26.6	19.5	79	34	6.5
November	25.1	16.2	77	07	6.7
December	22.6	13.4	74	00	6.6

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1207

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix IV. Analysis of variance of the data on plant height at different days after transplanting (DAT) and harvest as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		20 DAT	40 DAT	60 DAT	Harvest
Replication	2	0.570	1.472	0.188	2.963
Levels of nitrogen (A)	3	178.419**	185.043**	276.953**	197.107**
Error	6	5.923	4.679	47.676	30.111
Scented rice varieties (B)	3	287.858**	518.522**	963.390**	1317.457**
Interaction (A×B)	9	15.139**	89.242*	102.400**	164.903**
Error	24	4.785	16.420	31.924	45.659

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on number of tillers hill^{-1} at different days after transplanting (DAT) and harvest as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Number of tillers hill^{-1}			
		20 DAT	40 DAT	60 DAT	Harvest
Replication	2	0.111	0.007	0.093	0.231
Levels of nitrogen (A)	3	2.238**	2.488**	3.814*	12.987**
Error	6	0.155	0.117	0.627	0.464
Scented rice varieties (B)	3	3.531**	2.487**	15.547**	22.410**
Interaction (A×B)	9	0.336**	0.294*	1.779*	2.482*
Error	24	0.101	0.130	0.373	0.893

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1} and panicle length as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Chlorophyll content in flag leaf (mg g^{-1})	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
Replication	2	1.787	0.277	0.003	1.109
Levels of nitrogen (A)	3	42.301*	20.608**	0.885**	14.642**
Error	6	6.969	0.252	0.048	1.500
Scented rice varieties (B)	3	38.413**	28.857**	1.116**	20.549**
Interaction (A×B)	9	70.726**	2.131*	0.210**	2.884*
Error	24	9.437	0.924	0.066	1.184

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on filled, unfilled and total grains panicle^{-1} and weight of 1000-grains as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
Replication	2	9.791	0.401	7.560	0.006
Levels of nitrogen (A)	3	1466.895**	56.109**	982.178**	0.087^{NS}
Error	6	29.433	0.943	29.554	0.121
Scented rice varieties (B)	3	2872.435**	23.507**	2396.529**	7.537**
Interaction (A×B)	9	126.170*	3.087*	142.554*	1.782**
Error	24	59.727	1.311	63.377	0.338

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on grain, straw, biological yield and harvest index as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.033	0.001	0.034	4.916
Levels of nitrogen (A)	3	0.490*	0.844**	2.613**	3.408^{NS}
Error	6	0.086	0.032	0.120	10.138
Scented rice varieties (B)	3	4.284**	0.782**	7.812**	274.605**
Interaction (A×B)	9	0.249**	0.272*	0.479**	22.113**
Error	24	0.036	0.045	0.100	3.882

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on length and breadth of grain rice, weight of milled, head and broken rice and rice and husk ratio as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square					
		Length of grain rice (mm)	Breadth of grain rice (mm)	Weight of milled rice (g)	Weight of head rice (g)	Weight of broken rice (g)	Rice and husk ratio
Replication	2	0.020	0.004	0.157	0.260	0.021	0.021
Levels of nitrogen (A)	3	0.014^{NS}	0.004^{NS}	11.189**	16.120**	0.720**	0.534**
Error	6	0.082	0.019	1.131	1.205	0.093	0.064
Scented rice varieties (B)	3	0.527*	0.282**	10.946**	9.495**	0.329**	1.051**
Interaction (A×B)	9	1.683**	0.059**	6.513*	7.518**	0.283**	0.139**
Error	24	0.166	0.013	2.322	2.346	0.045	0.014

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix X. Analysis of variance of the data on protein, amylose, proline and 2-AP content as influenced by different levels of nitrogen and scented rice varieties

Source of variation	Degrees of freedom	Mean square			
		Protein content (%)	Amylose content (%)	Proline content (mg g^{-1})	Grain-2AP (µg g^{-1})
Replication	2	0.001	0.093	0.089	0.0001
Levels of nitrogen (A)	3	1.721**	2.055^{NS}	6.995**	0.017**
Error	6	0.036	0.742	0.656	0.002
Scented rice varieties (B)	3	3.722**	16.309**	30.288**	0.060**
Interaction (A×B)	9	0.396**	1.525*	9.383**	0.006**
Error	24	0.038	0.671	2.009	0.001

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance