EFFECT OF NITROGEN LEVELS ON GROWTH, YIELD AND SEED QUALITY OF WHEAT

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JUNE, 2015

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A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JANUARY-JUNE, 2015

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF NITROGEN LEVELS ON GROWTH, YIELD AND SEED QUALITY OF WHEAT**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of *bonafide* research work carried out by **MAHBUBA AKTER**, Registration number: **14-06340** 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 duly been acknowledged.

Dated:
Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to The Almightly and Kindfull trust on to "Omnipotent Creator" for His never-ending blessing. The author would like to express her profound thankfulness to her respected parents, who confers much hardship inspiring for prosecuting her studies to receive proper education.

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

The author also expresses her gratefulness and best regards to respected ***Co-Supervisor Dr. Abdullahil Baque,*** *Professor, Department of Agronomy, SAU, Dhaka, for his scholastic guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.*

It is also a great pleasure for the author to express her sincere and deep sense of gratitude to ***Prof. Dr. Md. Fazlul Karim,*** *Chairman, Department of Agronomy, SAU, Dhaka, for his encouragement and co-operation and for providing all the necessary facilities during entire period of this program.*

The author expresses her gratitude and indebtedness to all the honorable course instructors of the Department of Agronomy, SAU, Dhaka for the kind help and co-operation in various stages towards completion of this research work.

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

The Author

EFFECT OF NITROGEN LEVELS ON GROWTH, YIELD AND SEED QUALITY OF WHEAT

Abstract

A field experiment was conducted at the Research Field and Agronomy Laboratory of Sher-e-Bangla Agricultural University, Dhaka 1207 during the period from November, 2014 to March, 2015 to evaluate the effect of nitrogen levels on growth, yield and seed quality of wheat. The experiment comprised of five nitrogen levels viz. (i) N_0= Control (no nitrogen), (ii) N_1= 25% less nitrogen from the recommended dose, (iii) N_2= Recommended dose of nitrogen, (iv) N_3= 25% higher nitrogen than recommended dose, (v) N_4= 50% higher nitrogen than recommended dose and four wheat varieties viz. (i) V_1= BARI gom 21, (ii) V_2= BARI gom 23 (iii) V_3 = BARI gom 24 and (iv) V_4 = BARI gom 27. The experiment was laid out in a split plot design with three replications. Data were collected on different parameters of growth, yield attributes, yield and seed quality of wheat. Results revealed that N_3 (25% higher nitrogen than recommended dose) gave the highest grain yield (3.41 t ha-1) which was statistically at par with N_2 (recommended dose of nitrogen) (3.29 t ha-1). This might be attributed to highest number of spikes m^{-2}(194.46), spike length (15.61 cm), number of spikelets $spike^{-1}$(20.91), number of grains $spike^{-1}$ (48.17) and 1000-grain weight (47.08 g). Out of 4 varieties V_3 (BARI gom 24) showed highest grain yield (3.02 t ha^{-1}) which was statistically similar with V_4 (BARI gom 27) (2.89 t ha^{-1}). The variety BARI gom 27 (V_4) also showed higher number of grains $spike^{-1}$ (46.65) and 1000-grain weight (49.53 g). In respect of seed quality, N_2 (recommended dose) showed higher quality of seed which was statistically similar to N_3 (25% higher nitrogen dose than recommended) because this nitrogen dose gave highest germination percentage (96.67 %), vigor index (10.34), shoot length (19.94cm) and dry weight $seedling^{-1}$ (0.19 g). In the case of variety, V_4 (BARI gom 27) showed the higher seed quality attributes of germination percentage (95.20%), vigor index (10.52) shoot length (20.51cm) and dry weight $seedling^{-1}$ (0.18 g). Regarding the interaction of nitrogen doses and varieties, N_2V_3, N_2V_4 and N_3V_4 were shown best in producing quality seeds. From the above results it was concluded that the recommended dose and 25% higher nitrogen than recommended dose with BARI gom 27 shows better for producing higher yield and quality seed.

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LIST OF ACRONYMS

ABBREVIATION	ELABORATION
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BARI	Bangladesh Agriculture Research Institute
BAU	Bangladesh Agricultural University
Bot.	Botany
^{0}C	Degree Centigrade
cm	Centimeter
Conf.	Conference
CV	Coefficient of Variance
DAS	Days after sowing
Ecol.	Ecological
et al.	And others
G	Gram(s)
HI	Harvest Index
Intl.	International
Inst.	Institute
J.	Journal
LSD	Least Significant Difference
M	Meter
m^{-2}	Meter per square
NS	Non-significant
pH	Hydrogen in concentration
Res.	Research
Sci.	Science
t ha^{-1}	Ton per hectare
Univ.	University
%	Percentage

Chapter I

Introduction

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important food grain crop grown in the world. It ranks first both in area (21,360 thousand hectares) and production (5,76,317 thousand metric ton) of the world (FAO, 2014) cereal crops accounting for 30% of all cereal food worldwide and is a staple food for over 10 billion people in as many as 43 countries of the World. It provides about 20% of the total food calories for the human race. Wheat ranks second in Bangladesh accounting for 20% of all cereal food of Bangladesh and is cultivated on large scale in the country. Once wheat was a food for the poorer in Bangladesh. Most of people used to take wheat as 'Chapati' (locally known as ruti). The dietary habit of people of Bangladesh has changed to a considerable extent during the past decade. Wheat has now become an indispensable food item of the people of Bangladesh and it continues to fill the food gap caused by possible failure of rice crop. Within a period of 30 years of time, wheat has been firmly established as a secure crop in Bangladesh, mainly due to stable market price and two million farmers are currently involved in wheat production (Karim *et al.*, 2010).

Wheat is grown under different environmental condition ranging from humid to arid, sub tropical to temperate zone (Saari, 1998). It is grown under a wide range of climatic and soil conditions. It, however, grows well in clayey loam soils. In Bangladesh, it is a crop of Rabi season, requires dry weather and bright sunlight. Well distributed rainfall between 40 and 110 cm is congenial for its growth. It is cool-loving crop and adopted for cultivation in regions with cooler climatic conditions. Its grain growth and development rely on temperature range of $15^0/10^0$ to $18^0/15^0$ (Throne *et al.*, 1968), the best time of wheat sowing is the second half of November that needed around 110-120 days to complete its life cycle. It contains about 12.1% protein, 69.60% carbohydrate, 1.72% fat, 27.60% minerals and a good source of vitamin B complex (USDA, 2012).

Wheat production has increased steadily from around 0.115 million tons in 1971-72 and gradually decreased to 0.73 million tons in 2005-06 (BBS, 2006). It is cultivated on an area of 4.16 lac hectares with an annual production of 12.54 lac tones and an average yield of 2.8 tones per hectare. (BBS, 2012-13). Among various constraints limiting wheat productivity in Bangladesh, delayed sowing, lack of varieties, lower fertilizer rate

and water shortage, availability of good quality seed and sowing techniques is a major hindrance. Researchers from the International Food Policy Research Institute (IFPRI) and the International Maize and Wheat Improvement Centre (CYMMYT) recently examined the arguments for and against wheat production in Bangladesh. However, wheat production has generally stagnated due to, among other factors, high cost of production and low level of technology adoption in the wheat industry (Onsongo, 2003).

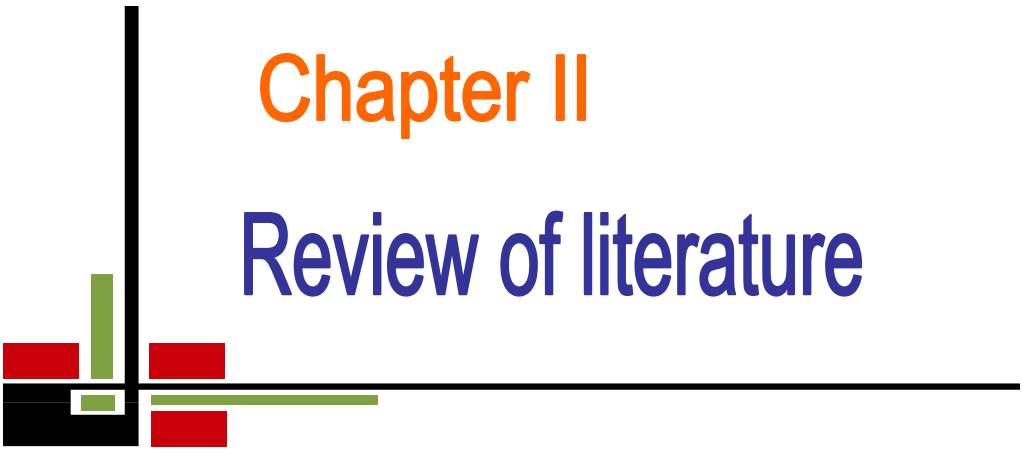
Nitrogen is the integral element of the chlorophyll and is the substrate needed for the synthesis of amino acid and proteins, which are constituents of protoplasm and chloroplast (Singh, 1997). Nitrogen helps to promote plant height, number of tillers and number of grains and is needed to maximize the spike number as much as possible at early and mid tillering stage and these parameters are adversely affected due to deficiency of nitrogen as the formation of enzymes, chlorophyll and proteins necessary for growth and development, gets restricted (Reddy, 2004). Nitrogen is the major nutrient added to increase crop yield (Camara *et al*., 2003). Consequently to get more production, nitrogen application is essential in the form of chemical fertilizer. Nitrogen fertilizer is known to affect the number of tillers m^{-2}, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, spike length and 1000-grain weight. Seed obtained from nitrogen applied plots showed increased germination percentage and more vigor. The protein content in the wheat grains increased with an increased in nitrogen. But urea is a fast releasing nitrogenous fertilizer which after application causes considerable losses as ammonia volatilization, immobilization, denitrification and surface runoff etc. and as such land experiences deficient in nitrogen. Lower soil nitrogen contents result in low protein content in wheat grain (Fowler *et al*., 1989). Nitrogen fertilization increases wheat protein content (Ortiz- Monasterio, 1997; Robinson *et al.*, 1979; Knowles *et al.*, 1991) which increases grain quality and vigor.

As for cultivation of wheat nitrogen have the greatest effect on plant growth, yield and seed quality. So, farmers use nitrogen fertilizer for wheat cultivation as traditionally which sometimes appears with more or less from the normal dose of and cause damage to the crop or reduce yield and quality of the seed which become unfavorable for the consumer and the environment. Economic use of nitrogen consequences a better environment and growing consumer demand for healthier product. But there is very limited work for the optimum dose of nitrogen in wheat seed cultivation. In view of the

importance of nitrogen for seed production of wheat, present study has been planned with the objectives to determine the optimum nitrogen requirement of the wheat.

Objectives:

1. To evaluate the variety for quality seed production of wheat
2. To find out the optimum nitrogen dose for quality seed of wheat varieties and
3. To find out the best combination of nitrogen doses and variety for quality seed production of wheat.



Chapter II

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief review of researches in relation to the effect of nitrogen level and variety in the crop field on growth, yield and seed quality of wheat. Some of the literatures pertinent to this study are reviewed below:

2.1 Effect of nitrogen level on growth parameters of wheat

2.1.1 Plant height

Ali (2010) carried out a field study to determine the influence of' varying nitrogen levels (0, 70, 140 and 210 kg ha^{-1}) applied to wheat cultivar i.e. lnqilab-91 and Bakhar-2000. Data for various growth and yield parameter of· the crops were collected and analyzed. Bakhar-2000 produced significantly more and taller plants throughout the crop growth stages and each increment of nitrogen increased plant height significantly. Significantly higher number of' tillers and fertile tillers was recorded in Bakhar-2000 and nitrogen applied at the rate of 210 kg ha^{-1}. This cultivar produced higher 1000-grain weight as well as grain yield than that of Inqlab-91.

Das (2003) steered out an experiment at the Agronomy Field Laboratory of the Bangladesh Agricultural University, Mymensingh to observe the effect of row spacing and nitrogen application on growth and yield of wheat. The experiment consists of four row spacing and four nitrogen levels. Results of the experiment showed that nitrogen had significant effect on plant height. At all growth stage the tallest plant was obtained from the 180 kg N ha^{-1}.

Sushila and Giri (2000) set an experiment with different nitrogen doses (0, 45, 90 kg ha^{-1}) and observed that plant height significantly increased with the increasing doses of nitrogen.

Kataria and Bassi (1999) conveyed a field experiment at Palampur during winter (Rabi) seasons of 1990-91 and 1991-92. The treatment consists of 3 levels of nitrogen (40, 80 and 120 kg ha^{-1}). They found that application of 80 kg N ha^{-1} produced significantly tallest plant than 40 kg N ha^{-1}.

Awasthi and Bhan (1993) noticed through an experiment that plant height of wheat increased significantly with increasing rates of nitrogen up to 60 kg ha^{-1}.

Patel and Upaddhyay (1993) reported that plant height was increased with increased N up to 150 kg N ha^{-1}.

Ahmed and Hossain (1992) reported that plant height of wheat were 79.9 cm, 82.3 cm and 84.4 cm with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height progressively increased with the increase of nitrogenous fertilizer.

Meneses and Ivan (1992) reported that plant height increased significantly with 0 to 200 kg N ha^{-1}.

2.1.2 Number of tillers m^{-2}

Ali (2011) a field trial was conducted at the research area of University College of Agriculture, Sargodha to determine the effect of different levels of nitrogen (N_0 = (control), N_1 = 80 kg ha^{-1} , N_2, 130 kg ha^{-1} , and N_3 180 kg ha^{-1}) on growth and yield of wheat variety 'Sahar-2006'. Result showed that all the nitrogen treatments significantly increased the number of tillers m^{-2} than control but 130 kg N ha^{-1} (N_2) resulted into maximum number of tillers m^{-2} (375.8).

Liaqat *et al.* (2008) conducted an experiment in the Rabi season in Pakistan to evaluate the response of wheat cv. Uqab-2000 to N at 84, 128, 150, 175 and 200 kg ha^{-1}. The number of· productive tillers m^{-2} (408), 1000-grain weight (41.2 g) and crop yield (5160 kg ha^{-1}) were highest at a rate of 150 kg N ha^{-1}. N at 175 kg ha^{-1} resulted in the highest number of grain $spike^{-1}$. Maximum plant height was obtained at 200 kg N ha^{-1}.

Shen *et al.* (2007) conducted a field experiment in China to identify the effect of application rates (180 and 240 kg ha^{-1}) on grain yield, protein and its components in wheat cv. Ningyan 1. The grain number per spike increased with the increase of application rate while the 1000-grain weight decreased. The ear number per unit area, dry matter accumulation, after flowering, leaf area index at heading stage and grain yield increased with the increased of nitrogen application rate. When the rate was 180 kg ha^{-1} the ear number was highest.

Akter (2005) conveyed an experiment with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1} and from that he has found that 100 kg N ha^{-1} gave the highest number of total tillers $plant^{-1}$.

Das (2003) showed the result through an experiment that nitrogen had significant effect on total tillers. The highest number of total tillers per plant was obtained from 180 kg N ha^{-1}.

Hameed *et al.* (2003) observed that application of 180 kg N ha^{-1} resulted into maximum number of tillers m^{-2} (369.0) and also observed that increasing nitrogen application increases the number of tillers m^{-2}.

Ayoub *et al.* (1994) conducted an experiment with four doses of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported increasing nitrogen fertilizer level significantly increased the number of tillers $plant^{-1}$.

Roy and Pradhan (1991) concluded that increasing N rate increased number of tillers $plants^{-1}$ and ears number m^{-2} but number of grains ear^{-1} and 1000 grain weight were not changed.

Chaudhry *et al.* (1989) reported from years experimental result that application of N @ 150 kg ha^{-1} resulted in highest (408.0 and 416.0) number of tillers m^2 in both the year.

2.1.3 Dry matter content

Wilhelm, (1998) reported that nitrogen plays a very vital role in the process of grain filling (Green, 1984), increase leaf area of the crop and may result in increased dry matter production by intercepting more sun light.

Knowles *et al.* (1991) reported that nitrogen fertilization increase wheat protein content which is a good indicator of grain quality and vigor.

Tisdale and Nelson (1984) observed that in cereals, dry matter production depends upon source sink relationship, where the source being the potential capacity for photosynthesis and the sink is the potential capacity to utilize the photosynthetic products. Balanced mineral nutrition is the most important for the best source sink regulation. An adequate supply of nitrogen to the crop plants during their early growth period is very important for the initiation of leaves and florets primordial.

2.2 Effect of nitrogen on yield contributing and yield attributes

Mondal (2014) conducted a field experiment at Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of wheat variety by different levels of nitrogen. The experiment included three varieties viz. BARI gom 23, BARI gom 24, and BARI gom 25 and four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. Result demonstrated that the variety BARI gom 24 with application of 125 kg N ha^{-1} produced the maximum grain yield (4.71t ha^{-1}) and harvest index (49.37 %).

Iqbal *et al.* (2012) conducted an experiment to investigate the effect of seeding rates and different levels of nitrogen on yield and yield components of wheat at Research Area, College of Agriculture, Dera Ghazi Khan where they found that nitrogen fertilization significantly affected spiklets/spike. He reported that plant height, number of tillers m^{-2} , spike length, number of spikelets/spike, number of grain/spike, 1000-grain weight, grain yield, biological yield and harvest index were highest at nitrogen at 125 kg/ha and lowest at zero level of nitrogen.

Oad *el al.* (2007) conducted a field experiment in Pakistan to assess the suitable nitrogen (level and placements for the yield and yield trait of wheat *CV.* Kiran-95. Three level (80. 120 and 150 kg ha^{-1} were incorporated through broadcast, split, pop-tip and foliar methods, split application of 120 kg N ha^{-1} significantly produced lengthy spikes, more grain number, $spike^{-1}$ better seed index and maximum grain yield $hectare^{-1}$ followed by broadcast, foliar and pop-up placement .

Akter (2005) carried a field experiment to study the effect of nitrogen levels under rainfed and irrigated conditions on yield and seed quality of wheat. The experiment was involved with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1}. From the experiment, it was noted that increasing nitrogen levels also increased the seed yield. He also found that increasing the nitrogen level up to 100 kg ha^{-1} the straw yield also increased.

Rahman (2005) found that most of the yield components of wheat as well as straw yield were significantly higher at 125 kg N ha^{-1}.

Yadav *et al.* (2005) observed from a field experiment during the winter seasons of 1999-2000 and 2000-2001 to assess the performance of zero tillage in wheat (*Triticum aestivum* L.) under varying levels of each successive increment of N 120 to 180 kg ha^{-1} that N levels did not influence the 1000- grain weight.

Yadav *et al.* (2005) reported that application of N up to 150 kg ha^{-1} significant increased the grain yield. The increase in grain yield was 12.3 and 17.3% with 150 and 180 kg ha^{-1}, respectively over 120 kg ha^{-1}.

Chandurkar *et al.* (2004) guided an experiment to determine the response of wheat to N content and uptake in grain and straw with increasing N fertilizer rates (90, 120 and 150 kg N ha^{-1}). The highest grain yield, N content, N uptake and protein content were obtained with 150 kg N ha^{-1}.

Liaqat *et al.* (2003) executed that nitrogen @ 150 kg ha^{-1} gave grain yield of 4330 and 5160 kg ha^{-1} during Rabi 2000–01 and 2001–02, respectively. Increasing N rates further resulted in reduction in grain yield during both the years.

Islam *et al.* (2002) steered out an experiment and reported that the plots are fertilized with 170 kg N ha^{-1} had the maximum number of grains per spike.

Maqsud *et al.* (2002) found that the application of 150 kg N ha^{-1} gave the maximum number of grains per spike.

Mozumder (2001) carried out an experiment to investigate the response the wheat at different of levels of nitrogen. Treatments of nitrogen in that experiment were 0, 30, 60, 90, and 120 kg ha^{-1}. He proposed that the effect of N on straw yield was significant. The highest straw yield was recorded from N at the rate of 120 kg ha^{-1}.

Awasthi and Bhan (1996) steered out an experiment with five varieties of wheat K56, K78, K72 , K8430 and K306 and 4 levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}). They indicated that straw yield of wheat increased significantly with the increasing rates of nitrogen up to 60 kg ha^{-1}.

Hossain *et al.* (1996) indicated that straw yield increased significantly by fertilizer. Straw yield was 5.18t ha^{-1} at N 160: P 100: K 80 kg ha^{-1}.

Singh *et al.* (1996) steered out a field experiment with 3 levels of nitrogen (40, 80 and 120 kg ha^{-1}) and reported that straw yield of wheat increased significantly with increasing rates of N up to 120 kg N ha^{-1}.

Ayoub *et al.* (1994) carried out an experiment with 4 doses of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and from he found that straw yield was increased by increasing nitrogen fertilizer level.

Awasthi and Bhan (1993) and Maqsood *et al.* (2002) concluded that 1000-grain weight significantly significant increased with increasing nitrogen levels.

Kausar *et al.* (1993) reported that grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling and however application of nitrogen increased the protein percentage, which in turn increased the grain weight.

Ahmed and Hossain (1992) executed that application of N at the rate of 135 kg ha^{-1} produced the highest seed yield ranging from 2.2 to 2.6 t ha^{-1}.

Chandra *et al.* (1992) observed that 1000-grain weight was enhanced by increasing nitrogen level from 120 kg N/ha to 150 kg N ha^{-1}.

Canko and Bano (1986) indicated that average grain yield of soft wheat CV. LBZ given N, P and K in various combination (in the ranges 66-330, 36-90 and 50 or 100 kg ha^{-1}, respectively) was 4.65- 6.22 t ha^{-1} compared with 2.48 t ha^{-1} when no NPK was applied. P and K rates had little effect on yield, which increased with increasing N rate up to 132 kg ha^{-1}.

Samad *et al.* (1984) conducted a field experiment in the Agronomy field laboratory of Bangladesh Agricultural University, Mymensingh on wheat cultivar Sonalika with 4

doses of N (40, 60, 80 and 100 kg ha^{-1}) and claim that N application at early tillering stage tended to give higher straw yield.

Malik (1981) found that increasing nitrogen from 0 to 120 kg ha^{-1} increased grain yield from 1.34 to 5.47 t ha^{-1}. Yields did not increase further with addition of 160 kg N ha^{-1}.

2.3 Effect on seed quality of wheat

Mondal (2014) conducted a field experiment at Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of wheat variety by different levels of nitrogen. The experiment included three varieties viz. BARI gom 23, BARI gom 24, and BARI gom 25 and four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. Result demonstrated that the variety BARI gom 24 with application of 125 kg N ha^{-1} produced the maximum protein content (10.88%).

Khan *et al.* (2010) works on seed quality determination tests and examined that higher electrical conductivity results poor germination.

Warraich *et al.* (2002) conducted a field experiment to evaluate the effect of different levels of N on grain quality and vigor in wheat which showed that nitrogen application improved grain protein and reduced phosphorous percentage and Seeds obtained from nitrogen fertilized plots showed increased final germination percentage, while time to 50% germination (T_{50}) and mean germination time (MGT) were significantly reduced with the nitrogen application. He also observed that seeds obtained from 120 kg N ha^{-1} treatment showed more vigor during electrical conductivity test as compare to 0, 60 and 180 kg N ha^{-1}. He also demonstrated that the performance of seed is determined by its viability, purity, germination percentage, electrical conductivity, field emergence and seedling dry weight were with nitrogen fertilization.

Ehdaie *et al.* (2001) found that the greater nitrogen supply increase shoot biomass by 29%, grain yield by 16%, protein by 5% but decrease harvest index by 10%.

Ottman *et al.* (2000) reported that the increase in germination percentage with nitrogen application may be due to increased grain volume, weight and kernel size of wheat and

maximum germination rate is one of the best measurement for good quality determination.

Vieira *et al.* (1999) also determined that higher EC is an indication of the low vigor due to an increase in membrane permeability of the lower vigor seeds. Sufficient supply of nitrogen at optimum planting times resulted vigorous seed.

Ortiz Monasterio (1997) found that nitrogen fertilization increases wheat protein content which increases grain quality and vigor.

Singh *et al.* (1992) reported that protein content of grain was significantly higher with increasing the level of nitrogen (120 kg N ha^{-1}).

Fowler *et al.* (1989), low soil nitrogen contents result in low protein content in wheat grain.

Konov *et al.* (1985), reported that nitrogen fertilizer increased the grain protein content from 30.3 to 40.98. They also found that application of NPK was most effective in increasing grain quality. FYM+ NPK was the best, its efficiency increased with increasing proportion of NPK, and FYM alone had little effect on the quality of wheat.

2.4 Effect of varieties

Khakwani *et al.* (2012) conveyed an experiment of 6 bread varieties (Damani, Hashim-8, Gomal-8, DN-73, Zam-04 and Dera-98) were subjected to 2 treatments i.e., control treatment (100% field capacity) and stressed treatment (20 days water stress was given during booting stage and 20 days water stress after anthesis). The findings revealed highly significant differences among means of wheat varieties in all yield traits.

Alam and Rahman (2008) carried out a research work with twenty wheat varieties / lines to study the effect of source-sink manipulation on grain yield in wheat. Significant variations among the genotypes were observed for grains spike-1, 1000-grain weight and grain yield main $spike^{-1}$. Removal of flag leaf caused decreased in grain $spike^{-1}$, 1000-grain weight and grain yield main $spike^{-1}$ by 9.94%, 7.65% and 16.88%, respectively. Similarly removal of all leaves caused reduction of grains $spike^{-1}$, 1000-grain weight and

grain yield main spike^{-1} by 17.17%, 13.27% and 27.92%, respectively. On the other hand, removal of 50% spikelets decreased 41.03% and 37.01% in grains spike^{-1} and grain yield main spike^{-1} and increased 9.44% in 1000-grain weight. Similarly, 25% spikelets removal reduced grains spike^{-1} and grain yield main spike^{-1} by 25.13% and 23.38%, respectively but increased 4.08% in 1000-grain weight. The variety / lines BL-1020, Ananda and Akbar showed high decrease in grain spike^{-1}, 1000-grain weight and grain yield main spike^{-1} by defoliation treatment.

Jalleta (2004) conveyed an experiment in farmer's field with number of improved wheat varieties for production in the different climatic zones. Farmers identified earliness, yield and quality as the main criteria for adaptation of wheat varieties and they also found that the variety HAR-710 gave 2.56t ha^{-1} and PAVON-76 gave 2.49 t ha^{-1}.

BARI (2003) steered out an experiment in Wheat Research Centre at Nasipur Dinajpur, tested some varietal performance in Rajshahi and found that Satabdi produced highest (3.2 t ha^{-1}) followed by Gourab (3.13 t ha^{-1}) and lowest yield produced by Kanchan (2.96 t ha^{-1}).

Hussain *et al.* (2001) investigated to assess the growth and yield response of three wheat varieties (Inqalab-91, Karchia and Parwaz-94) to different seeding densities i.e. 100, 125 and 150 kg ha^{-1} were carried out on a sandy loam soil. The results indicated that seeding densities significantly affected various growth and yield parameters like germination count, total number of tillers m^{-2}, number of grains spike-1 and grain yield, but total leaf area plant^{-1}, straw yield and harvest index were not affected significantly. The varieties differed significantly from one another with respect to the yield and yield contributing parameters. Wheat variety Inqalab-91 when sown @ 150 kg ha^{-1} gave the highest yield.

Hossain *et al.* (1996) observed that plant height of Akbar was 85.1 cm with the fertilizer rate 160 N; 100 P; 80 K kg ha^{-1}. He also reported that grains per spike were 28.6 in Akbar variety.

Sarkar *et al.* (1996) reported that 1000-grain weight was variable for different wheat varieties, namely Lerma -52, RR-21, UP-262, Tribeni, Lumbini, Bhaskar, Siddhartha and Binayak.

Arbinda *et al.* (1994) observed that the grain yield was significantly affected by different varieties in Bangladesh. The genotypes CB-15 produced higher grain yield (3.7 t ha^{-1}) due to more number of spikes m-2 and grains $spike^{-1}$.

Amin *et al.* (1993) reported that plant height of Agrahani and Kanvhan were 90.13 and 93.38cm, respectively.

Bakshi *et al.* (1992) conducted field experiments at Ludhiana, Punjab with eight bread wheat and seven drum wheat varieties sown on 1 or 15 November or 15 December, and given 0, 40, 80 or 120 kg N ha^{-1} with one or two irrigation. Seed yield was highest when wheat was sown on 1 Nov. with 120 kg N ha^{-1} and two irrigations. Varieties Raj 3037, HD-4594, WL-711 and WH-841 gave the highest seed yield.

Bostal *et al*. (1989) executed that wheat cv. Slavia was given 150 kg N as N, 42 kg P and 100 kg K/ha. N was applied at various growth stages which increased grain yield by 48-82%.

Islam *et al.* (1987) reported that nitrogen fertilizer increased average grain yield of Sonalika from 1.3 t/ha in the unfertilized control to 3.54 t/ha with 180 kg/ha nitrogen. The maximum of 3.82 t/ha of grain was obtained from 180 kg/ha nitrogen and 80 kg/ha P_2O_5 application.

Ali *et al.* (1984) found that Sonalika gave maximum average grain yields due to the highest treatment N 160, P 80, K 60, S 30 and Zn 8 which were 3.2, 3.3, 2.6 and 4.1 t/ha, respectively for Mymensingh, Jamalpur, Madhupur and Ishurdi. They reported that addition of 40 kg S/ha in Madhupur soil significantly increased the grain yield of cv. Sonalika with a record of 2.4 t/ha in S added plot and 1.96 t/ha in the control.

Anonymus (1972) reported that varieties differed significantly in producing total tillers and fertile per plant. He also reported that all these characters were highest in penjano-62 variety.

Anonymus (1972) observed that Aghrani and Kanchan were found responsive to high dose of N level and gave increased yield with increased rate of N. But Akbar showed positive response up to 60 kg/ha N application.

2.5 Effect of interaction of nitrogen and variety on growth, yield and seed quality of wheat

Mondal (2014) conducted a field experiment at Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of wheat variety by different levels of nitrogen. The experiment included three varieties viz. BARI gom 23, BARI gom 24, and BARI gom 25 and four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. Result demonstrated that among twelve treatment combinations, the variety BARI gom 24 showed the best performance when fertilized with 125 kg N ha^{-1} along with recommended amount of other nutrients.

Iqbal *et al.* (2012), the interaction between seeding rates and nitrogen levels was found non significant for plant height, number of tillers m spike length, number of spikelets/spike and 1000-grain weight while a significant interaction was noted for number of grain/ spike, grain yield, biological yield and harvest index and were maximum at seeding rate of 150 kg/ha with nitrogen level of 125 kg/ha.

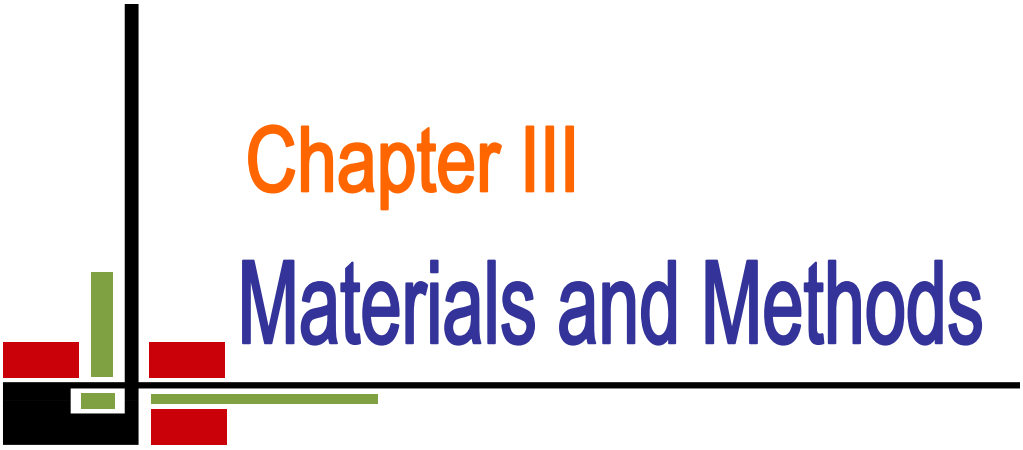
Ataur *et al.* (2011) conducted a field experiment at the central research farm of Bangladesh Agricultural Research Institute, Gazipur to verify the yield response of wheat variety Prodip to different doses and split applications of N fertilizer to determine appropriate N dose and application method for increasing NUE and grain yield of wheat. The treatments comprised of 12 combinations of three doses of nitrogen (80, 100, and 120 kg/ha) from urea, which were assigned in the main plots and four methods of N splitting viz., application of all N as basal; 2/3rd basal plus 1/3rd as top dress at crown root initiation (CR1) stage; 1 /2 basal plus 1 /2 as top dress at CR1 stage; and 1/3rd basal with 1/3rd as top dress at CR1 plus 1/3rd as top dress at 1st node stage which were tested in the sub plots. Nitrogen content in wheat grain and straw was not affected significantly by different N treatment and their combinations.

Islam (2011) conveyed an experiment at Agronomy Field Lab of Bangladesh Agricultural University (BAU), Mymensingh during the period from November 2009 to

March 2010 with a view of finding out the effect of appropriate dose of USG on growth and yield of wheat. Three wheat varieties (Shatabdi, Bijoy and Prodip) and six levels of nitrogen were applied as treatments in this study. Among the application of USG on morpho-physiological and growth characters of wheat the maximum plant height (98.33cm, number of spikelets (21.33) and sterile spikelet (19.87) were found from V_3T_3. Similarly, V_2T_3 produced the highest no. of spikelet spike^{-1} (11.50) and grain yield (2.75 t ha^{-1}) whereas similar treatment also showed the maximum no. of non-effective tiller (1.07) with V_1T_3. The treatment combination of V_2T_2 was recorded the highest on 1000-grain weight (51.98g), no. of non sterile spike (2.07), and no. of grains spike^{-1} (48.87). The highest no. of total tiller hill^{-1} (5.13) and effective tiller (4.33) were taken from the treatment combinations of V_1T_5. The highest Straw yield (4.67 t ha^{-1}) was recorded in V_2T_4.

Gwal *et al.* (1999) conducted an experiment with four wheat varieties sown in December at Sehore, Madhya Pradesh, Fertilized with 0-0-0, 60-30-30, 120-60-60 or 180-90-90 kg N-P2O5-K2O, respectively. Averaged from the varieties, plant height, number of tillers plant^{-1}, spike length, grain protein content, grain yield and straw yield increased with NPK rate. Grain yield averaged 6.79, 9.98, 9.99, and 5.47t ha-1 in cv. Lok-1, HD-2236, WH-147 and Raj-1555, respectively.

Srinivas *et al.* (1997) studied with three levels of nitrogen (80, 120 and 160 kg ha^{-1}) and three wheat cultivars (HD-4502, HD-2189 and Hd-2281) to the response of wheat to dry matter production and noticed that HD-2189 gave the highest dry matter with 120 kg N ha^{-1}.



Chapter III

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

This experiment was conveyed at the Research Field of Sher-e- Bangla Agricultural University (SAU), Dhaka-1207, during the period of November 17, 2014 to March 11, 2015. Methodologies followed and materials used in this experiment have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted in the Agronomy Field, Sher-e-Bangla Agricultural University (SAU), Dhaka 1207 during the period of November 17, 2014 to March 11, 2015 to study the effect of different level of nitrogen on growth, yield and seed quality of wheat. The experimental field is located at $23^0$41' N latitude and $90^0$22' E longitude at a height of 8.6 m above the sea level (Appendix I).

3.1.2 Soil

The soil of the experimental site was clay loam belonging to the "Madhupur Tract" under AEZ 28. It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The soil was silty clay in texture having pH of 6.7. The physical and chemical properties of the soil have been presented in Appendix III.

3.1.3 Climate

The experimental field was situated under sub-tropical climate; usually the rainfall is heavy during Kharif season, (April to September) and scanty in Rabi season (October to March. In Rabi season temperature is generally low and there is plenty of sunshine. The temperature tends to increase from February as the season proceeds towards kharif. Rainfall was almost nil during the period from November 2014 to March 2015 and scanty from February to March. The monthly total rainfall, average temperature during the study period (November to March) has been presented in Appendix IV.

3.2 Treatments

The experiment consists of two factors and they were the wheat genotypes and different levels of nitrogen. Five different levels of nitrogen and four wheat genotypes were used under the present study. The treatments of the experiment were as follows:

Factor A: Nitrogen levels (0-4)

N_0 = No Nitrogen (control)

N_1 = 25% lower nitrogen than recommended dose

N_2 = Recommended dose (200 kg N ha^{-1})

N_3 = 25% higher nitrogen than recommended dose

N_4 = 50% higher nitrogen than recommended dose

Factor B: Wheat varieties (1-4)

V_1 = BARI gom 21 (Satabdi)

V_2 = BARI gom 23 (Bijoy)

V_3 = BARI gom 24 (Prodip)

V_4 = BARI gom 27

3.3 Details of the field operations

3.3.1 Land preparation

Repeated ploughing with power tiller and country plough was done on 7 November and final land was prepared on 16 November, 2014. Ploughing was followed by laddering in order to break clods as well as level the land. All weeds, stubbles and crop residues were removed from the experimental plot. The layout of the experiment was done as per statistical design.

3.3.2 Experimental design

The experiment was laid out in a split plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into 5 main plots in which nitrogen doses were applied at random. Each main plot was further divided into 4 unit plots or subplots and varieties were assigned at random. There were altogether 60 (20×3) unit plots, each plot measuring 3m × 2.5 m. Inter-block and inter-plot spacing were 1m and 0.5m, respectively. The layout of the experiment has been shown in Appendix II.

3.3.3 Fertilizer application

The following doses of manure and fertilizers were used:

Cowdung	:	10 t ha^{-1}
Urea	:	as per treatment
TSP	:	150 kg ha^{-1}
MoP	:	110 kg ha^{-1}
Gypsum	:	110 kg ha^{-1}
Zinc oxide	:	4 kg ha^{-1}
Boric acid	:	5 kg ha^{-1}

Urea was applied as per treatment. The whole amount of triple super phosphate (TSP), muriate of potash (MoP), Gypsum Zinc oxide, Boric acid and one third of urea (as per treatment) were incorporated in each plot (except control plot) at the time of final land preparation. Rest two third of urea was applied in two equal splits at crown root initiation stage (21 DAS) and spike initiation stage (55 DAS).

3.3.4 Collection and sowing of seeds

As per treatment seeds of different wheat varieties were collected from wheat division, Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur. At a good tilth condition, furrows were made with hand rakes for sowing. Before sowing, seeds were treated with Provax 200EC @ 2.5 g powder for kg^{-1} seed. Seeds were sown continuously in line on 17th November 2014 @ 125 kg ha^{-1}. The line to line distance was maintained 25 cm. After sowing the seeds were covered with soil and lightly pressed by hand. Two guards were appointed from early to morning to protect the wheat seeds from birds specially Pigeons.

3.3.5 Intercultural operation

Following intercultural operations were done to ensure normal growth of the crop:

3.3.5.1 Irrigation

Three irrigations were applied , the first irrigation after 20 days of sowing at crown root initiation (CRI) stage, the second after 45 days at heading stage and the third irrigation after 62 days at grain filling stage. During the irrigation enough care was taken so that water could not flow from one plot to another or overflow the boundary of the plot. Excess water of the field was drained out.

3.3.5.2 Weeding

Weeding was done two times during the whole growing period, the first weeding after 18 days of sowing and the second other after 40 days after sowing.

3.3.5.3 Insect and pest control

The crop was attacked by different kinds of insects (cereal aphid and grass hopper) during the growing period. The experimental plot was sprayed at 35 days with Diazinon to control the Aphids. Insecticides were applied to the plots after irrigation at afternoon at 60 DAS.

3.3.6 Harvesting and sampling

The crop was harvested at different dates on the basis of physiological maturity. The variety BARI gom 21 (Shatabdi) was harvested on 09 March, 2015, BARI gom 23 (Bijoy) on 07 March, 2015, BARI gom 24 (Prodip) on 03 March, 2015 and BARI gom 27 (Francolin) on 01 March, 2015. Ten sample plants were collected randomly from each plot leaving undisturbed two meter square in the centre. The selected sample plants were then harvested, bundled, tagged and carefully carried to the threshing floor in order to collect the yield components data. For recording yield data, plants collected from central $2m^2$ area in each plot. Threshing, cleaning and drying of grains were done separately for each treatment. Properly dried grain and straw were weighed and converted into t ha^{-1} basis.

3.4 Data collection

Data were collected on the following growth, yield and yield contributing components and quality of seed:

A) Crop growth characters

1. Plant height at 30, 50, 70, 90 DAS and at harvest
2. Tillers per square meter at 30, 50, 70, 90 DAS and at harvest
3. Dry matter weight per plant at 30, 50, 70, 90 DAS and at harvest
4. Days to flowering
5. Days to maturity

B) Yield contributing characters

1. Spike m^{-2} (no.)
2. Number of spikelets $spike^{-1}$

3. Grains spike^{-1} (no.)
4. 1000-grain weight (g)

C) Yield:

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

D) Seed quality data

1. Germination percentage (%)
2. Speed of germination
3. Seed vigor
4. Electrical conductivity

3.4.1 Plant height

From each plot, 5 plants were selected and tagged them. Plant height for all sampling dates were collected from these sample plants. The plant height was measured from the ground level to top of the plant at 30, 50, 70, 90 DAS and at harvest.The height of the 5 plants were averaged to get the height per plant basis.

3.4.2 Number of tillers m^{-2}

An area of 1m^2 from each plot was selected randomly by using a quadrate. The number of total tillers from 1m^2 area was counted at 30, 50, 70, 90 DAS and at harvest.

3.4.3 Dry weight plant^{-1}

With the help of hand weeder (nirani) 3 plants were uprooted and cleaned with water. Plants were oven dried at 70^0 C for 72 hours until a constant weight was obtained. The dry weight of plants were recorded in gram and converted into dry weight plant^{-1} basis. The data were collected at 30, 50, 70, 90 DAS and at harvest.

3.4.4 Days to flowering

The flowering date was reported as the number of days from sowing until the crop initiate to bloom.

3.4.5 Days to maturity

The maturity days was reported as the number of days from sowing until the crop attained 95% maturity.

3.4.6 Number of spikes m^{-2}

One m^2 area was selected from each plot randomly with the help of a quadrate. The number of total spikes from $1m^2$ area was counted at harvest.

3.4.7 Spike length (cm)

Spike length was measured with a meter scale from the base to the tip of the spike of ten randomly selected spikes and the average value was recorded as spike length.

3.4.8 Number of spikelet $spike^{-1}$

Total number of spikelets from ten randomly selected spike from each plot was calculated and then averaged to have number of spikelets $spike^{-1}$.

3.4.9 Number of grains $spike^{-1}$

Ten spikes were selected and the total grains from each plot were calculated and then averaged to have number of grains $spike^{-1}$.

3.4.10 Thousand grain weight (g)

Thousand grains were counted from a randomly selected sample of each plot and the weight (g) of grains was recorded after sun drying by an electrical balance.

3.4.11 Grain yield (t ha^{-1})

Grains from central $2m^2$ area in each unit plot were dried and then weighed carefully. The results were expressed as t ha^{-1} on 14% moisture basis.

3.4.12 Straw yield (t ha^{-1})

Like grain yield, dry weight of straw for $2m^2$ area in each plot was recorded and expressed as t ha^{-1}.

3.4.13 Biological yield (t ha^{-1})

Biological yield was calculated from the following formula:

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

3.4.14 Harvest Index (%)

Harvest Index was calculated on the ration of economic yield (grain yield) to biological yield and expressed in terms of percentage. It was calculated by using the following formula (Donald, 1963).

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

3.4.15 Germination percentage (%)

Standard germination test was conducted in the laboratory. 100 seeds from each treatment replicated 4 times were placed in germination trays between two sheets of standard germination paper and the trays were kept at 25°C for 7 days. The germination trays were monitored daily and water was applied when needed. The percentage of germination was calculated by following equation:

$$\text{Germination (\%)} = \frac{\text{Number of seeeds germinated}}{\text{Total number of seeds}} \times 100$$

3.4.16 Vigor index

The number of germinated seedlings were counted everyday and it was divided by the day of counting. This process was repeated up to 14 days after that it was totaled. The vigor index was calculated by following equation:

Vigor index = Number of germinated seedlings/ 1st day of count+ …….+ No. of germinated seedlings/ 14th day of count

3.4.17 Shoot length (cm)

The shoot length of 10 seedlings were recorded in cm after 14 days of germination.

3.4.18 Root length (cm)

Plumule length of the 10 seedlings were recorded in cm. At the end, average length was calculated.

3.4.19 Dry weight/ seedling (g)

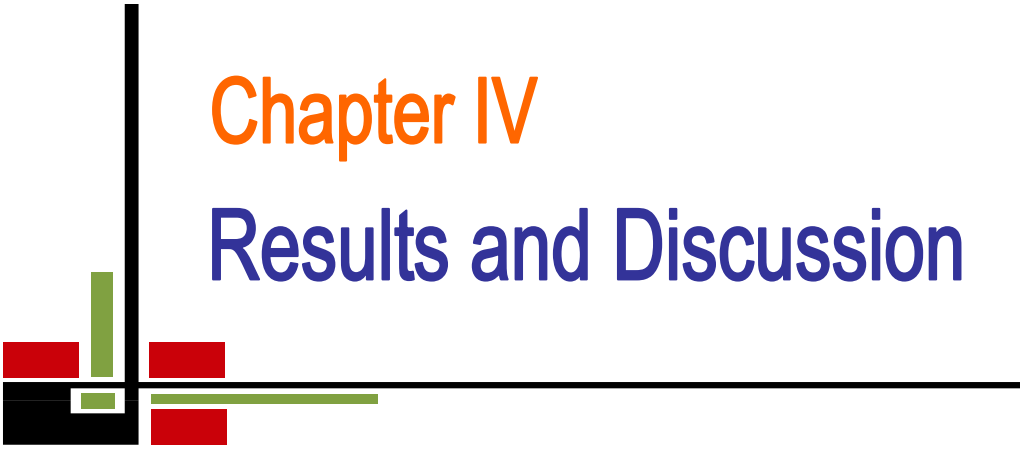
The seedlings obtained after standard germination test were used for seedling dry weight test. The plumule and radicals were detached from coleoptiles and were placed in paper bags, dried in oven at 60ºC for 24 hours (Khan *et al*., 2010).

3.4.20 Electrical conductivity (mS/cm)

The seeds were soaked into water for 24 hours then data was collected through a electrical conductivity machine AD (3000) EC/TDS & Temperature Meter.

3.5 Statistical analysis

The collected data of each plot were statistically analyzed to obtain the level of significance using the computer based software MSTAT-C developed by Russel (1986). Mean difference among the treatments were tested with the least significant difference (LSD) test at 5 % level of significance.



Chapter IV

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

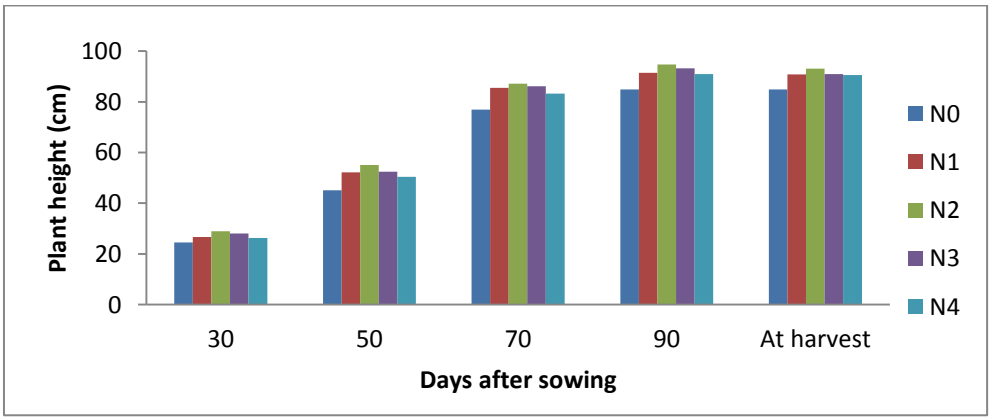
This chapter comprised of presentation of data and probable discussions were made on the results obtained from the study. The effect of nitrogen doses, varieties and their interaction on growth, yield and seed quality have been presented in Table 1 to Table 11 and Figure 1 to Figure 16.

4.1 Growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of nitrogen doses

Different nitrogen doses affect the plant height significantly at all sampling dates (Fig. 1). Figure shows that plant height increased sharply at the early stages of growth (up to 70 DAS) after that the growth rate was minimum for all the nitrogen doses. It was found that the tallest plant was obtained from N_2 (recommended dose) treatment at all growth stages (28.95, 55.08, 87.13, 94.73 and 93.10 cm at 30, 50, 70, 90 DAS and at harvest, respectively) which was statistically similar with the N_1(25% lower than recommended dose) treatment at 50, 70, 90 DAS and at harvest , N_3 (25% higher nitrogen than recommended dose) treatment at 30, 50, 70, 90 DAS and at harvest and N_4 (50% higher nitrogen than recommended dose) treatment at 70, 90 DAS and at harvest. On the other hand, the shortest plant stature was found in control (N_0) treatment (24.51, 45.12, 76.90, 84.75 and 84.87 cm at 30, 50, 70, 90 DAS and at harvest, respectively). The result found from the present experiment was similar with the result observed by Liaqat *et al.* (2008).

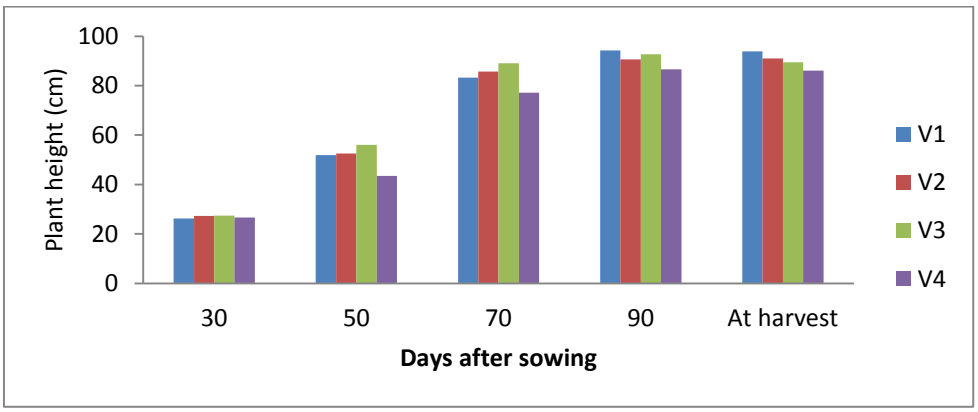


Here: N0= Control (No Nitrogen), N1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N3 = 25% higher nitrogen than recommended dose, and N4 = 50% higher nitrogen than recommended dose.

Fig. 1 Effect of different nitrogen doses on plant height at different growth duration of wheat ($LSD_{0.05}$= 1.85, 4.19, 6.39, 5.25 and 4.21 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.1.2 Effect of variety

The result showed that the effect of variety on plant height was significant at all growth duration (Fig. 2).The figure indicated that irrespective of varieties, plant height increased rapidly up to 70 DAS after that the rate of increase in plant height was much slower up to 90 DAS. After 90 DAS the height slightly reduced for all the varieties. The variety BARI gom 24 (V_3) produced the significantly tallest plant height (27.45, 56.07, 89.01 and 92.75 cm at 30, 50, 70 and 90 DAS, respectively) which was superior from all other varieties. But at 90 DAS and at harvest BARI gom 21(V_1) produced the tallest plant height (94.27 and 93.79 cm respectively) which was statistically similar with BARI gom 23(V_2) at harvest and BARI gom 24 (V_3) at 90 DAS. On the other hand, BARI gom 27 (V_4) produced the dwarf plant from 50 DAS to at harvest (43.53, 77.17, 86.60 and 86.03 cm at 50, 70, 90 and at harvest, respectively).



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 2 Plant height as influenced by different varieties at different growth duration of wheat ($LSD_{0.05}$= 1.00, 2.87, 3.61, 2.60 and 2.92 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.1.2 Interaction effect of nitrogen doses and variety

The plant height differed significantly due to the interaction effect of different nitrogenous fertilizer doses and variety at all sampling dates (Table 1). Results showed that the tallest plant was obtained from N_2V_2 at 30 and 50 DAS (29.57 and 58.80 cm, respectively) which was statistically similar to the N_2V_1, N_2V_3 and N_3V_3 at 30 and 50 DAS, N_2V_4 at 30 DAS and N_3V_2 at 50 DAS. But at 70 DAS the tallest plant was obtained from N_2V_3 (94.27 cm) and also at 90 DAS and at harvest the tallest plant was found from N_3V_1 (97.73 and 95.67 cm, respectively). On the other hand, the shortest plant

stature (23.45, 37.40, 72.53 81.33 and 81.07 cm, respectively) was recorded from N_0V_4 combination at 30, 50, 70, 90 DAS and at harvest.

Table 1. Interaction effect of nitrogen doses and variety on plant height at different duration of growth of wheat

Nitrogen doses × Variety	Plant height (cm) at different days after sowing (DAS)				
	30 DAS	**50 DAS**	**70 DAS**	**90 DAS**	**At harvest**
N_0V_1	23.98 gh	46.13 d-g	75.07 gh	88.53 de	90.41 a-e
N_0V_2	25.13 f-h	46.53 d-g	77.07 gh	82.67 fg	85.60 c-g
N_0V_3	25.46 f-h	50.40 c-e	82.93 b-g	86.87 e-g	82.40 fg
N_0V_4	23.45 h	37.40 h	72.53 h	81.33 g	81.07 g
N_1V_1	26.67 c-f	53.00 a-c	85.47 b-f	93.87 a-d	93.97 ab
N_1V_2	26.69 c-f	54.53 a-c	86.60 a-d	91.33 b-e	90.73 a-e
N_1V_3	26.99 b-f	58.00 ab	89.73 a-c	92.00 a-e	90.40 a-e
N_1V_4	26.37 d-f	43.00 f-h	80.27 d-h	88.47 d-f	88.27 b-f
N_2V_1	28.31 a-d	54.80 a-c	85.87 b-e	97.07 ab	94.13 ab
N_2V_2	29.57 a	58.80 a	90.87 ab	95.07 a-c	94.17 ab
N_2V_3	29.17 ab	57.07 ab	94.27 a	97.13 ab	93.37 ab
N_2V_4	28.75 a-c	49.67 c-e	77.53 f-h	89.67 c-e	90.73 a-e
N_3V_1	26.95 b-f	51.80 b-d	87.40 a-d	97.73 a	95.67 a
N_3V_2	27.21 b-f	54.33 a-c	88.87 a-c	93.60 a-d	91.73 a-d
N_3V_3	29.54 a	58.03 ab	90.67 ab	94.27 a-d	91.63 a-d
N_3V_4	28.75 a-c	45.33 e-g	77.53 f-h	87.20 ef	84.73 e-g
N_4V_1	25.41 f-h	53.87 a-c	82.40 c-g	94.13 a-d	94.77 ab
N_4V_2	27.71 a-e	48.87 c-f	85.23 b-f	90.13 c-e	92.60 a-c
N_4V_3	26.10 d-g	56.87 ab	87.47 a-d	93.47 a-d	89.70 a-e
N_4V_4	25.83 e-g	42.27 gh	78.00 e-h	86.33 e-g	85.33 d-g
LSD(0.05)	**2.68**	**6.95**	**9.46**	**7.27**	**6.53**
CV(%)	**5.01**	**7.55**	**5.78**	**3.83**	**4.97**

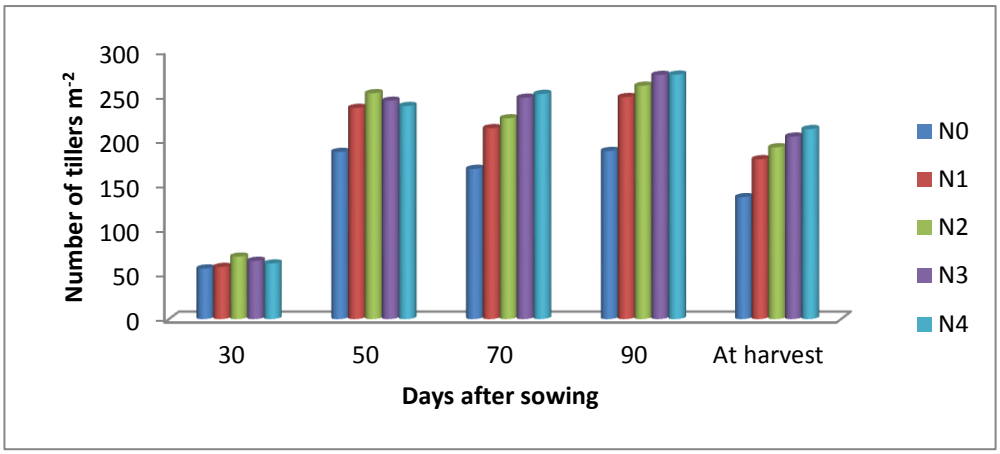
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.1.2 Number of tillers m^{-2}

4.1.2.1 Effect of nitrogen doses

Significant variation was observed on number of tillers m^{-2} due to different doses of nitrogen application in the field (Fig.3). It was found that the highest number of tillers m^{-2} was found with N_2 (70.08 and 252.8 nos. at 30 and 50 DAS) but at 70 and 90 DAS and at harvest the highest number of tillers were recorded from N_4 (252.0, 273.4 and 212.8, respectively) which was followed by N_3. On the other hand, the lowest number of tillers m^{-2} (56.75, 187.4, 168.4, 188.4 and 136.8 at 30, 50, 70, 90 DAS and at harvest, respectively) were found in N_0 (control).

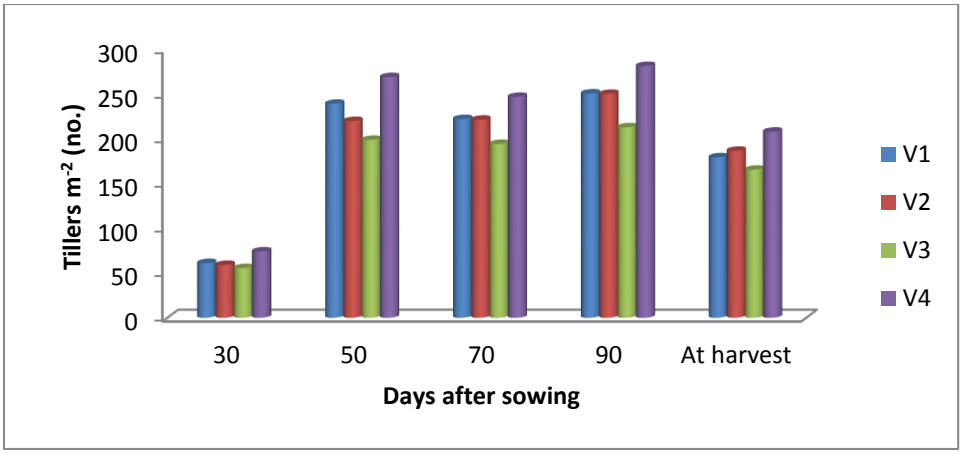


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig. 3 Number of tillers m^{-2} as influenced by different nitrogen doses at different growth duration of wheat varieties ($LSD_{0.05}$= 5.91, 20.69, 17.85 and 25.339 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.2.2 Effect of variety

The result revealed that the effect of variety on number of tillers m^{-2} was significant at all growth intervals studied (Fig.4). The figure also revealed that tillers m^{-2} increased gradually at the advancement of growth stages and the highest increament was found at the sampling date of 90 DAS. Numerically, BARI gom 27 (V_4) produced the maximum number of tillers m^{-2} (74.27, 269.1, 247.0, 281.5 and 208.2 at 30, 50, 70 and 90 DAS, and at harvest, respectively). Result also showed that BARI gom 21 (V_1) showed second highest with almost similar number of tillers m^{-2} of BARI gom 23 (V_2) at 30, 70 and 90 DAS, and at harvest. On the other hand, BARI gom 24 (V3) produced the minimum number of tillers m^{-2} (55.67, 199.1, 194.5, 213.1 and 165.8 at 30, 50, 70 and 90 DAS, and at harvest, respectively).



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 4 Number of tillers m^{-2} as influenced by different varieties at different growth stages of wheat varieties ($LSD_{0.05}$= 5.10, 16.46, 15.12 and 20.40 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.2.3 Interaction effect of nitrogen doses and variety

Number of tillers m^{-2} was significantly influenced by the interaction of nitrogenous fertilizer dose and variety at different days after sowing (DAS) (Table 2). Result showed that the maximum number of tillers m^{-2} was obtained from N_2V_4 at 30 DAS (84.67) which was statistically similar with N_0V_4 (75.67) and N_3V_4 (75.00). The lowest tillers m^{-2} was recorded with N_0V_3 (42.00) which were statistically similar with N_0V_2 (50.67). Interaction of N_2V_4 showed the higher level of tillers m^{-2} for all sampling dates i.e. 50, 70 and 90 DAS. But at 70 and 90 DAS, interaction of N_4V_4 produced the highest number of tillers m^{-2} (287.3 and 326.7, respectively). However, at 90 DAS interaction of N_4V_4, N_3V_4, N_1V_4 and N_2V_2 showed statistically similar number of tillers m^{-2}, whereas, the lowest number of tillers m^{-2} was recorded at N_0V_3 interaction which similar with N_0V_1 and N_0V_2 interaction at the same sampling date.

Table 2. Interaction effect of nitrogen doses and variety on number of tillers m^{-2} at different growth stages of wheat

Nitrogen doses × Variety	Number of tillers per m^2 at different days after sowing (DAS)				
	30 DAS	50 DAS	70 DAS	90 DAS	At harvest
N_0V_1	58.67 d-g	180.7 gh	173.3 jk	197.3 g-i	139.0 gh
N_0V_2	50.67 gh	179.7 gh	177.0 jk	194.0 hi	149.7 fg
N_0V_3	42.00 h	155.3 h	143.7 k	156.3 i	105.7 h
N_0V_4	75.67 ab	234.0 de	179.7 ij	206.0 gh	152.7 fg
N_1V_1	53.67 fg	240.7 c-e	212.3 f-i	261.3 c-f	171.3 e-g
N_1V_2	61.00 c-g	236.3 de	217.7 d-h	234.0 e-h	184.0 c-f
N_1V_3	53.33 gh	214.7 e-g	184.0 h-j	210.3 gh	153.3 fg
N_1V_4	66.00 b-e	254.0 cd	241.0 c-f	288.3 a-c	208.0 a-e
N_2V_1	70.33 bc	277.0 a-c	226.7 c-g	261.7 c-f	182.3 c-f
N_2V_2	67.00 b-e	232.0 de	222.7 c-g	282.0 a-d	203.7 b-e
N_2V_3	58.33 e-g	210.0 e-g	199.7 g-j	222.3 f-h	174.7 d-g
N_2V_4	84.67 a	292.0 ab	250.0 b-d	278.7 b-e	209.3 a-d
N_3V_1	65.00 b-f	258.0 b-d	247.7 b-e	269.7 b-e	194.3 b-e
N_3V_2	56.00 e-g	225.0 d-f	251.7 bc	278.7 b-e	182.7 c-f
N_3V_3	65.33 b-e	190.0 f-h	215.0 e-h	236.3 e-h	212.7 a-c
N_3V_4	75.00 ab	304.7 a	277.0 ab	308.0 ab	228.0 ab
N_4V_1	58.67 d-g	240.0 de	251.7 bc	264.0 b-f	211.0 a-d
N_4V_2	61.67 c-g	227.7 de	239.0 c-f	263.3 b-f	214.3 a-c
N_4V_3	59.33 c-g	225.7 d-f	230.0 c-g	240.0 d-g	182.7 c-f
N_4V_4	70.00 b-d	260.7 b-d	287.3 a	326.7 a	243.0 a
LSD(0.05)	**11.50**	**37.94**	**33.34**	**43.32**	**40.84**
CV(%)	**10.93**	**9.52**	**9.16**	**10.99**	**12.01**

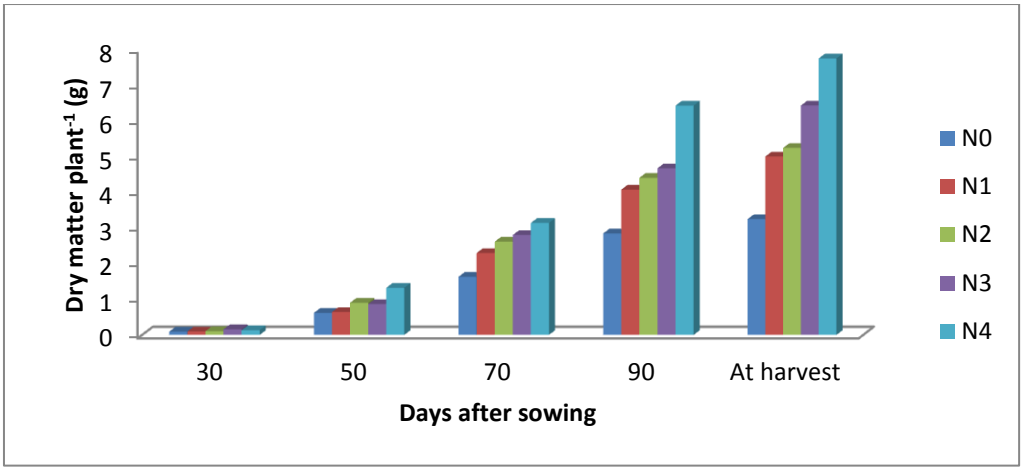
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.1.3 Dry weight $plant^{-1}$

4.1.3.1 Effect of nitrogen doses

Significant variation was observed on dry weight $plant^{-1}$ due to different doses of nitrogenous fertilizer application in wheat (Fig. 5). A trend of steady increase in dry matter $plant^{-1}$ of wheat was observed with the increase of growth times. The figure showed that the rate of increase in dry matter $plant^{-1}$ was more rapid in the early growth stages than later stages for all nitrogen doses. Among the nitrogen doses, dry weight $plant^{-1}$ increases with the increased doses of nitrogen, irrespective of sampling dates.

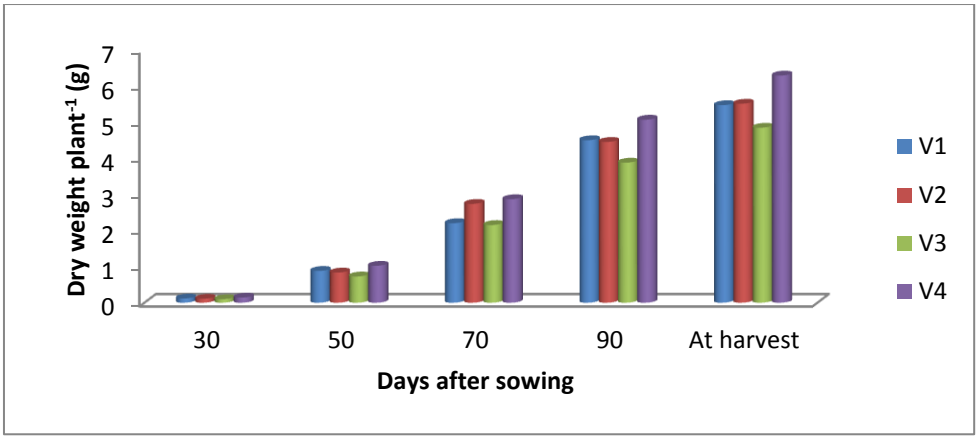


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig. 5 Dry weight plant^{-1} as influenced by different nitrogen doses at different growth stages of wheat varieties ($LSD_{0.05}$= 0.02, 0.08, 0.26, 0.37 and 0.75 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.3.2 Effect of variety

Significant variation among varieties were observed on dry weight plant^{-1} at all growth duration of wheat (Fig 6). It was revealed that dry weight plant^{-1} increased gradually from the 30 DAS to at harvest and the rate of increase in dry weight was found much higher in the early growth stages. The highest increase in dry weight plant^{-1} was found in BARI gom 27 (V_4) and that of the lowest was observed in BARI gom 24 (V_3) varieties. Other two varieties BARI gom 21 (V_1) and BARI gom 23 (V_2) showed similar level of dry weight plant^{-1} for all sampling dates except 70 DAS. Numerically, the maximum dry weight plant^{-1} (0.14, 1.02, 2.87, 5.07 and 6.29 g at 30, 50, 70, 90 DAS and at harvest, respectively) was found with BARI gom 27 (V_4). On the other hand, BARI gom 24 (V_3) produced the minimum dry weight plant^{-1} at 30, 50, 70, 90 DAS and at harvest as 0.097, 0.73, 2.15, 3.89 and 4.85 g, respectively. Variations of plant height with among varieties might be due to cause of genetic make up and/or nutrient availability, nutrient uptake capacity of the varieties that might be to increase dry weight plant^{-1}.



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig.6 Dry weight plant^{-1} as influenced by different varieties at different growth duration of wheat varieties ($LSD_{0.05}$= 9.84, 0.08, 0.15, 0.40 and 0.50 for 30, 50, 70, 90 DAS and at harvest, respectively)

4.1.3.3 Interaction effect of nitrogen doses and variety

Dry weight plant^{-1} was significantly influenced by the interaction of nitrogen dose and varieties at different days after sowing (DAS) (Table 3). Result showed that the highest dry weight plant^{-1} was obtained from N_3V_4 at 30 DAS (0.20 g), N_4V_1 at 50 and 70 DAS (1.51 and 3.58 g) and N_4V_4 at 90 DAS and at harvest (7.40 and 8.61 g respectively). At 90 DAS and at harvest the interaction of N_4V_4 and N_4V_1 produced highest and statistically similar dry matter plant^{-1} of wheat. The lowest dry matter plant^{-1} was found in N_0V_3 at 90 DAS and at harvest (2.55 g and 3.05 g, respectively) which was statistically similar with N_0V_1, N_0V_2 and N_0V_4 interactions at 90 DAS and at harvest.

Table3. Interaction effect of nitrogen doses and variety on dry matter plant^{-1} at different growth sampling times of wheat

Nitrogen doses × Variety	Number of tillers per m^2 at different days after sowing (DAS)				
	30 DAS	50 DAS	70 DAS	90 DAS	At harvest
N_0V_1	0.10 f-i	0.56 h	1.41 g	2.85 hi	3.46 h
N_0V_2	0.09 g-i	0.55 h	1.63 g	2.89 hi	2.89 h
N_0V_3	0.09 hi	0.55 h	1.36 g	2.55 i	3.05 h
N_0V_4	0.09 g-i	0.81 d-f	2.12 f	3.07 g-i	3.58 gh
N_1V_1	0.11 f-h	0.67 gh	1.67 g	4.33 d-f	4.74 f
N_1V_2	0.04 j	0.76 fg	2.53 de	4.37 d-f	5.68 c-f
N_1V_3	0.09 g-i	0.24 i	2.26 ef	3.01 hi	3.43 h
N_1V_4	0.14 c-e	0.95 cd	2.72 cd	4.55 de	6.15 b-d
N_2V_1	0.11 f-h	0.85 d-f	2.11 f	3.59 f-h	4.66 fg
N_2V_2	0.11 e-g	0.88 d-f	3.00 bc	4.41 d-f	5.26 d-f
N_2V_3	0.08 i	0.94 c-e	2.25 ef	3.93 e-g	4.92 ef
N_2V_4	0.12 d-f	0.93 c-e	3.08 b	5.66 bc	6.11 b-d
N_3V_1	0.17 b	0.89 d-f	2.26 ef	5.00 b-d	6.03 b-e
N_3V_2	0.15 bc	0.78 ef	3.00 bc	4.78 c-e	6.64 bc
N_3V_3	0.11 e-g	0.84 d-f	2.73 cd	4.23 d-f	6.03 b-e
N_3V_4	0.20 a	0.95 cd	3.19 b	4.66 de	7.00 b
N_4V_1	0.10 f-h	1.51 a	3.58 a	6.74 a	8.463 a
N_4V_2	0.14 cd	1.22 b	3.55 a	5.85 b	7.10 b
N_4V_3	0.12 e-g	1.07 bc	2.17 f	5.71 b	6.83 b
N_4V_4	0.17 b	1.48 a	3.26 ab	7.40 a	8.610 a
LSD(0.05)	**0.02**	**0.16**	**0.39**	**0.85**	**1.23**
CV(%)	**11.32**	**11.77**	**8.19**	**11.92**	**12.25**

In a column means having similar letter(s) are statisticlly similar and those having dissimilar letter(s) differ significantly at 5% level of significance

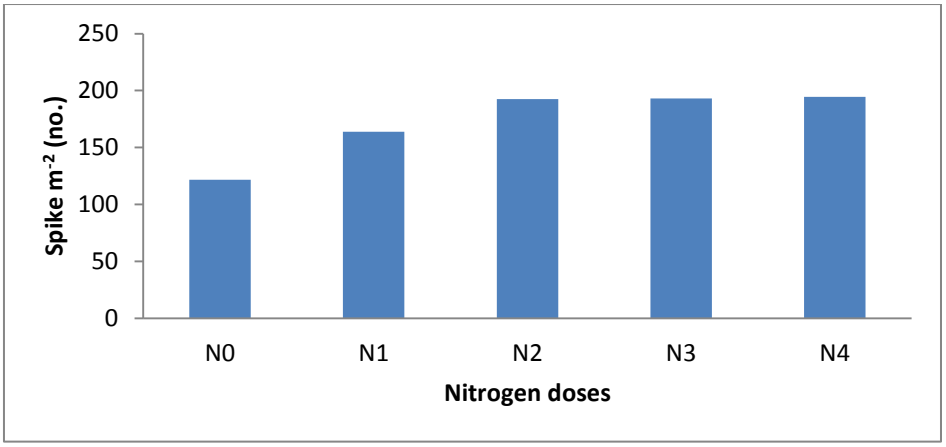
Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.2 Yield attributes

4.2.1 Spike m^{-2}

4.2.1.1 Effect of nitrogen doses

Number of spike m^{-2} was significantly influenced by the different nitrogen doses (Fig. 7). The figure showed an increasing trend of number of spike m^{-2} with the increases in nitrogen doses and rate of increase was more rapid up to N_2 treatment after that the rate of increase was minimum. However, numerically, the maximum spike m^{-2} (194.46) was found with N_4 which was significantly similar with the treatments N_2 and N_3. On the other hand, minimum number of spike m^{-2} (121.7) was found from N_0 which was significantly different from all other treatments.

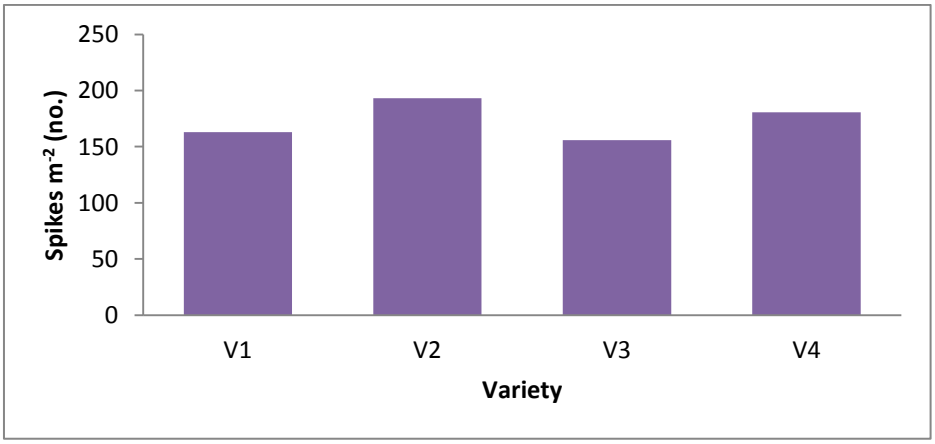


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig.7 Effect of different nitrogen doses on spike m^{-2} of wheat varieties ($LSD_{0.05}$= 5.18)

4.2.1.2 Effect of variety

Significant differences were recorded for spikes m^{-2} of wheat varieties (Figure 8). The figure revealed that the maximum number of spikes m^{-2} was recorded from the variety BARI gom 27 (V_4) followed by BARI gom 27 (V_4). On the other hand, the minimum number of spikes m^{-2} (155.73) was found from the variety BARI gom 24 (V_3) which also significantly different from all other variety.



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 8 Effect of different varieties on spikes m^{-2} of wheat varieties ($LSD_{0.05}$= 5.43)

4.2.1.3 Interaction effect of nitrogen doses and variety

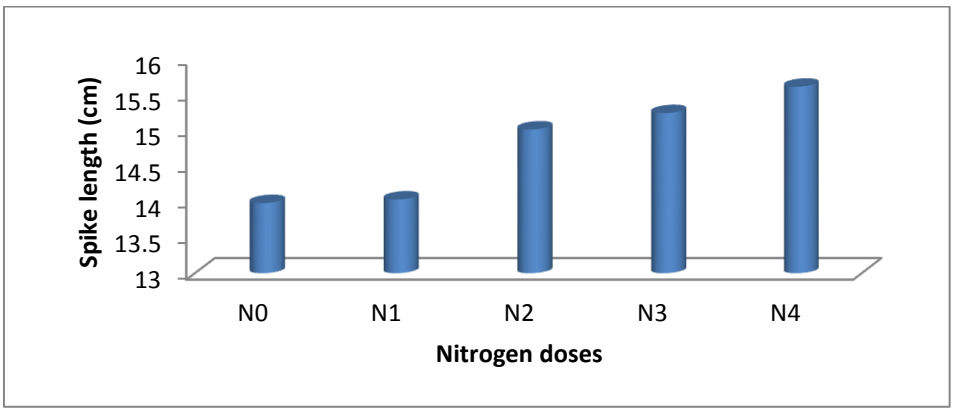
Spikes m^{-2} was significantly influenced by the interaction of nitrogenous fertilizer doses at different doses and variety (Table 4). Results showed that the maximum number of spikes m^{-2} (216.9) was recorded from the combination of N_2V_2 which was statistically

similar with the combinations N_2V_4, N_3V_2 and N_4V_2. On the other hand, the minimum number of spikes m^{-2} (99.83) was found from the combination N_0V_3 which was significantly different from all other combinations.

4.2.2 Spike length (cm)

4.2.2.1 Effect of nitrogen doses

Significant variation was observed on spike length due to application of different doses of nitrogen (Fig. 9). The figure showed that longest spike (15.61 cm) was found from N_4 (50% higher nitrogen than recommended dose) treatment which was statistically similar with the treatments N_2 and N_3. On the other hand, the shortest spike (13.98 cm) was found from N_0 (control) which was statistically similar with N_1 (25% lower nitrogen than recommended dose).

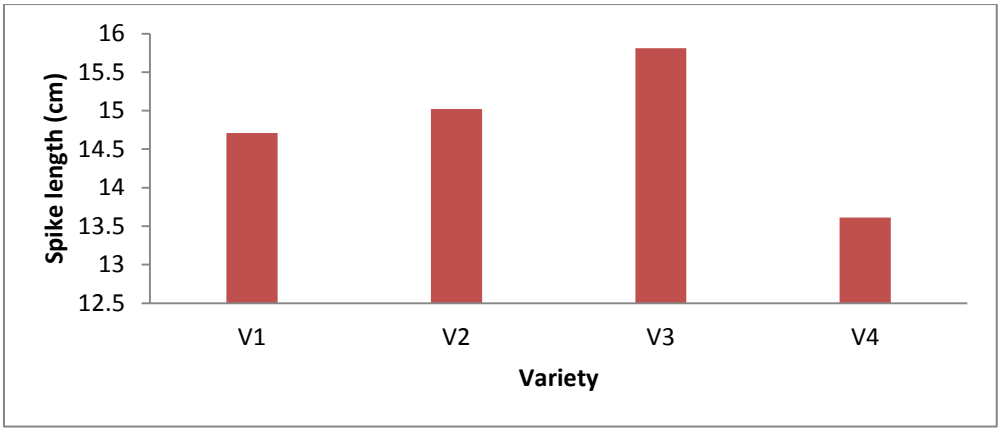


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig.9 Effect different nitrogen doses on spike length of wheat varieties ($LSD_{0.05}$= 0.71)

4.2.2.2 Effect of variety

Significant differences were recorded for spike length in wheat due to varieties (Fig. 10). The figure showed that the variety BARI gom 24 (V_3) produced the longest spike (15.81 cm) followed by V_2 (BARI gom 23). On the other hand, the variety BARI gom 27 (V_4) produced the shortest spike (13.61 cm) which was significantly different from other varieties but the other two varieties BARI gom 21(V_1) and BARI gom 23(V_2) were produced the intermediate level of spike length and they are statistically similar.



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 10 Effect of different varieties on spike length of wheat varieties ($LSD_{0.05}$= 0.72)

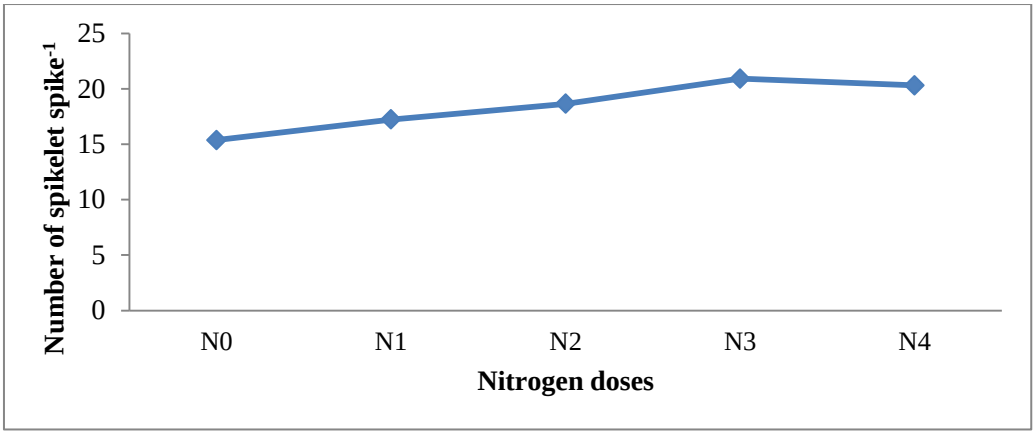
4.2.2.3 Interaction effect of nitrogen doses and variety

Spike length was significantly influenced by interaction of nitrogen doses and variety (Table 4). Results showed that the highest spike length (16.64 cm) was obtained from N_3V_3 which was statistically similar with N_0V_3, N_1V_3, N_2V_1, N_2V_2, N_2V_3, N_3V_1, N_3V_2, N_4V_1 and N_4V_2. On the other hand, the lowest spike length (12.80 cm) was observed from the combination N_0V_4 which was statistically similar with N_0V_1, N_1V_1 and N_1V_4.

4.2.3 Number of spikelets spike^{-1}

4.2.3.1 Effect of nitrogen doses

Significant variation was recorded on number of spikelets spike^{-1} in the case of different doses of nitrogen application in the field (Fig. 11). It was found from the figure that the maximum number of spikelets spike^{-1} (20.91) was achieved from N_3 (25% higher nitrogen than recommended dose) which was statistically similar with the treatment N_2 and N_4. On the other hand, the lowest number of spikelets spike^{-1} (15.37) was found in N_0 (control) which was statistically similar with the treatment N_1 and N_2.

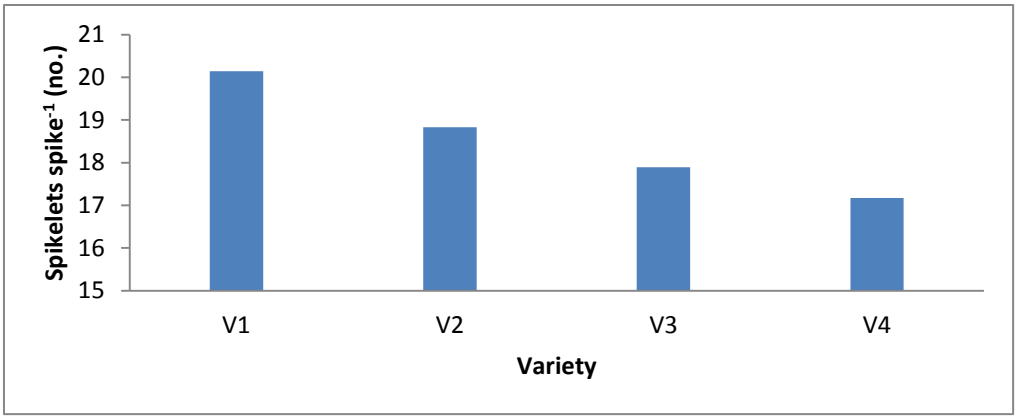


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig.11 Effect of different nitrogen doses on number of spikelets spike^{-1} of wheat varieties ($LSD_{0.05}$= 2.32)

4.2.3.2 Effect of variety

Number of spikelets spike^{-1} was significantly influenced by different varieties used in the present study (Figure 12). This figure showed that the highest number of spikelets spike^{-1} (20.15) was found in BARI gom 21 (V_1) which was statistically similar with BARI gom 23 (V_2). On the other hand, the lowest number of spikelets spike^{-1}(17.17) was found from BARI gom 27 (V_4) which was statistically similar with BARI gom 23 (V_2), BARI gom 24 (V_3) and BARI gom 27 (V_4).



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig.12 Effect of different varieties on number of spikelets spike^{-1} of wheat varieties ($LSD_{0.05}$= 1.20)

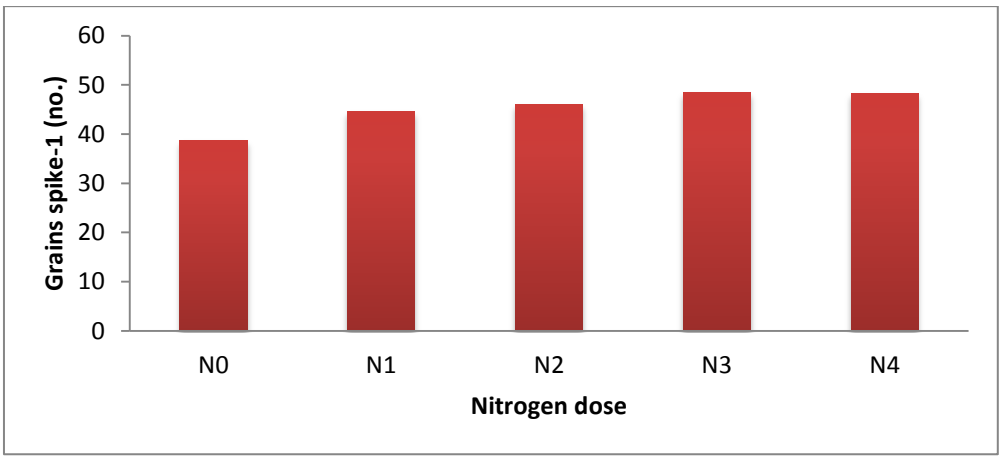
4.2.3.3 Interaction effect of nitrogen doses and variety

Number of spikelet spike^{-1} was significantly influenced by interactions of nitrogen doses and variety (Table 4). Result showed that the maximum number of spikelets spike^{-1} (22.63) was found from the combination N_3V_1 which was statistically similar with the combinations N_3V_2, N_4V_1 and N_4V_2. On the other hand, the lowest number of spikelets spike^{-1} (12.33) was recorded from the combination N_0V_4 which was significantly different from all other combinations.

4.2.4 Number of grains spike^{-1}

4.2.4.1 Effect of nitrogen doses

Number of grains spike^{-1} was significantly influenced by different doses of nitrogen application in the field (Figure 13). The figure showed that the increasing trend up to the increase of 25% higher nitrogen dose than recommended dose (N_3) which is statistically similar with N_4 followed by N_2. On the other hand the treatment N_0 showed lowest number of grains spike^{-1}.

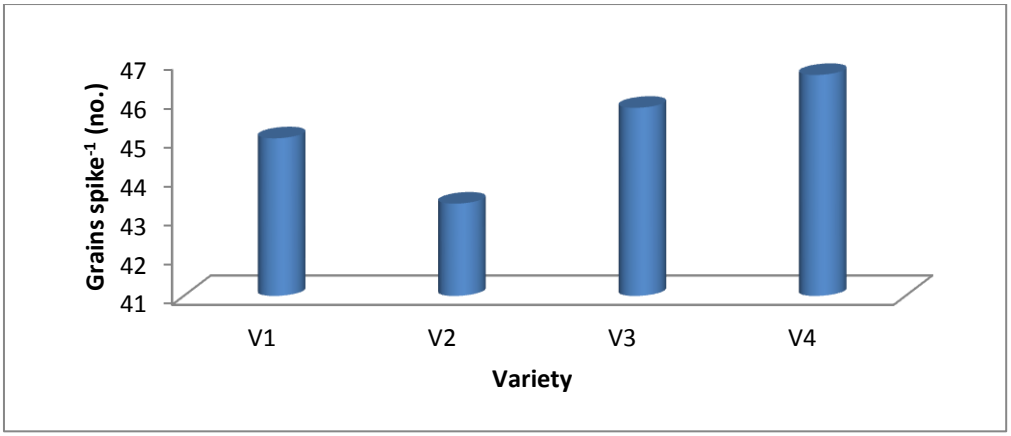


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig.13 Effect of different nitrogen doses on number of grains spike^{-1} of wheat varieties ($LSD_{0.05}$= 5.65)

4.2.4.2 Effect of variety

Number of grains spike^{-1} was non-significantly influenced by different varieties used in the study (Figure 14). In the figure it was found that the highest number of grains spike^{-1} (46.65) was found from the variety BARI gom 27 (V_4) but it was statistically similar with all other varieties.



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 14 Effect of different varieties on number of grains spike^{-1} of wheat varieties ($LSD_{0.05}$= 4.25)

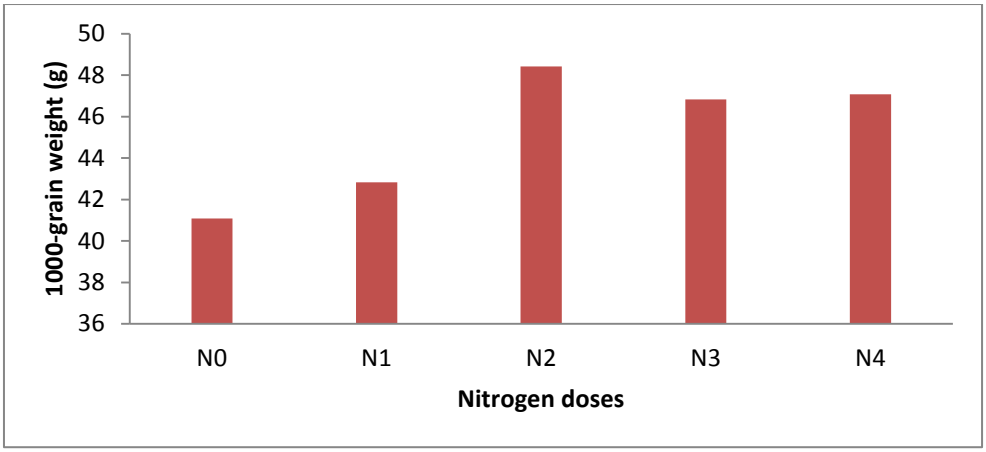
4.2.4.3 Interaction effect on nitrogen doses and variety

Number of grains spike^{-1} was significantly influenced by interactions of variety and nitrogen doses (Table 4). Results showed that the maximum number of grains spike^{-1} (50.60) was found from the combination N_3V_4 which was statistically similar with all the treatment combinations except control treatment combined with variety. On the other hand, the lowest number of grains spike^{-1} (35.90) was recorded from the combination N_0V_2.

4.2.5 Thousand (1000) - grain weight

4.2.5.1 Effect of nitrogen doses

Significant variation was recorded on 1000-grain weight (g) (Fig.15). It was found that the maximum weight of 1000 grain (48.51 g) was recorded from the treatment N_2 (recommended dose) which was statistically similar with N_3 (25% higher nitrogen than recommended dose) and N_4 (50% higher nitrogen than recommended dose). On the other hand, the minimum weight of 1000 grain (41.08 g) was recorded from the treatment N_0 (control) which was statistically similar with the treatment N_1 (25% lower nitrogen than recommended dose).

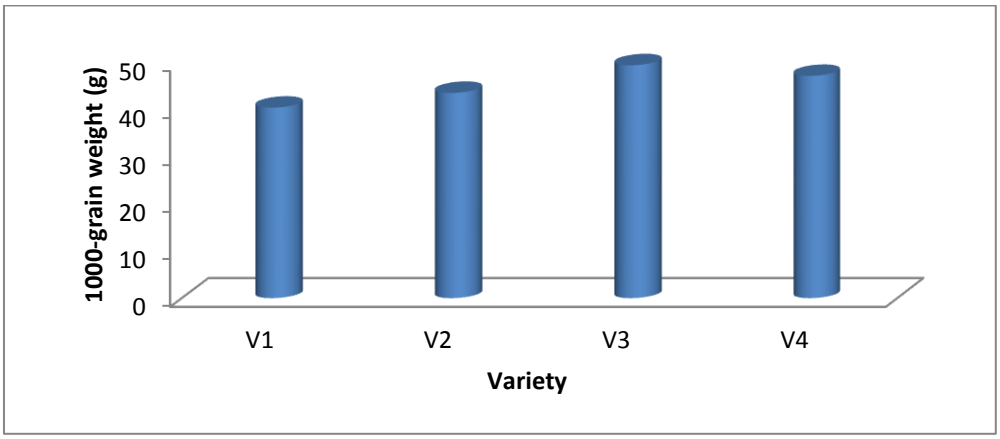


Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Fig.15 Effect of different nitrogen doses on weight of 1000 grain of wheat varieties ($LSD_{0.05}$= 5.27)

4.2.5.2 Effect of variety

1000-grain weight (g) was significantly influenced by different varieties (Fig. 16). Figure showed that the maximum weight of 1000 grain (49.53 g) was recorded from BARI gom 24 (V_3) which was statistically similar with BARI gom 23 (V_2) and BARI gom 27 (V_4). On the other hand, the minimum weight of 1000 grain was recorded from the variety BARI gom 21 (V_1) which was statistically similar with the variety BARI gom 23 (V_2).



Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Fig. 16 Effect of different varieties on weight of 1000 grains of wheat varieties ($LSD_{0.05}$ = 3.43)

4.2.5.3 Interaction effect of nitrogen doses and variety

1000-grain weight was significantly influenced by interactions of nitrogen doses and variety (Table 4). It was found that the maximum weight of 1000 grain was recorded from the treatment combination N_3V_3 and the minimum weight of 1000 grain was found from the treatment combination N_0V_1 which was statistically similar with N_1V_1 and N_1V_2 treatment combination.

Table 4. Interaction effect of nitrogen doses and variety on yield attributes of wheat

Wheat interaction	Spike m^{-2} (no.)	Spike length (cm)	Spikelets $spike^{-1}$ (no.)	Grains $spike^{-1}$ (no.)	1000-grain weight (g)
N_0V_1	116.3 j	13.49 ef	17.47 f-i	38.33 cd	34.3 g
N_0V_2	151.5 i	14.45 c-e	16.57 hi	35.93 d	42.00 d-f
N_0V_3	99.80 k	15.19 a-d	15.10 i	40.27 b-d	45.00 a-e
N_0V_4	119.3 j	12.80 f	12.33 j	40.47 b-d	43.00 a-e
N_1V_1	157.8 i	13.53 ef	18.50 d-h	44.67 a-d	36.30 fg
N_1V_2	171.5 f-h	14.53 b-e	17.17 g-i	43.00 a-d	38.70 e-g
N_1V_3	155.5 i	15.24 a-d	16.37 hi	45.11 a-d	49.00 a-d
N_1V_4	170.0 gh	12.82 f	16.90 g-i	45.40 a-d	47.3 a-d
N_2V_1	176.2 e-g	15.18 a-d	20.10 b-d	45.93 a-c	45.7 a-e
N_2V_2	216.9 a	15.13 a-d	18.70 c-h	45.00 a-d	47.00 a-e
N_2V_3	162.8 hi	15.70 a-c	18.30 d-h	46.42 a-c	50.6 a-c
N_2V_4	214.3 ab	14.04 d-f	17.50 e-i	47.00 a-c	50.30 a-d
N_3V_1	180.0 e-g	15.33 a-d	22.63 a	47.93 a-c	43.30 b-f
N_3V_2	209.0 ab	15.37 a-d	21.20 a-c	47.00 a-c	45.70 a-e
N_3V_3	178.5 e-g	16.64 a	20.00 b-e	48.53 ab	51.70 a
N_3V_4	204.9 bc	13.83 d-f	19.80 b-f	50.60 a	46.70 a-e
N_4V_1	184.0 de	16.03 ab	22.03 ab	48.27 ab	43.00 c-f
N_4V_2	216.7 a	15.61 a-c	20.50 a-d	45.87 a-c	45.00 a-e
N_4V_3	182.0 ef	16.26 a	19.37 c-g	48.73 ab	51.30 ab
N_4V_4	195.2 cd	14.56 b-e	19.30 c-g	49.80 ab	49.00 a-d
LSD(0.05)	**11.72**	**1.55**	**3.28**	**9.88**	**8.46**
CV(%)	**4.21**	**6.50**	**8.01**	**12.61**	**10.15**

In a column means having simila letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.3 Yields

4.3.1 Grain yield (t ha^{-1})

4.3.1.1 Effect of nitrogen doses

Grain yield showed significant differences for application of different doses of nitrogen on wheat (Table 5). The result revealed that grain yield of wheat with the increased with nitrogen doses up to 25% higher than recommended nitrogen dose after that grain yield reduced significantly. As such, the highest grain yield (3.41 t ha^{-1}) was found from N_3 treatment (25% higher nitrogen dose than recommended) which was statistically similar with the treatment N_2 (recommended dose of nitrogen), while the lowest (1.66 t ha^{-1}) yield was obtained from N_0 (No nitrogen) which was significantly different from all other treatment. The result corroborates with findings of Iqbal *et al.* (2012) who observed higher yield with higher nitrogen doses.

4.3.1.2 Effect of variety

Significant variation was recorded on grain yield due to varieties of wheat (Table 6). Results showed that the maximum grain yield (3.02t ha^{-1}) was observed from BARI gom 24 (V_3) which was statistically similar with BARI gom 27 (V_4). On the other hand, the minimum grain yield (2.46 t ha^{-1}) was found from the variety BARI gom 23 (V_2) which was significantly different from all other varieties. This result was supported by Jalleta (2004), Alam and Rahman (2008) in that different varieties showed differences of grain yield.

4.3.1.3 Interaction effect of nitrogen doses and variety

Grain yield (t ha^{-1}) was significantly influenced by interactions of nitrogen doses and variety (Table 7). It was found that the maximum grain yield (3.76t ha^{-1}) was recorded from the treatment combination N_3V_3 which was statistically similar with the treatment combinations N_2V_3 and N_2V_4 and the minimum grain yield (1.29t ha^{-1}) was found from the treatment combination N_0V_2 which was significantly different from all other treatment combinations.

Table 5. Effect of nitrogen doses on yield and harvest index of wheat

Nitrogen doses	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0	1.66 d	2.38 d	4.04 d	40.82 d
N_1	2.57 c	3.14 c	5.71 c	44.96 c
N_2	3.29 a	3.80 a	7.09 a	46.38 bc
N_3	3.41 a	3.58 ab	6.98 a	48.77 a
N_4	2.93 b	3.34 bc	6.27 b	46.60 b
LSD (0.05)	**0.25**	**0.24**	**0.47**	**1.49**
CV (%)	**5.72**	**4.48**	**6.74**	**2.02**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Table 6. Effect of variety on yield and harvest index of wheat

Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	2.71 b	3.33 a	6.04 a	44.32 b
V_2	2.46 c	3.08 b	5.54 b	43.77 b
V_3	3.02 a	3.30 a	6.32 a	47.47 a
V_4	2.89 ab	3.29 a	6.17 a	46.47 a
LSD (0.05)	**0.22**	**0.19**	**0.39**	**1.79**
CV (%)	**6.03**	**4.45**	**5.04**	**3.06**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Table 7. Interaction effect of treatment and variety on yield and harvest index of wheat

Nitrogen doses ×Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0V_1	1.68 k	2.57 i	4.25 g	39.15 j
N_0V_2	1.29 l	2.25 j	3.54 h	36.43 k
N_0V_3	1.84 k	2.34 ij	4.18 g	44.05 g-i
N_0V_4	1.83 k	2.36 ij	4.19 g	43.66 hi
N_1V_1	2.50 ij	3.17 h	5.67 f	44.09 g-i
N_1V_2	2.32 j	3.08 h	5.40 f	42.99 i
N_1V_3	2.75 g-i	3.13 h	5.88 ef	46.77 b-f
N_1V_4	2.70 hi	3.17 h	5.87 ef	45.99 e-g
N_2V_1	3.25 c-f	3.92 ab	7.17 bc	45.35 e-h
N_2V_2	2.84 gh	3.70 b-d	6.54 d	43.43 hi
N_2V_3	3.60 ab	3.72 b-d	7.32 ab	49.21 a
N_2V_4	3.49 a-c	3.86 a-c	7.35 ab	47.51 a-e
N_3V_1	3.28 c-e	3.49 d-f	6.77 cd	48.32 a-d
N_3V_2	3.14 ef	3.19 gh	6.33 de	49.66 a
N_3V_3	3.76 a	4.01 a	7.77 a	48.43 a-d
N_3V_4	3.43 b-d	3.62 c-e	7.05 bc	48.67 a-c
N_4V_1	2.83 gh	3.51 d-f	6.34 de	44.66 f-i
N_4V_2	2.73 g-i	3.16 h	5.89 ef	46.34 d-g
N_4V_3	3.16 d-f	3.30 f-h	6.46 d	48.89 ab
N_4V_4	2.98 fg	3.42 e-g	6.40 d	46.51 c-f
LSD(0.05)	**0.28**	**0.24**	**0.51**	**2.32**
CV(%)	**6.03**	**4.45**	**5.04**	**3.06**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.3.2 Straw yield (t ha^{-1})

4.3.2.1 Effect of nitrogen doses

Significant variation was recorded on straw yield (t ha^{-1}) for different doses of nitrogen application in the field (Table 5). It was found that the maximum straw yield (3.80 t ha^{-1}) was recorded from the treatment N_2 (recommended dose) which was statistically similar with N_3 (25% higher nitrogen than recommended dose). On the other hand, the minimum straw yield (2.38 t ha^{-1}) was recorded from the treatment N_0 (control) which was significantly different from all other treatments.

4.3.2.2 Effect of variety

Straw yield (t ha^{-1}) was significantly influenced by different varieties used in the present study (Table 6). Results showed that the maximum straw yield (3.33 t ha^{-1}) was recorded from BARI gom 21 (V_1) which was statistically similar with varieties BARI gom 24 (V_3) and BARI gom 27 (V_4). On the other hand, the minimum straw yield was recorded from BARI gom 23 (V_2) which was significantly different from all other variety.

4.3.2.3 Interaction effect of nitrogen doses and variety

Straw yield (t ha^{-1}) was significantly influenced by the interactions of variety and nitrogen doses (Table 7). It was found that the maximum straw yield (4.01t ha^{-1}) was recorded from the treatment combination N_3V_3 which was statistically similar with N_2V_1 and N_2V_4. While the minimum straw yield (2.25t ha^{-1}) was found from the treatment combination N_0V_2 which was statistically similar with N_0V_3 and N_0V_4 treatment combinations.

4.3.3 Biological yield (t ha^{-1})

4.3.3.1 Effect of nitrogen doses

Significant variation was recorded on biological yield (t ha^{-1}) due to different doses of nitrogen application in the field (Table 5). It was found that the maximum biological yield (7.09 t ha^{-1}) was recorded from the treatment N_2 which was statistically similar with N_3 followed by N_4. On the other hand, the minimum biological yield (4.04 t ha^{-1}) was recorded from the treatment N_0 (control) which was significantly different from all other treatments.

4.3.3.2 Effect of variety

Biological yield (t ha^{-1}) was significantly influenced by different varieties used in the present study (Table 6). Results showed that the maximum biological yield (6.32 t ha^{-1}) was recorded from the variety BARI gom 24 (V_3) which was statistically similar with varieties BARI gom 21 (V_1) and BARI gom 27 (V_4). On the other hand, the minimum biological yield (5.54 t ha^{-1}) was recorded from the variety BARI gom 23 (V_2) which was significantly different from all other variety.

4.3.3.3 Interaction effect of nitrogen doses and variety

Biological yield (t ha^{-1}) was significantly influenced by interaction of varieties and nitrogen doses (Table 7). It was found that the maximum biological yield (7.77t ha^{-1}) was

recorded from the treatment combination N_3V_3 which was statistically similar with N_2V_3 and N_2V_4 and the minimum biological yield (3.54 t ha^{-1}) was found from the treatment combination N_0V_2 which was significantly different from all other variety.

4.3.4 Harvest Index (%)

4.3.4.1 Effect of nitrogen doses

Significant variation was recorded on harvest index (%) for different doses of nitrogen application in the field (Table 5). It was found that the maximum harvest index (48.77 %) was recorded from the treatment N_3 which was significantly different from all other treatments. On the other hand, the minimum harvest index (40.82 %) was recorded from the treatment N_0 (control) which was significantly different from all other treatments.

4.3.4.2 Effect of variety

Harvest index (%) was significantly influenced by different varieties used in the present study (Table 6). It was found that the highest harvest index (47.47%) was recorded from BARI gom 24 (V_3) which was statistically similar with varieties BARI gom 27 (V_4). On the other hand, the minimum harvest index (43.77 %) was recorded from BARI gom 23 (V_2) which was statistically similar with the variety BARI gom 21 (V_1).

4.3.4.3 Interaction effect on nitrogen doses and variety

Harvest index (%) was significantly influenced by the interaction of varieties and nitrogen doses (Table 7). Results showed that the maximum harvest index (49.66%) was found from the combination N_3V_2 which was statistically similar with the treatment combinations N_3V_1, N_3V_3, N_3V_4 and N_4V_3. On the other hand, the minimum harvest index (36.43%) was recorded from the combination N_0V_2 which was significantly different from all other treatment combinations.

4.4 Seed quality characters

4.4.1 Germination percentage (%)

4.4.1.1 Effect of nitrogen doses

Germination percentage was significantly differences in application of different nitrogen doses (Table 8). Results recorded that the highest speed of germination (10.34) was found from the treatment N_2 (recommended dose) which was statistically similar with N_3 (25% higher nitrogen than recommended dose). On other side, the lowest speed of germination

(8.48) was found from the treatment N_0 (control) which was significantly different from all other treatments.

4.4.1.2 Effect of variety

Germination percentage (%) was significantly influenced by different varieties used in the present study (Table 9). Results revealed that the highest germination percentage (95.20%) was recorded from BARI gom 27 (V_4) which was significantly different from all other treatments. On the other hand, the lowest germination percentage (86.80 %) was found from BARI gom 23 (V_2) which was significantly different from all other treatments.

4.4.1.3 Interaction effect on nitrogen doses and variety

Germination percentage (%) was significantly influenced by the interaction of varieties and nitrogen doses (Table 10). Results showed that the maximum germination percentage (98.67%) was found from the combination N_2V_4 which was statistically similar with the treatment combinations N_1V_4, N_2V_1, N_2V_2, N_2V_3, N_3V_1, N_3V_3, N_3V4, N_4V_3 and N_4V_4. On the other hand, the minimum germination percentage (72.00 %) was recorded from the combination N_0V_2 which was significantly different from all other treatment combinations.

Table 8. Effect of nitrogen doses on seed and seedling quality of wheat

Nitrogen doses	Germination (%)	Seed vigor test		Seedling vigor		
		Vigor index	Electrical conductivity (mS/cm)	Shoot length (cm)	Root length (cm)	Dry weight/seedling (g)
N_0	81.00 c	8.48 c	211.52 a	17.44 b	18.12 a	0.14 c
N_1	90.50 b	9.54 b	200.65 b	18.82 a	18.71 a	0.16 b
N_2	96.67 a	10.34 a	182.44 c	19.94 a	18.28 a	0.19 a
N_3	94.67 ab	10.32 a	183.59 c	19.40 a	18.48 a	0.18 a
N_4	93.50 ab	9.56 b	194.60 b	19.32 a	18.39 a	0.15 b
LSD (0.05)	**4.99**	**0.59**	**7.12**	**1.26**	**0.92**	**7.08**
CV (%)	**5.81**	**6.53**	**3.89**	**7.04**	**5.33**	**4.56**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

Table 9. Effect of variety on seed and seedling quality of wheat

Variety	Germination	Seed vigor test		Seedling vigor		
		Vigor index	Electrical conductivity	Shoot length	Root length (cm)	Dry weight/ seedling
	(%)		(mS/cm)	(cm)		(g)
V_1	90.67 b	10.11 ab	187.36 c	19.13 b	17.52 c	0.18 b
V_2	86.80 c	8.53 c	214.50 a	17.79 c	18.64 b	0.14 d
V_3	92.40 b	9.44 b	199.12 b	18.51 bc	19.48 a	0.16 c
V_4	95.20 a	10.52 a	177.26 d	20.51 a	17.94 bc	0.18 a
LSD (0.05)	**2.64**	**0.77**	**5.84**	**0.81**	**0.72**	**4.64**
CV (%)	**3.88**	**10.60**	**4.03**	**5.72**	**5.22**	**3.78**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21, V_2= BARI gom 23, V_3= BARI gom 24 and V_4= BARI gom 27

Table 10. Interaction effect of nitrogen doses and variety on seed and seedling quality of wheat

Nitrogen doses ×Variety	Germination	Seed vigor test		Seedling vigor		
		Vigor index	Electrical conductivity	Shoot length	Root length	Dry weight/ seedling
	(%)		(mS/cm)	(cm)	(cm)	(g)
N_0V_1	83.00 f	9.22 b-d	213.28 b	17.50 f-h	16.41 e	0.14 h
N_0V_2	72.00 g	7.25 e	219.30 b	15.92 h	18.82 a-d	0.11 j
N_0V_3	84.00 f	8.11 de	214.15 b	16.83 gh	19.00 a-c	0.13 i
N_0V_4	85.00 ef	9.33 b-d	199.35 c	19.53 b-d	18.25 a-d	0.18 c-e
N_1V_1	88.00 d-f	9.98 ab	222.80 b	19.32 b-e	18.58 a-d	0.17 d-f
N_1V_2	86.00 ef	8.26 c-e	222.50 b	17.60 e-h	18.85 a-d	0.13 ij
N_1V_3	90.00 c-e	9.41 b-d	196.20 c	18.15 d-g	19.86 a	0.15 g
N_1V_4	98.00 a	10.51 ab	161.10 gh	20.21 a-c	17.54 c-e	0.18 c-e
N_2V_1	96.00 ab	10.44 ab	175.55 ef	20.12 a-c	17.48 c-e	0.21 a
N_2V_2	94.00 a-c	9.41 b-d	189.25 cd	19.04 c-f	18.31 a-d	0.17 d-f
N_2V_3	98.00 a	10.41 ab	199.40 c	19.65 a-d	19.75 a	0.18 c
N_2V_4	98.67 a	11.13 a	165.55 fg	20.95 ab	17.60 c-e	0.18 cd
N_3V_1	94.33 a-c	10.52 ab	176.10 d-f	19.22 b-f	17.29 de	0.19 c
N_3V_2	92.00 b-d	9.92 a-c	195.80 c	18.91 c-f	18.69 a-d	0.17 f
N_3V_3	94.00 a-c	10.10 ab	190.95 c	19.00 c-f	19.48 ab	0.18 c-e
N_3V_4	98.33 a	10.75 ab	171.50 fg	20.48 a-c	18.45 a-d	0.19 b
N_4V_1	92.00 b-d	10.39 ab	149.05 h	19.49 b-d	17.82 b-e	0.16 f
N_4V_2	90.00 c-e	7.79 de	245.65 a	17.52 e-h	18.54 a-d	0.13 hi
N_4V_3	96.00 ab	9.18 b-d	194.90 c	18.90 c-f	19.31 ab	0.15 g
N_4V_4	96.00 ab	10.88 ab	188.80 c-e	21.38 a	17.88 b-e	0.17 ef
LSD(0.05)	**7.13**	**1.59**	**13.35**	**2.01**	**1.66**	**0.01**
CV(%)	**3.88**	**10.60**	**4.03**	**5.72**	**5.22**	**3.78**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance

Here: V_1= BARI gom 21 (Shatabdi), V_2= BARI gom 23(Bijoy), V_3= BARI gom 24 (Prodip) and V_4= BARI gom 27 (Francolin); N_0= Control (No Nitrogen), N_1= 25% lower nitrogen than recommended dose, N_2 = Recommended dose, N_3 = 25% higher nitrogen than recommended dose, and N_4 = 50% higher nitrogen than recommended dose.

4.4.2 Seed vigor test

4.4.2.1 Vigor index

4.4.2.1.1 Effect of nitrogen doses

Vigor index was significantly differences in case of application of different nitrogen doses (Table 8). It was found that the maximum vigor (10.34) was recorded from recommended dose (N_2) which was statistically similar with25% higher nitrogen than recommended dose (N_3). On the other hand, the minimum vigor (8.48) was found from no nitrogen (N_0) which was significantly different from all other treatment.

4.4.2.1.2 Effect of variety

Vigor index was significantly influenced by different varieties used in the present study (Table 9). It was found that the maximum vigor (10.52) was recorded from the variety BARI gom 27 (V_4) which was statistically similar with BARI gom 21(V_1). On the other hand, the minimum vigor (8.53) was found from BARI gom 23 (V_2) which was significantly different from all other variety.

4.4.2.1.3 Interaction effect on nitrogen doses and variety

Vigor index was significantly influenced by interaction of variety and nitrogen doses (Table 10). Results showed that the maximum vigor (11.13) was found from the combination N_2V_4 while the minimum vigor was recorded from the combination N_0V_2 which was statistically similar with N_0V_3, N_1V_2 and N_4V_2.

4.4.2.2 Electrical conductivity (EC) (mS/cm)

4.4.2.2.1 Effect of nitrogen doses

Electrical conductivity was significantly affected by the application of different nitrogen doses (Table 8). Results recorded that the maximum electrical conductivity (211.52 mS/cm) was found from the treatment N_0 (control) which was significantly different from all other treatments. On other side, the minimum EC (182.44 mS/cm) was found from the treatment N_2 which was statistically similar with the treatment N_3.

4.4.2.2.2 Effect of variety

Electrical conductivity was significantly influenced by different varieties used in the present study (Table 9). It was found that the maximum electrical conductivity (214.50 mS/cm) was recorded from the variety BARI gom 23 (V_2) which was significantly different from all other variety. On the other hand, the minimum EC (177.26mS/cm) was found from BARI gom 27 (V_4) which was significantly different from all other variety.

4.4.2.2.3 Interaction effect on nitrogen doses and variety

Significant variation was recorded from different combination of nitrogen doses and variety in this study (Table 10). It was found that the maximum electrical conductivity (245.65 mS/cm) was found from the combination N_4V_2 while the minimum electrical conductivity (149.05 mS/cm) was recorded from the combination N_4V_1 which was statistically similar with N_1V_4.

4.4.3 Seedling vigor

4.4.3.1 Shoot length (cm)

4.4.3.1.1 Effect of nitrogen doses

Shoot length was significantly differences in the case of application of different nitrogen doses (Table 8). Results recorded that the longest shoot (19.94 cm) was found from the treatment N_2 (recommended dose) which was statistically similar with N_1, N_3 and N_4 treatment. On other side, the shortest shoot (17.44 cm) was found from the treatment N_0 which was significantly different from all other treatments.

4.4.3.1.2 Effect of variety

Seedling length was significantly influenced by different varieties used in the present study (Table 9). It was found that the longest shoot (20.51cm) was recorded from the variety BARI gom 27 (V_4) which was significantly different from all other variety. On the other hand, the shortest shoot (17.79 cm) was found from BARI gom 23 (V_2) which was statistically similar with BARI gom 24 (V_3).

4.4.3.1.3 Combination effect of nitrogen doses and variety

Significant variation in shoot length was recorded from different combination of nitrogen doses and variety in this study (Table 10). It was found that the longest shoot was found

from the combination N_4V_4 while the shortest shoot (15.92 cm) was recorded from the combination N_0V_2 which was statistically similar with N_0V_1, N_0V_3, N_1V_2 and N_4V_2.

4.4.3.2 Root length

4.4.3.2.1 Effect of nitrogen doses

Root length (cm) was non-significant in the case of application of different nitrogen doses in field (Table 8). Numerically, the longest root (18.71 cm) was found from the treatment N_1 (25% lower nitrogen than recommended dose) which was statistically similar with N_0, N_2, N_3 and N_4 treatment.

4.4.3.2.2 Effect of variety

Root length was significantly influenced by different varieties used in the present study (Table 9). It was found that the longest root (19.48cm) was recorded from the variety BARI gom 24 (V_3) which was significantly different from all other variety. On the other hand, the shortest root (17.52 cm) was found from BARI gom 21 (V_1) which was statistically similar with BARI gom 27 (V_4).

4.4.3.2.3 Combination effect of nitrogen doses and variety

Significant variation of root length was recorded from different combination of nitrogen doses and variety in this study (Table 10). It was found that the longest root (19.86 cm) was found from the combination N_1V_3 while the shortest root (16.41 cm) was recorded from the combination N_0V_1.

4.4.3.3 Dry weight/ seedling (g)

4.4.3.3.1 Effect of nitrogen doses

Significant variation was observed on dry weight /seedling (g) in the case of different doses of nitrogen application (Table 8). It was recorded that maximum dry weight per seedling (0.19 g) was found from N_2 (recommended dose) treatment which was significantly similar with the treatments N_3. On the other hand, the minimum dry weight (0.14 g) was found from the treatment N_0 (control) which was significantly different from all other treatments.

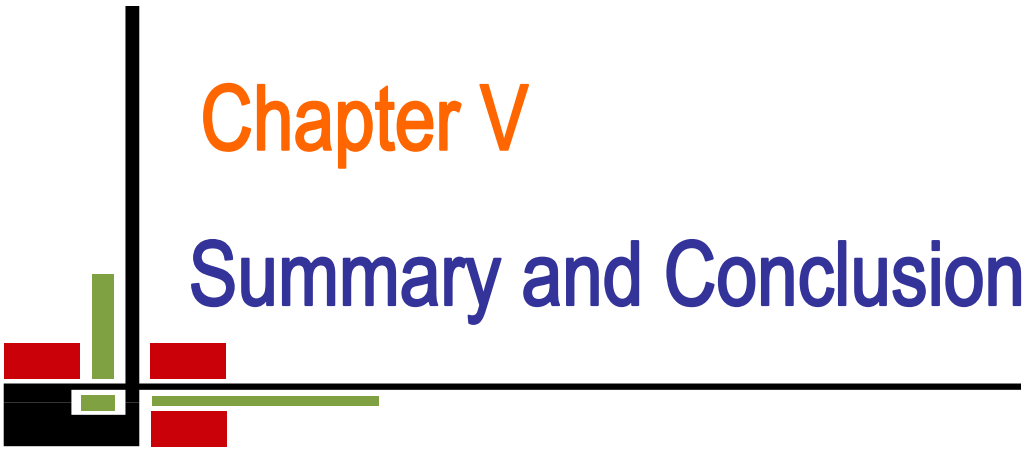
4.4.3.3.2 Effect of variety

Dry weight/ seedling (g) was significantly influenced by different varieties used in the present study (Table 9). Result showed that the highest dry weight/ seedling (0.18 g) was

found in BARI gom 27 (V_4) and BARI gom 21 (V_1) which was significantly different from all other varieties. On the other hand, the lowest dry weight seedling-1(0.14 g) was found from BARI gom 23 (V_3) which was was significantly different from all other varieties under study.

4.4.3.3.3 Combination effect of nitrogen doses and variety

Dry weight/ seedling were significantly influenced by the interaction of nitrogen doses and varieties (Table 10). Results showed that the maximum dry weight /seedling (0.21g) was found from the combination N_2V_1 which was significantly different from all other treatment combinations. On the other hand, the minimum dry weight /seedling (0.11 g) was recorded from the combination N_0V_2 which was statistically similar with the treatment combination N_1V_2.



Chapter V

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was carried out at the Research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2014 to March 2015 to evaluate the effect of different level of nitrogen on growth, yield and seed quality of wheat. The experiment comprised of five nitrogen levels viz. (i) N_0= Control (No nitrogen), (ii) N_1= 25% less Nitrogen from the recommended dose, (iii) N_2= Recommended dose for Wheat cultivation, (iv) N_3= 25% higher Nitrogen, (v) N_4= 50% higher Nitrogen and four improved wheat varieties viz. (i) V_1= BARI gom 21, (ii) V_2= BARI gom 23 (iii) V_3 = BARI gom 24 and (iv) V_4 = BARI gom 27. The experiment was laid out in a split-plot design with three replications. The data were collected on plant height (cm), tillers m^{-2}, dry weight $plant^{-1}$, spike m^{-2}, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, 1000-grain weight, grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield(t ha^{-1}) and harvest index(%).

Collected data were compiled and analyzed by split plot design to find out the statistical significance of experimental results. The means for all recorded data were calculated and analyses of variance for all characters were performed. The mean separations among the treatments were tested with the least significant differences (LSD) test at 5% level of significance.

Different nitrogen doses showed significant variations on all growth stages, yield and yield contributing characters. Different wheat varieties also showed same effect on different plant characters. Interaction effect of nitrogen doses and variety also showed the significant variation on growth and yield parameters.

With the application of different doses of nitrogen, the tallest plant (93.19 cm) was obtained by the nitrogen dose N_2 where N_0 showed the lowest plant (84.87 cm) at harvest. N_2 gave the highest number of tillers m^{-2} (212.8) at harvest where the lowest number of tillers m^{-2} (136.8) at harvest was found in N_0. The maximum dry weight $plant^{-1}$ (7.75 g) was found with N_3 at harvest while, the minimum dry weight $plant^{-1}$ (3.24 g0 at harvest was found in N_0. Results showed that the maximum spikes m^{-2} (194.46) was found with N_4 and minimum number of spikes m^{-2} (121.7) was found from N_0. The highest spike length (15.61 cm) was found from N_4 (50% higher nitrogen than recommended dose) treatment while the lowest spike length (13.98 cm) was found from the treatment N_0. The maximum number of spikelets $spike^{-1}$ (20.91) was achieved from

N_3 and the lowest number of spikelets spike^{-1} (15.37) was found in N_0. The highest number of grains spike^{-}1 (48.51) was recorded from the treatment N_3 where the lowest number of grains spike^{-1} (38.75) was recorded from the treatment N_0. The maximum weight of 1000 grain (48.51 g) was recorded from the treatment N_2 where the minimum weight of 1000 grain (41.08 g) was recorded from the treatment N_0. The higher grain yield (3.41 t ha^{-1}) was found from N_3 treatment (25% higher nitrogen dose than recommended), while the lower (1.66 t ha^{-1}) from N_0 (No nitrogen). The maximum harvest index (48.77 %) was recorded from the treatment N_3 and the minimum harvest index (40.82 %) was recorded from the treatment N_0. The highest germination (96.67%) was recorded from N_2 and lowest germination (81.00%) was from N_0. The maximum vigor (10.34) was found from N_2 while the minimum vigor (8.48) was found from N_0. The treatment N_0 gave the highest (211.52 mS/cm) electrical conductivity and the lowest (182.44 mS/cm) one was found from N_2. The longer shoot length (19.94 cm) was recorded from N_2 and lowest (17.44) from N_0 but the root length was non- significant. The treatment N_2 gave maximum dry weight seedling $^{-1}$ (0.19 g) and the minimum dry weight seedling^{-1} (0.14g) from N_0.

Regarding the varieties, the variety V_1 produced the tallest plant height 93.79 cm whereas the variety V_4 produced the dwarf plant stature (86.03 cm) at harvest. The maximum number of tillers m^{-2} (208.2) was produced from the variety V_4 at harvest while the variety V_3 produced the minimum number of tillers per m^{-2} (165.8) at harvest. The maximum dry weight plant^{-1} (6.29 g) was found with V_4 at harvest whereas the variety V_3 produced the minimum dry weight plant^{-1} at harvest as 4.85 g. The maximum number of plants m^{-2} was recorded from the variety V_4 while the minimum number of spikes m^{-2} (155.73) was found from the variety V_3. The variety V_3 produced the longest spike (15.81 cm) and the variety V_4 produced the shortest spike length (13.61 cm). The highest number of spikelets spike^{-1} (20.15) was found in V_1 and the lowest spikelets spike^{-1}(17.17) was found from V_4. Number of grains spike^{-1} was non-significant and the highest number of grains spike^{-1} (46.65) was found from the variety V_4. The maximum grain yield (2.98t ha^{-1}) was observed from the variety V_3 where the minimum grain yield (2.24 t ha^{-1}) was found from the variety V_2. The highest harvest index (47.44 %) was recorded from the variety V_3 and the minimum harvest index (43.68 %) was recorded from the variety V_2. The highest germination (95.20%) was recorded from V_4 and lowest germination (86.80%) was from V_2. The maximum vigor (10.52) was found from V_4

while the minimum vigor (8.53) was found from V_2. The treatment V_2 gave the highest (214.50 mS/cm) electrical conductivity and the lowest one (177.26 mS/cm)) was found from V_4. The longer shoot length (20.51 cm) was recorded from V_4 and lowest (17.79 cm) from V_2 but the root length was non- significant. V_1 and V_4 gave maximum dry weight seedling $^{-1}$ (0.18 g) and the minimum dry weight seedling^{-1} (0.14g) from V_2.

In combination with nitrogen doses and variety, N_2V_2 gave the tallest plant at 30 and 50 DAS (29.57 and 58.80 cm respectively) but N_2V_3 gave tallest plant at 70 DAS (94.27 cm) and also at 90 DAS and at harvest tallest plant height obtained from N_2V_1 (97.73 and 95.67 cm, respectively) and the shortest plant stature (23.45, 37.40, 72.53 81.33 and 81.07 cm, respectively) was obtained from N_0V_4 treatment combination at 30, 50, 70, 90 DAS and at harvest. N_2V_4 gave the maximum number of tillers per m2 at 30 DAS (84.67), N_3V_4 gave maximum number of tillers at 50 DAS and N4 treatment with V4 variety gave maximum number of tillers (304.7) at 70, 90 DAS and at harvest (287.3, 326.7 and 243.0 respectively) where the minimum number of tillers per m^2 at 30, 50, 70, 90 DAS and at harvest was observed as 42.00, 155.3, 143.7, 156.3 and 105.7, respectively when V_3 fertilized with N_0 (no nitrogen). N_3V_4 treatment produced the highest dry weight plant^{-1} at 30 DAS, N_4V_1 at 50 and 70 DAS (1.51 and 3.58 g) and N_4V_4 at 90 DAS and at harvest (7.40 and 8.61 g respectively) and the lowest dry weight plant^{-1} (0.04 g at 30 DAS), from N_1V_2, (0.55, 1.36 and 2.55 g at 50, 70, and 90 DAS) from N_0V_3 and 2.89 g at harvest from N_0V_2 was found. BARI gom 23 (V2) fertilized with recommended dose of nitrogen (N2) gave the maximum number of plants m^{-2} (216.9) where the minimum number of plants m^{-2} (99.83) was found from the combination N_0V_3. The highest spike length (16.64 cm) was obtained from N_3V_3 while the lowest spike length (12.80 cm). The maximum number of spikelets spike^{-1} (22.63) was found from the combination N_3V_1 while the lowest number of spikelets spike^{-1} (12.33) was recorded from the combination N_0V_4. N3V4 combination produced the maximum number of grains spike^{-1} (50.60) was found from the combination while the lowest number of grains spike^{-1} (35.90) was recorded from the combination N_0V_2. 25% higher nitrogen than recommended dose with BARI gom 24 (V3) produced the maximum weight of 1000 grain and the minimum weight of 1000 grain was found from the treatment combination N_0 (no nitrogen) and BARI gom 21 (V_1). The maximum grain yield (3.76 t ha-1) was recorded from the treatment combination N_3V_3 and the minimum grain yield (1.29 t ha-1) was found from the treatment combination N_0V_2. In treatment

combination, the maximum harvest index (49.66%) was found from the combination N_3V_2 and the minimum harvest index (36.43 %) was recorded from the combination N_0V_2. The highest germination percentage (98.67%) was found from N_2V_4 treatment combination and the lowest was found from N_0V_2 combination. The combination N_2V_4 gave the maximum vigor (11.13) while the minimum was given by the treatment combination N_0V_2. The maximum electrical conductivity (245.65 mS/cm) was recorded from the treatment combination N_4V_2 and the minimum from N_4V_1 (149.05 mS/cm). In case of seedling vigor test the longer shoot (21.38 cm) was found from the treatment combination N_4V_4 which was statistically similar with N_1V_4, N_2V_1, N_2V_3 and N_2V_4while the shortest one from N_0V_2 combination. The maximum dry matter weight seedling^{-1} (0.21g) was recorded from N_2V_1 treatment combination but the minimum dry matter weight seedling^{-1} was from N_0V_2 combination.

From the above result it was revealed that N_2 (recommended dose) and N_3 (25% higher nitrogen than recommended dose) gave similar and highest grain yield and higher quality seed. Among the varieties V_3 (BARI gom 24) and V_4 (BARI gom 27) gave similar and higher yield but V_4 (BARI gom 27) gave the higher quality seed. Regarding the interaction N_2V_3 (recommended dose of nitrogen with BARI gom 24), N_2V_4 (recommended dose of nitrogen with BARI gom 27) and N_3V_4 (25% higher nitrogen than recommended dose with BARI gom 27) seems to be promising in respect of seed yield and seed quality.

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

- This was a single year experiment and conducted only in one AEZ (AEZ-28). So for wider adaptability of the result, experiment of similar nature could be carried out in different Agro-Ecological Zones (AEZ) of Bangladesh.

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Appendices

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh

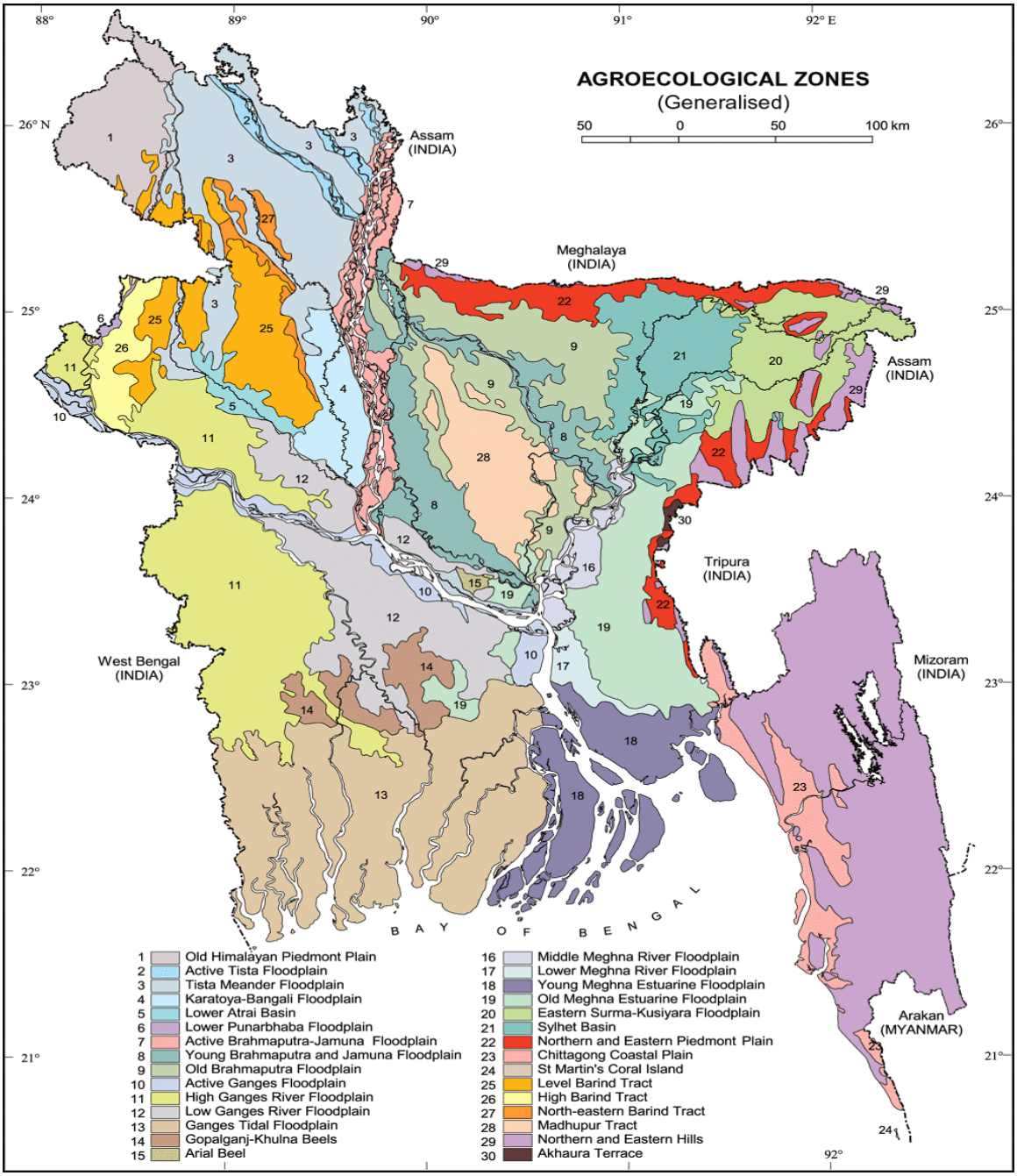
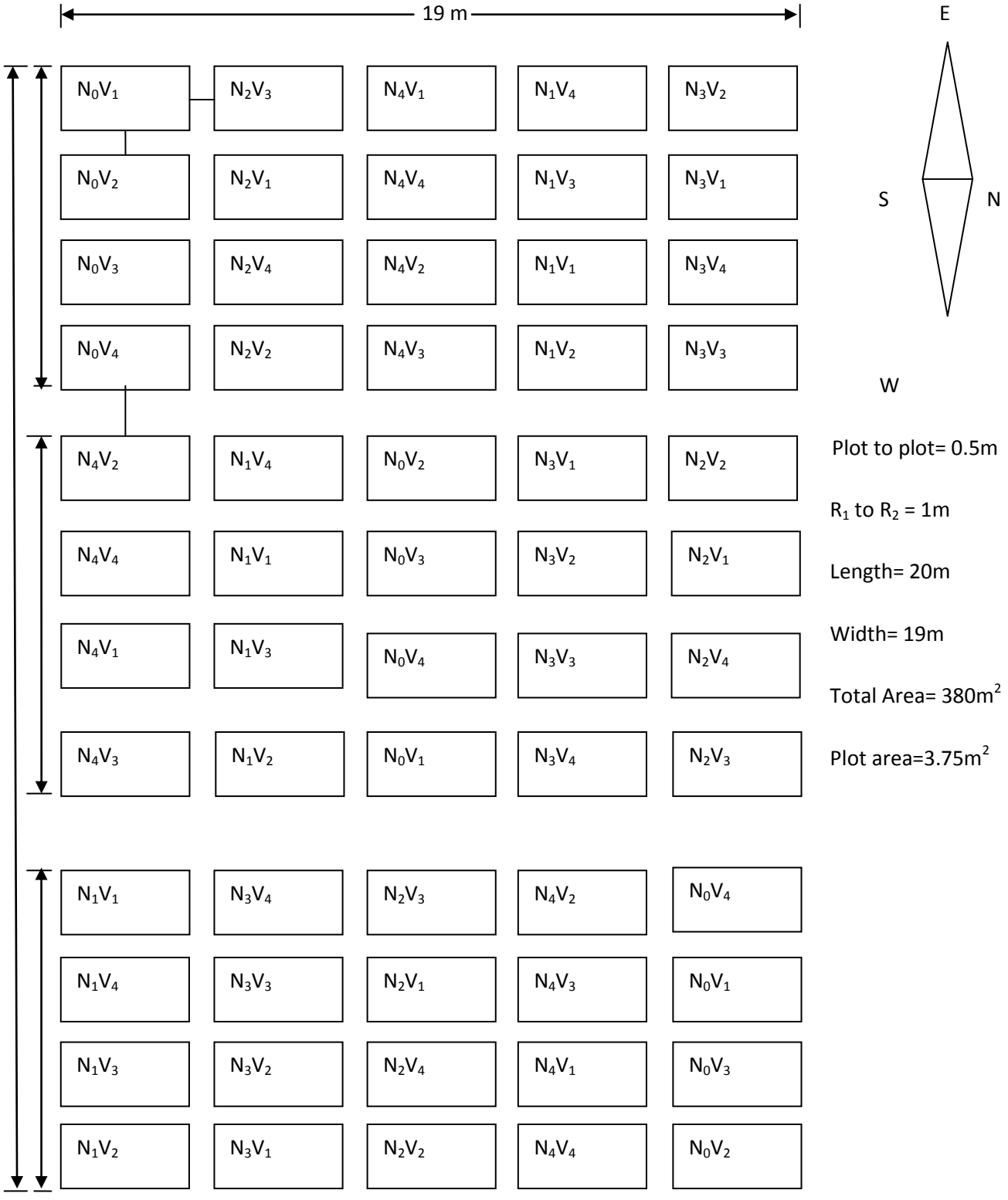


Figure: The map of Bangladesh showing experimental site

Appendix II. Layout of the experimental plot



Appendix III. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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

Appendix IV. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from November 2014 to April 2015

Months	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2014	25.82	16.04	78	00
December, 2014	22.40	13.50	74	00
January, 2015	24.50	12.40	68	00
February, 2015	27.10	16.70	67	30
March, 2015	31.40	19.60	54	11
April, 2015	33.5	22.6	61	160.4

Source: Bangladesh Meteorological Department (Climate and weather Division), Agargoan, Dhaka- 1207

PLATES

Plate 1. Field view of the experimental plot at vegetative stage

Plate 2. Field view of the experimental plot at maturity stage

Plate 3. View of the germination test in the Agronomy Lab

Plate 4. View of the seedling length of the germinated seedlings

Plate 5. View of the electrical conductivity test of wheat seed after harvest