RESPONSE OF WHEAT TO LEVELS OF NITROGEN AND PLANT SPACING

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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: JULY-DECEMBER, 2008

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CERTIFICATE

This is to certify that the thesis entitled **"Response of wheat to levels of nitrogen and plant spacing"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfilment of the requirements for the degree of **Master of Science in Agronomy embodies** the result of a piece of *bona fide* research work carried out by **Monira Begum, Registration No. 07-02602** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated 28/12/2008
Dhaka, Bangladesh

....
(Prof. Dr. Md. Hazrat Ali)
Supervisor

Dedicated to
My
Beloved Parents

ACKNOWLEDGEMENT

All praises are due to Almighty Allah, the most gracious and merciful. The lord of the universe, who enabled the author to conduct and completed this work with the stipulated period of time.

The author expresses her deepest sense of gratitude, profound and ever indebtedness to her research supervisor Prof. Dr. Md. Hazrat Ali, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his sincere supervision, untiring guidance, constant encouragement, valuable suggestions and constructive comments through out the period of research work and preparation of manuscript of the thesis.

The author expresses her sincere appreciation, profound sense, respect and immense indebtedness to her co-supervisor Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for extending his generous help, untiring guidance, constructive criticism, continuous inspiration and valuable suggestions during the research work and preparation of manuscript of the thesis.

The author would like to express her deepest respect and boundless gratitude to all her respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for the valuable teaching, sympathetic co-operation and inspiration through out the course of this study and research work.

The author appreciates the assistance rendered by the staff of the Department of Agronomy and Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka-1207, for their help during her period of study and research.

RESPONSE OF WHEAT TO LEVELS OF NITROGEN AND PLANT SPACING

ABSTRACT

An experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka during December to March, 2007-2008 to investigate the response of wheat cv. Shourav to different levels of nitrogen and plant spacing. The treatment consisted of three nitrogen levels (120, 180 and 240 kg ha^{-1}) and four plant spacing (3, 5, 7 and10 cm) in a row of 20 cm apart. The experiment was laid out in a split plot design with three replications. Results revealed that nitrogen level and plant spacing influenced plant towards higher yield either singly or in combination. Nitrogen at the rate of 180 kg ha^{-1} performed maximum yield components and grain yield (3.46 t ha^{-1}). Almost similar grain yield (3.76 t ha^{-1}) was achieved at plant spacing of 20 cm x 5 cm. The combined effect of nitrogen 180 kg ha^{-1} along with 20 cm x 5 cm plant spacing produced greater effective tillers $plant^{-1}$ (5.46), length of spike $plant^{-1}$ (12.07 cm), 1000-grain weight (44.73 g) and grain yield (3.94 t ha^{-1}), which were positively supported by maximum value of harvest index (46.27%).

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ACRONYMS

AEZ	=	Agro – Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CEC	=	Cation Exchange Capacity
CGR	=	Crop Growth Rate
cm	=	Centi-meter
CO_2	=	Carbon di-oxide
CV%	=	Percentage of Coefficient of Variance
cv.	=	Cultivar(s)
DAS	=	Days After Sowing
DM	=	Dry Matter
et al.	=	And others
etc	=	Etcetera
g	=	gram (s)
ha	=	hectare
hr	=	hour (s)
K_2O	=	Potassium Oxide
Kg	=	kilogram (s)
LSD	=	Least Significant Difference
L_n	=	Natural Logarithm
m^2	=	meter square
mg	=	mili gram
mm	=	millimetre
N	=	Nitrogen
NS	=	Non significant
P_2O_5	=	Phosphorous penta oxide
PK	=	Phosphorous, Potassium
ppm	=	Parts per million
RGR	=	Relative Growth Rate
S	=	Sulphur
SA	=	Surface area
$Spike^{-1}$	=	Per spike
$t\ ha^{-1}$	=	Tonnes per hectare
var.	=	Variety
%	=	Percent
@	=	At the rate of
^0C	=	Degree Centigrade
&	=	and

Chapter 1
Introduction

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the number one cereal crop of the world followed by rice and the second important cereal crop of Bangladesh. It is a staple food for about one billion people in as many as 43 countries and provides about 20% of total food calories. It contains carbohydrate (78.1%), protein (14.7%), minerals (2.1%), fat (2.1%) and considerable proportion of vitamins (Peterson, 1965). In Bangladesh, it covers 3, 88,000 hectares of land with an annual production of 8, 44,000 metric tons (BBS, 2008).

Wheat is grown across a wide range of environments around the world. Wheat is cool loving crop and adopted for cultivation in regions with cooler climatic condition. Its production is concentrated between latitudes 30^0 and 60^0 N and 27^0 and 40^0 S (Nuttonson, 1995). Bangladesh lies in the warmer part of the world and wheat is grown in the winter or cold season of the country. In consideration of the facts that growing of wheat in a location is decided by the temperature limits of 20^0 and 25^0 C (Ray and Nathan, 1986) and its grain growth and development depend on temperature range of $15^0/10^0$ C to $18^0/15^0$ C (Thorne *et al.*, 1968). The best time of sowing of wheat in Bangladesh is the second half of November that needed around 105 days to complete its life cycle.

In Bangladesh, the yield of wheat in the farmer's field is much lower than that of the research farm. The low yield of wheat in Bangladesh might be due to various factors as lack of quality seeds, untimely seeding, imbalanced fertilization and seed rate and lack of proper agronomic management practices. Among them nitrogen fertilization and plant spacing are the important factors which influence the yield of wheat (Mozumder, 2001).

Nitrogen is an essential plant nutrient that plays a significant role in growth and yield of wheat. Excessive or deficient supply of this element adversely affects the growth and yield (Ahmed and Hossain, 1992). Nitrogen fertilizer should be applied at a right dose for increasing its use efficiency. Application of nitrogen above the optimum dose decreased grain and straw yields (Gehl *et al.*, 1990). The balanced use of fertilizer as a single factor can increase the wheat productivity 5 times more than the use of all components such as high yielding varieties, irrigation facilities and plant protection (Pasricha and Brar, 1999).

Seed rate is another important factor for securing good yield of wheat with optimum plant population. Seed rate influence yield and yield contributing characters of wheat (Singh and Singh, 1987). Optimum plant density produces optimum number of plant per unit area resulting better yield contributing character leading to better grain and straw yields of wheat (Singh, 1992). High plant density results intra-plant competition there by affecting the yield.

Tiller mortality is greater at high plant density, and the number of fertile spike lets spike^{-1} along with the yield components are mostly affected by plant density (Saradon *et al.*, 1988). Decreasing the planting density increases the amount of photosynthetic assimilation and provides a canopy structure which gives increased physiological activities after anthesis leading to a decrease rate of photosynthetic, increased total photosynthetic assimilation and increased sink effect on grain yield (Zhenhua *et al.*, 1995).

Optimum plant spacing ensures proper growth of the aerial and under ground part of the plant through efficient utilization of solar radiation, nutrient uptake as well as air, space and water. The vital research work on optimum plant spacing is very scarce and there may be a positive response between optimum nitrogen and plant spacing in order to get higher grain yield of wheat. Therefore, a problem oriented research such as plant spacing and nitrogen effect seems to be important factors for increasing the yield of wheat in the country.

A study was, therefore, undertaken with the following objectives:

1. To find out effect of different levels of N fertilizer on the growth, yield contributing characters and yield of wheat.

2. To evaluate the influence of different plant spacing on growth, yield components and yield of wheat.

3. To determine the interaction effects of nitrogen and plant spacing on the growth and yield of wheat.

Chapter 2
Review of Literature

REVIEW OF LITERATURE

Wheat is a leading cereal crop in the world, a good number of researchers have conducted enormous number of study on various aspects of its growth and yield at different ecological situations. Nitrogen fertilizer plays a significant role on growth and yield of wheat. On the effect of nitrogen fertilizer application a number of research works also have been carried out in home and abroad. Yield of wheat is also dependent on plant spacing. Therefore, for having a clear understanding on the effect of different nitrogen levels and plant spacing on the yield of wheat potential research(s) carried out through out the world have been reviewed.

2.1 Effect of Nitrogen

2.1.1 Plant height

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that the highest plant height (97.07 cm) was obtained from 140 kg N ha^{-1}.

An experiment was performed by Akter (2005) to examine the effect of nitrogen levels under rainfed and irrigated condition on yield and seed quality of wheat. The experiment was included four nitrogen levels viz. 0 (Control), 50, 100 and 150 kg ha^{-1} and found progressive increase of plant height with the increasing levels of nitrogen.

Ram *et al.* (2004) conducted a trial to find out the effects of different N levels (0, 40, 80, 120 and 160 kg ha^{-1}) on the growth and yield of wheat. They observe increased plant height with the increasing rate of nitrogen.

Das (2003) carried 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 the growth and yield of wheat. The experiment consists of four row spacing and four nitrogen levels. Results of that experiment showed that nitrogen had significant effect on plant height. At growth stage the tallest plant was obtained from 180 kg N ha^{-1}.

An experiment was evaluated by Kumar *et al.* (2003) in India to determine the effect of N application at 0, 50, 75, 100, 125 and 150 kg ha^{-1} on the chlorophyll content, dry biomass of whole plant and plant height of late sown winter wheat cv. HD 2285. Plant height was found positively correlated with nitrogen levels up to 125 kg ha^{-1}.

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

Kumar *et al.* (1999) conducted a field experiment on sandy loam soils, applied five levels of nitrogen (0, 45, 90, 135 and 180 kg N ha^{-1}) and two cutting management practice. It was observed that plant height increased with increasing rates of nitrogen up to180 kg ha^{-1}.

Kataria and Bassi (1999) conducted a field experiment with 3 levels of nitrogen (40, 80, 120 kg ha^{-1}) and two levels of mulch (no mulch and mulched). They observed that application of 80 kg N ha^{-1} produced significantly tallest plant height than 40 kg N ha^{-1}.

Sarker *et al.* (1997) fertilized wheat with 100, 120 and 160 kg N ha^{-1} to observe the effect of nitrogen level and duration of weed competition on weed biomass, yield and yield attributes of wheat. They found no significant response of nitrogen to plant height.

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

Patel and Upadhyay (1993) found that plant height of wheat increased significantly with increasing rates of N up to150 kg ha^{-1}.

Ahmed and Hossain (1992) observed that plant heights of wheat where 79.9 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. Dhuka *et al.* (1991) also reported that wheat provided highest plant height with 120 kg N ha^{-1}.

2.1.2 Dry Matter

Chanda and Gunri (2004) worked with the study of effect of N fertilizer (100, 125, 150, 175 and 200 kg ha^{-1}) on hybrid (Pratham 7050 and Pratham 7070) and high yielding (Sonalika) wheat genotypes. They reported that dry matter accumulation at all the stages increase with increasing levels of N up to 200 kg ha^{-1}. Dry matter accumulation was low at early stages of crop growth and increased with advancement in crop age.

Experiment was conducted by Khan *et al.* (2002) to study the effect of different levels of nitrogen on growth and physiological attribute of wheat. Two varieties of wheat (Aghrani and Kanchan) and seven levels of nitrogen (0, 40, 80, 120, 160, 200 and 240 kg ha^{-1}) were tested. They found that stem dry matter increased with increasing of nitrogen level up to 200 kg ha^{-1} and then decreased.

Spring wheat (*Triticum aestivum* cv. Dingxi No. 8654) was treated by Li and Kang (2002) with five rates of nitrogen fertilizer (0, 50, 100, 150 and 200 mg kg^{-1} soil) to study the atmospheric CO_2 concentration effect on dry matter accumulation and N uptake of spring wheat. They observed that effect of CO_2 enrichment on the shoot and total mass dependent largely on soil nitrogen level, and the shoot and total mass increased significantly in the moderate to high N treatments but didn't increase significantly in the low N treatment.

Convertini *et al.* (1998) performed an experiment to investigate the effect of N levels (40, 80, 120, 160 and 200 kg ha^{-1}) on dry matter production of wheat. Result showed that N fertilizer had significant effect on dry matter accumulation.

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

Kumar *et al.* (1997) conducted an experiment in the winter season to evaluate the response of wheat to different level of nitrogen fertilizer. They worked with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and found that dry matter increased with increasing level of nitrogen.

Singh *et al.* (1996) conducted a pot experiment to evaluate the effect of N fertilizer on dry matter production of wheat (cv. WH-157). They used four levels of nitrogen (0, 50, 100 and 200 ppm) and found that dry matter yield increased up to100 ppm N.

Roy *et al.* (1991) conducted a field experiment to find out the effect of planting geometry and nitrogen application on the growth and yield of wheat. They used three levels of nitrogen (40, 80 and 120 kg ha^{-1}) and found that nitrogen increased the dry matter production significantly.

2.1.3 Crop Growth Rate (CGR)

Shukla *et al.* (2004) reported that crop growth rate was not significantly different with or without basal N application at 21 days after seeding in wheat.

Khan *et al.* (2002) found that there was significant effect of nitrogen rates on crop growth rate (CGR) during 25-45, 45-65 and 65-85 DAS. CGR increased with the increasing rate of nitrogen up to 200 kg ha^{-1} within the period 25-45, 45-65 and 65-85 DAS. Nitrogen nutrient plays a vital role in vegetative growth of plant and for this CGR increased with the increase of N fertilization.

Roy *et al.* (1991) studied with 2 levels of nitrogen to see the response of wheat to CGR and noticed that variation in N level didn't show any significant effect on the spike growth rate.

2.1.4 Relative Growth Rate (RGR)

Khan *et al.* (2002) conducted an experiment to study the effect of different levels of nitrogen on growth and physiological attributes of wheat. They found that all growth parameters except LAR (leaf area ratio) and SLA (specific leaf area) increased with the increase of age of plant irrespective of N fertilization. The effect of nitrogen was significant on relative growth rate.

2.1.5 Number of total tillers

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that the highest number of tillers (6.43) at 140 kg N ha^{-1}.

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) effects on spring wheat yield and yield components. They found that total tiller number increased significantly by N levels.

Rahman (2005) conducted an experiment with four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1} to find out the effect of nitrogen, sulpher and boron fertilizers on the yield and quality of wheat cv. Kanchan. He reported that number of total tillers $hill^{-1}$ was significantly higher at 125 kg N ha^{-1}.

Hossain (2006) conducted an experiment to study the effect of planting methods (bed planting & conventional planting) and nitrogen levels (50, 100 and 150 kg N ha^{-1}) on the yield and yield attributes of wheat cv. Protiva. He found that total tiller number increased significantly with 150 kg N ha^{-1}.

Akter (2005) worked with four nitrogen levels (0, 50, 100 and 150 kg ha^{-1}) and found that 100 kg N ha^{-1} gave the highest number of total tillers $plant^{-1}$.

Das (2003) conducted an experiment to observe the effect of row spacing and nitrogen application on the growth and yield of wheat. Results of that experiment showed that nitrogen had significant effect on total tillers. The highest number of total tillers per plant was obtained from 180 kg N ha^{-1}.

Das (2002) set up an experiment to evaluate the effect of nitrogen fertilization on the yield of wheat cv. Kanchan and found that total number of tillers $plant^{-1}$ was statistically different with different rate of nitrogen fertilizer. The maximum number of total tillers $plant^{-1}$ was obtained at 120 kg N ha^{-1}.

Khan *et al.* (2002) carried out an experiment to evaluate the effect of different levels of nitrogen on growth and physiological attributes of wheat. Six levels of nitrogen (40, 80, 120, 160, 200 and 240 kg ha^{-1}) was used and found that there was significant effect of nitrogen on tiller number per plant at 25, 45, 65 and 85 DAS. Tiller number per plant increase with the increase of nitrogen fertilization up to 160 kg ha^{-1} at different growth stage.

Mozumder (2001) reported that nitrogen fertilization exerted significant effect on number of total tillers $plant^{-1}$. The highest number of total tillers $plant^{-1}$ was recorded from 120 kg N ha^{-1}.

Sushila and Giri (2000) studied an experiment to see the influence of farmyard manure, nitrogen and bio fertilizer on growth, yield attributes and yield of wheat under limited water supply. They used three levels of nitrogen (0, 45 and 90 kg ha^{-1}) in their experiment and found that total tillers m^{-2} was increased with increasing level of nitrogen.

2.1.6 Number of effective tillers

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that effective tiller number increased significantly and the highest effective tiller number obtained from 140 kg N ha^{-1}.

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) effects on spring wheat yield and yield components. They observed that effective tiller number increased significantly by N levels.

An experiment was conducted by Rahman (2005) including four levels of nitrogen (75, 100, 125 and 150 kg ha^{-1}). He reported that number of effective tillers per hill was significantly higher at 125 kg N ha^{-1}.

Akter (2005) found that number of effective tillers plant $^{-1}$ increased with the increasing level of nitrogen up to100 kg N ha^{-1}. The highest number of effective tillers plant $^{-1}$ was recorded from 100 kg N ha^{-1} which was statistically similar to 50 and 150 kg N ha^{-1}.

Pandey *et al.* (2004) performed an experiment to investigate the effect of fertilizer levels and seed rate on growth and yield of surface seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1}in the experiment and calculated that number of effective tillers m^{-2} increased significantly only up to120 kg N ha^{-1} and further increase in fertilizer levels didn't show significant effects.

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

Mozumder (2001) reported that nitrogen fertilization had significant effect on production of numbers of effective tillers $plant^{1}$. In the experiment it was found that the highest number of effective tillers plant $^{-1}$ was obtained with 90 kg N ha^{-1} was applied. The lowest number of effective tillers $plant^{-1}$ was observed in control treatment.

Kataria and Bassi (1999) carried out a field experiment with three levels of N (40, 80 and 120 kg ha^{-1}) and two levels of mulch (no mulch and mulched). They concluded that number of effective tillers m^{-2} increased significantly at the N application of 80 kg ha^{-1}.

Kumar *et al.* (1995) conducted a field experiment with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and reported that productive tillers increased significantly with the increase of N levels from 0-120 kg ha^{-1}, but differences in productive tillers between 120 and 180 kg N ha^{-1} were not significant.

Singh *et al.* (1991) reported that nitrogen fertilization showed marked improvement in yield attributes of wheat. Number of effective tillers m^{-2} was highest at 120 kg N ha^{-1}.

2.1.7 Spike length

Hossain (2006) conducted an experiment to study the effect of planting methods (bed planting & conventional planting) and nitrogen levels (50, 100 and 150 kg N ha^{-1}) on the yield and yield attributes of wheat cv. Protiva. He observed that spike length increased significantly with N levels.

Rahman (2005) carried out an experiment to evaluate the effect of nitrogen, sulpher and boron fertilizers on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen (75, 100,125 and 150 kg ha^{-1}). He reported that length of spike was significantly increases with the application of nitrogen at 125 kg ha^{-1}.

Akter (2005) performed an observation to examine the effect of nitrogen levels on yield of wheat. She used four nitrogen levels (0, 50, 100 and 150 kg ha^{-1}) and found that spike length increase with the increasing length of nitrogen up to100 kg ha^{-1}.

Das (2003) studied an experiment with four row spacing and four nitrogen levels to observe the effect of row spacing and nitrogen application on the growth and yield of wheat. He found that nitrogen had significant effect on spike length. The highest spike length was observed from the 180 kg N ha^{-1}.

Das (2002) set up an experiment to evaluate the effect of planting density and rate of nitrogen application on the yield of wheat cv. Kanchan. He used four levels of nitrogen

(0, 40, 80 and 120 kg ha^{-1}) and found that spike length increase with the increasing rate of nitrogen up to120 kg ha^{-1}.

Sushila and Giri (2000) conducted an experiment with three levels of nitrogen (0, 45 and 90 kg ha^{-1}) to see the influence of farmyard manure, nitrogen and bio fertilizer on growth, yield attributes and yield of wheat. They found increased spike length with increasing level of nitrogen.

Patel and Upadhyay (1993) examine that spike length of wheat increase significantly with increasing rate of N up to150 kg ha^{-1}.

Bhagawati *et al.* (1992) carried out an experiment with 0, 40, 80 and 120 kg N ha^{-1} and reported that spike length of wheat were significantly increase by nitrogen application. Maximum spike length was obtained at 120 kg N ha^{-1}. Singh *et al.* (1991) reported that spike length of wheat increase significantly with increasing rates of nitrogen up to 80 kg ha^{-1}.

A filed trial was conducted at Institute of Agricultural Sciences, Banaras Hindu University during 1979-81 with wheat cv. HD 1553 under three levels of N (40, 80 and 120 kg ha^{-1}). The results of the experiment were found that spike length increased markedly with increasing levels of nitrogen up to120 kg ha^{-1} (Singh and Singh, 1987).

2.1.8 1000 Grain Weight

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and with four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that 1000 grain weight increased significantly with N levels and 140 kg N ha^{-1} produced the highest weight.

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) on effects of spring wheat yield and yield components. They observed that 1000 grain weight decreased with increasing N level and were influenced by genotype.

Hossain (2006) conducted an experiment to study the effect of planting methods (bed planting & conventional planting) and nitrogen levels (50, 100 and 150 kg N ha^{-1}) on the yield and yield attributes of wheat cv. Protiva. He observed highest 1000 grain weight at 150 kg N ha^{-1}.

An experiment was carried out by Akter (2005) to examine the effect of nitrogen levels on yield and seed quality of wheat and observed increased 1000 seed weight with the increasing rate of nitrogen up to 100 kg N ha^{-1} and decline thereafter.

Mazurkiewicz and Bojarczyk (2004) carried out an experiment to evaluate the effect of nitrogen fertilizer on yield of wheat. There were six levels of nitrogen viz. 0, 50, 100, 150, 200 and 250 kg ha^{-1}. They found that differentiation of the level of nitrogen fertilizer didn't significantly influence the 1000 grain weight.

Das (2003) showed that nitrogen had significant effect on 1000 grain weight. The maximum weight of 1000 grain was obtained from 180 kg N ha^{-1}.

Das (2002) set up an experiment to evaluate the effect of different levels of nitrogen fertilization on the yield of wheat cv. Kanchan. He used four levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and found that rate of nitrogen application did not show any significant effect on 1000 grain weight.

Mozumder (2001) reported that 1000 grain weight responded significantly following different levels of nitrogen. The highest 1000 grain weight was observed from 120 kg N ha^{-1}.

Sushila and Giri (2000) studied an experiment to observe the influence of farmyard manure, nitrogen and biofertilizers on growth, yield attributes and yield of wheat under limited water supply. They used 0, 45 and 90 kg N ha^{-1} and found 1000 grain weight was significantly increased up to45 kg N ha^{-1}. Kumar *et al.* (1999) reported that 1000 grain weight increased with increasing rate of N up to 180 kg ha^{-1}.

Upadhyay and Tiwari (1996) conducted an experiment on two wheat cultivars (Sonalika and Lok 1) with three levels of N (90, 120 and 150 kg ha^{-1}) and observed that nitrogen application up to 120 kg ha^{-1} increased the number of fertile spike lets $spike^{-1}$ and 1000 grain weight with lower doses (90 kg N ha^{-1}).

Ayoub *et al.* (1994) conducted an experiment at the Lods Agronomy Research Centre, McGill University, Macdonald Campus and at the crop Federee Research farm. Ste-Rosalie, Canada in 1990 and 1991 on four cultivars (Columbus, Max, Katepwa and Hege) with four doses of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and reported that increasing nitrogen fertilizer level significantly increased thousand 1000 grain weight.

Patel and Upadhyay (1993) conducted an experiment with three levels of N (0, 120 and 150 kg ha^{-1}) and reported that 1000 grain weight of wheat increased significantly with the increasing rates of nitrogen up to 150 kg N ha^{-1}.

Patra (1990) conducted a field experiment with two wheat varieties (Sonalika and Sagarika) under different levels of nitrogen fertilizer (40, 80 and 120 kg N ha^{-1})and reported that significant response of 1000 seed weight to N were observed up to the level of 120 kg N ha^{-1}.

Pandey *et al.* (1986) studied an experiment in wheat (Sonalika) with four doses of N (0, 60, 120 and 180 kg ha^{-1}) and observed that 1000 seed weight of wheat increase with the increasing rate of nitrogen from 40-120 kg N ha^{-1}.

2.1.9 Grain yield

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that 140 kg N ha^{-1} produced the highest grain yield (3.44 t ha^{-1}) and the lowest grain yield (1.57 t ha^{-1}) at control.

Rahman (2005) reported that most of the yield components and grain yield of wheat were significantly higher at 120 kg N ha^{-1}. An experiment was conducted by Akter (2005) to study the effect of nitrogen levels under rainfed and irrigated condition 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 N levels increased the seed yield.

Chandurkar *et al.* (2004) conducted a field experiment to determine the response of wheat on 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}.

Das (2003) showed that nitrogen had significant effect on green yield. Nitrogen application at the rate of 180 kg ha^{-1} produced the highest grain yield (3.13 t ha^{-1}).

Bellido *et al.* (2000) carried out a field experiment with four levels of N (0, 50, 100 and 150 kg N ha^{-1}). They observed that grain yield of wheat increase significantly at the nitrogen rate of 150 kg ha^{-1}.

Halvorson *et al.* (2000) carried out a field experiment on spring wheat with three doses of N (0, 22 and 45 kg N ha^{-1}) and reported that increasing level of N gave significantly higher grain yield. Maximum grain yield was obtained at 45 kg N ha^{-1}.

Singh *et al.* (1996) carried out a field experiment with wheat consisting three levels of N (40, 80 and 120 kg N ha^{-1}) and observed that seed yield of wheat increased significantly with the increasing rate of nitrogen up to 120 kg ha^{-1}.

Singh and Singh (1995) carried out a field trial with three levels of N (0, 40 and 80 kg N ha^{-1}) applied with three method. The experimental result showed that the rate of 80 kg N ha^{-1} increased the seed yield by 15.6% over at 40 kg N ha^{-1}.

Prasad and Singh (1995) conducted an experiment with four levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and reported that seed yield increased with the increasing rate of nitrogen up to 80 kg ha^{-1}. Maximum seed yield of wheat was obtained at 120 kg N ha^{-1}.

An observation was performed by Abou-Salama (1995) where 120 -130 kg N ha^{-1} was applied in full at mid tillering, stem elongation or anthesis stages or one-third as dasal and the rest two-thirds at mid tillering stem elongation or anthesis stages. He reported that more grain yield was found by applying total amount of nitrogen at the stem elongation or anthesis stage instead of applying at mid tillering stage.

Ayoub *et al.* (1994) carried out an experiment on four cultivars (Columbus, Max, Katepwa and Hege) with four doses of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and reported that increasing level of nitrogen fertilizer level significantly increased the seed yield.

Tomar *et al.* (1993) reported that wheat seed and straw yield increased with increasing rates of N fertilizer. Application of 120 kg N ha^{-1} gave the highest seed yield.

Singh *et al.* (1991) found that the seed yield of wheat increased with the increase of N from 40-120 kg N ha^{-1}. Significant increase of seed yield was observed only up to 80 kg N ha^{-1}.

Rajput *et al.* (1989) reported that wheat cv. Zarghoon-79 was given 0-50 kg N ha^{-1} as urea. Seed yield was highest with 50 kg N ha^{-1} and further dose decrease the seed yield.

Kumar (1995) carried out an experiment applying four levels of N (0, 60, 120 and 180 kg ha^{-1}) and with four cultivars of wheat (HP 1267, HW 135, HP 1379 and HP 1207). He reported that increasing levels of N up to 120 kg ha^{-1} increased the grain and straw yield of wheat significantly.

2.1.10 Straw yield

Alam *et al.* (2007) conducted an experiment with two planting methods (bed planting & conventional planting) and four nitrogen levels (0, 60, 100 and 140 kg N ha^{-1}). They found that there was significant difference between 0 (control) and 140 kg N ha^{-1} which produced 4.52 and 2.36 t ha^{-1} straw yield respectively.

Hossain (2006) conducted an experiment to study the effect of planting methods (bed planting & conventional planting) and nitrogen levels (50, 100 and 150 kg N ha^{-1}) on the yield and yield attributes of wheat cv. Protiva. He found that straw yield was highest (4.83 t ha^{-1}) at 150 kg N ha^{-1}.

Rahman (2005) reported that most of the yield components of wheat including straw yield was significantly higher at 125 kg N ha^{-1}. Akter (2005) studied with four nitrogen levels viz. 0 (control), 50, 100, 150 kg $ha^{-1}$to evaluate the effect of nitrogen levels under rainfed and irrigated condition on yield and seed quality of wheat. The straw yield was found to increase in nitrogen level up to 100 kg ha^{-1}.

Pandey *et al.* (2004) conducted an experiment to study the effect of fertilizer levels and seed rate on growth and yield of surface seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1} and observed that grain and straw yields differed significantly under varying fertilizer levels.

Nitrogen application at the rate of 180 kg ha^{-1} produced the highest straw yield (4.17 t ha^{-1}). The straw yield increased gradually with the increase of nitrogen dose (Das, 2003).

Das (2002) set up an experiment to evaluate the effect of planting density and rate of nitrogen application on the yield of wheat. He found that straw yield increased with the increasing rate of nitrogen application. The highest straw yield was produced by the application of 120 kg N ha^{-1}. The second highest straw yield was obtained with 80 kg N ha^{-1}.

Mozumder (2001) carried out an experiment to investigate the response of wheat at different levels of nitrogen. Treatments of nitrogen in the experiment were 0, 30, 60, 90 and 120 kg ha^{-1}. He reported 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}.

Ottman *et al.* (2000) carried out a field experiment on a Gasa Grande sandy loam soil during 1995 and 1996 growing seasons at the University of Arizona Maricopa Agricultural Center. The treatments consisted of four levels of N (0, 3, 4 and 8.7 g N m^{-2}) until anthesis. It was observed that nitrogen application near anthesis of 3.4 g N m^{-2} gave highest straw yield.

Sushila and Giri (2000) studied an experiment to see the influence of farmyard manure, nitrogen and bio fertilizer on growth, yield attributes and yield of wheat under limited water supply. They used three levels of nitrogen (0, 45 and 90 kg ha^{-1}) in their experiment and found that straw yield was significantly increased up to 90 kg N ha^{-1}.

Singh *et al.* (1996) conducted a field experiment with three 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 ha^{-1}.

Ayoub *et al.* (1994) conducted an experiment at the Lods Agronomy Research Centre, McGill University, Macdonald Campus and at the crop Federee Research farm. Ste-Rosalie, Canada in 1990 and 1991 on four cultivars (Columbus, Max, Katepwa and Hege) with four doses of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and reported that straw yield was significantly increased by increasing nitrogen fertilizer level.

Sharma and Dillon (1993) reported that application of nitrogen remarkably improved the straw yield of wheat and application of 120 kg N ha^{-1} gave the highest straw yield. Patel and Upadhyay (1993) also found that straw yield of wheat increased significantly with the increasing level of nitrogen fertilizer up to 150 kg ha^{-1}.

Awasthi and Bhan (1993) conducted a field experiment consisting of five varieties of wheat K65, K78, K72, K8430 and K306 and four levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}). They observed that straw yield of wheat increased significantly by increasing rate of nitrogen up to 60 kg ha^{-1}. Tomar *et al.* (1993) conducted a field experiment to observe the response of wheat varieties to irrigation under different fertility levels and reported that wheat seed and straw yield increased significantly by increasing rate of N fertilizer.

Rathor and Patel (1991) carried out an experiment in Rabi seasons with three levels of nitrogen (40, 80 and 120 kg N ha^{-1}) using a seed rate of 120 kg ha^{-1} and reported that increasing level of nitrogen gave significantly higher straw yield of wheat. Maximum straw yield was obtained at 120 kg N ha^{-1}.

Dhuka *et al.* (1991) conducted a field experiment on GW 120 with three levels of nitrogen (40, 80 and 120 kg N ha^{-1}) and reported that straw yield was significantly increased by N application.

Vostal *et al.* (1989) reported that wheat cv. Slavia was given 150 kg N as urea. Urea was applied in split doses at various stages which increased seed yield, by 48-82%. Straw yield of wheat remarkably influenced with different levels of N application. Split application of N gave significantly higher straw yield of wheat.

Kumar (1995) carried out an experiment applying four levels of N (0, 60, 120 and 180 kg ha^{-1}) and with four cultivars of wheat (HP 1267, HW 135, HP 1379 and HP 1207). He reported that increasing levels of nitrogen up to 120 kg ha^{-1} increased the grain and straw yields of wheat significantly.

Samad *et al.* (1984) carried out an experiment in the Agronomy Field Laboratory of the Bangladesh Agricultural University, Mymensingh on wheat cultivar Sonalika with four doses of nitrogen (40, 60, 80 and 100 kg ha^{-1}) and reported that N application at early tillering stage tended to give higher straw yield.

2.1.11 Harvest index

Alam *et al.* (2007) conducted an experiment and found that harvest index was significantly highest at 140 kg N ha^{-1}.

Hossain (2006) conducted an experiment to study the effect of planting methods (bed planting & conventional planting) and nitrogen levels (50, 100 and 150 kg N ha^{-1}) on the yield and yield attributes of wheat cv. Protiva. He observed that highest harvest index (43.29%) at 150 kg N ha^{-1}.

Rahman (2005) conducted an experiment with four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1} to find out the effect of nitrogen, sulpher and boron fertilizers on the yield and quality of wheat cv. Kanchan. He reported that harvest index was significantly higher at 125 kg N ha^{-1}.

Akter (2005) used four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1} in an experiment to examine the effect of nitrogen levels under rainfed and irrigated condition on yield and seed quality of wheat and found highest harvest index was observed at 100 kg N ha^{-1}.

Pandey *et al.* (2004) performed an experiment to investigate the effect of N fertilizer levels and seed rate on growth and yield of surface seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1}in the experiment and calculated that harvest index increased significantly up to 120 kg N ha^{-1} but decreased thereafter.

In an experiment Das (2003) showed that nitrogen had significant effect on harvest index. The maximum harvest index was obtained at 180 kg N ha^{-1}. Das (2002) also found that harvest index increased with the increasing rate of nitrogen application. The maximum harvest index was obtained at 120 kg N ha^{-1}.

Mozumder (2001) carried out an experiment to find out the effect of different levels of nitrogen and seed rate on the yield and yield contributing character of wheat. Nitrogen treatments were 0, 30, 60, 90 and 120 kg ha^{-1}. He reported that N fertilizer exhibited significant effect on harvest index. The highest harvest index (37.04%) was observed N at the rate 60 kg ha^{-1} which was followed by 36.53% and 36.50% N at the rate of 30 and 90 kg ha^{-1} respectively. But the difference among them was not significant.

Sushila and Giri (2000) studied an experiment to see the influence of farmyard manure, nitrogen and bio fertilizer on growth, yield attributes and yield of wheat under limited water supply. They used three levels of nitrogen (0, 45 and 90 kg ha^{-1}) in their experiment and found that harvest index was increased up to 90 kg N ha^{-1}.

Awasthi and Bhan (1993) conducted a field experiment consisting of five varieties of wheat K65, K78, K72, K8430 and K306 and four levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}). They observed that harvest index of wheat increased significantly with the increasing rates of nitrogen up to 60 kg ha^{-1}.

2.2 Effect of plant spacing

2.2.1 Plant Height

Dixit and Gupta (2004) conducted an experiment to investigate the effect of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat cv. HUW-234 in Varanasi, Uttar Pradesh, India. They reported that increasing the seeding rate significantly increased the plant height.

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates (125, 150 and 175 kg ha^{-1}) on growth and yield of surface seeded wheat. They reported that plant height did not differ significantly among the seed rates.

An observation was under taken by Arif *et al.* (2002) to study the effect of different swing rates (50, 100, 120 and 150 kg ha^{-1}) on yield components of wheat cultivars (Inqilab-91) and Bakhtawar-92. Maximum plant height (97 cm) was recorded at sowing rates of 150 kg seed ha^{-1}. Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that planting density did not significantly influence plant height.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat. He reported that there was no significant effect in respect of plant height of wheat due to different levels of seed rate.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 500 and 600 seed m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and observed that there were no significant difference among the seed rate in case of plant height.

Gaffer and Shahidullah (1985) conducted an experiment to study the effect of seed rates (100, 140 and 180 kg seed ha^{-1}) on the performance of wheat cv. India-66. Plant height was significantly higher at 100 kg seed ha^{-1} than the other rates.

2.2.2 Dry matter

The effect of crop density (300, 450 and 600 plants m^{-2}) on dry matter accumulation and distribution in spring triticale and spring wheat were studied by Nierobca (2002). At crop densities of 300 and 450 plants m^{-2}, spring triticale showed greater dry matter accumulation in shoots than spring wheat. However at 600 plants m^{-2}, spring wheat exhibited greater dry matter accumulation in shoots than spring triticale.

Nag *et al.* ((1998) conducted an experiment to investigate the response of growth and yield of wheat to different seed rates. It appeared that increasing seed rate resulted in increased total dry matter in wheat.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 500 and 600 seed m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and observed that dry matter production per plant was highest with 100 seeds m^{-2}.

Saradon *et al.* (1988) reported that sown to give plant densities of 120-360 plants m^{-2} in field experiment at Myanmar. They found that at higher plant densities translocation of dry matter to the ear begun earlier and were greater than in plant grown at lower densities. Dry matter distribution at harvest was not affected by plant density.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plant m^{-2}) to find out the effect of planting density on growth and yield of wheat. They reported that dry matter production per plant was higher at the lower plant densities.

2.2.3 Crop growth rate (CGR)

Nag *et al.* (1998) carried out an experiment to investigate the response of growth and yield of wheat to different seed rates. They found that crop growth rate differ significantly by the different growth stage of wheat but didn't influence significantly due to seed rates.

2.2.4 Relative growth rate (RGR)

Nag *et al.* (1998) carried out an experiment to investigate the response on growth and yield of wheat to different seed rates. They found that RGR was significantly influenced at maximum tillering stage. At the ripening stage RGR was negligible. On the other hand the maximum RGR was obtained from the seed rate at 200 kg ha^{-1} and minimum from 100 kg seed ha^{-1}.

In a field trial, plant densities were 27, 54 and 81 plant m^{-2} and growth indices were analyzed using classical and regression methods. RGR decressed with age of the plant due to the increase level of self shading (Govil and Pandey, 1995).

2.2.5 Number of total tillers

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) on the effect of spring wheat yield and yield components. They observed that total tiller number increased significantly by seed rates.

Dixit and Gupta (2004) conducted an experiment to investigate the effect of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat. It was observed that increasing the seeding rate significantly reduced the number of tillers.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that total number of tillers $plant^{-1}$ was significantly influenced by planting density. The lowest planting density of 188 seeds m^{-2} produced highest number of total tillers $plant^{-1}$.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used in an experiment. In that experiment seed rates exerted significant effect on total tillers $plant^{-1}$.

Mozumder (2001) reported that increasing seed rates showed significant effect regarding total tiller $plant^{-1}$. The highest number of total tiller $plant^{-1}$ was obtained from the lowest seed rate (75 kg seed ha^{-1}).

Sun yuanmin *et al.* (1996) studied on the optimization of plant populations for high yield of wheat production and showed that reducing plant density coupled with early sowing and increased fertilizer application at middle and late growth stages, increased number of tillers $plant^{-1}$ and percentage of fertile tillers m^{-2}.

Kumar *et al.* (1991) reported that four high yielding recommended wheat cultivars and four new cultivars with longer spikes and more grains spike^{-1} (low tillering) were sown at 100, 125 and 150 kg seed ha^{-1} in a rows 22.5, 18 and 15 cm apart, respectively. Higher seed sowing rates coupled with decreased in row spacing increased the number of tillers m^{-2} and grain yields.

Saradon *et al.* (1988) reported that wheat sown to give plant densities of 120-360 plants m^{-2} in field experiment at Myanmar. They found that tiller mortality was greater at high plant density and in the tall cultivar (Klein Toledo).

A filed experiment was under taken by Chatha *et al.* (1986) to observe the yield of wheat cultivars as affected by different seed rates (18.5, 37, 55.5, 74 and 92.5 kg seeds ha^{-1}) under irrigated conditions. They found that increasing sowing rates had no significant effect on 1000 grains weight but increased immergence and tillers per unit area and grain yields.

Gaffer and Shahidullah (1985) conducted an experiment to study the effect of seed rates (100, 140 and 180 kg seed ha^{-1}) on the performance of wheat and observed that tillers plant^{-1} was significantly higher at 100 kg seed ha^{-1} than the other rates but grain yields was highest at 140 kg seed ha^{-1} and straw yield was highest at 180 kg seed ha^{-1}.

Borojevic and Kraljevic (1983) studied with five wheat cv. sown at 300, 500 and 700 seeds m^{-2} the number of plant produced was 12.7, 14.4 and 15.9 % respectively. They also found that production of tillers was 50% greater at the low sowing rate and 25% lower at the higher sowing date then at the intermediate rate and was most intensive at the low sowing rate in 6 cm rows.

In a field trial to find out the seed rate, Black and Aase (1982) sown three wheat cv. At high end low sowing rates at the rate 148-480 plants m^{-2} and given 0 or 45 kg ha^{-1}. They found that sowing rate and N application had little effect on grain yield and high sowing rate of average 14-46 % more tillers m^{-2} than low density.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plant m^{-2}) to find out the effect of planting density on the growth of yield of wheat. At lower plant densities both the main shoot and the tillers showed better growth.

2.2.6 Number of effective tillers

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates (125, 150 and 175 kg ha^{-1}) on growth and yield of surface seeded wheat. They reported that seed rate of 175 kg ha^{-1} recorded significantly higher effective tillers m^{-2}.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material and noticed significant effect on effective tillers m^{-2}.

Sun yuanmin *et al* . (1996) studied on the optimization of plant populations for high yield of wheat production and showed that reducing plant density coupled with early sowing and increased fertilizer application at middle and late growth stages, increased the number of tillers m^{-2} and percentage of fertile tillers and biomass at maturity.

Mahajan *et al.* (1991) conducted an experiment with three seed rates of 100, 125 and 150 kg ha^{-1} and with three seed treatments (unsoaked, water soaked or sprouted). They marked that number of effective tillers m^{-2} decreased with the increase in sowing rate and was highest with unsoaked seeds.

Sharar *et al.* (1987) observed that increasing the sowing density of wheat from 125-313 seeds m^{-2} increased seed densities from 44.7 to100.4 plants/3600 cm^2 and fertile tiller number from 146-182.9/3600 cm^2 and decreased average grain number ear^{-1} from 56 to 44.5.

2.2.7 Spike length

Dixit and Gupta (2004) conducted an experiment to investigate the effect of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat. They found that increasing the seed rate significantly reduced the spike length.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that planting density frequencies differed significantly in respect of spike length of wheat.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material. In that experiment, seed rates exerted significant effect on spike length.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat. He reported that spike length varied significantly due to increasing seed rate. The longest spike of 8.98 cm was produced from the treatment where 75 kg seed ha^{-1} which was followed by 8.76 and 8.4 cm obtained from the seed rate 100 and 125 kg ha^{-1}.

Torofder (1993) conducted an experiment to find out the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akber, Barkat, Ananda and Kanchan) were included in the study and found that length of spike decreased with the increase of seed rate.

Gaffer and Shahidullah (1985) conducted an experiment to study the effect of seed rates (100, 140 and 180 kg seed ha^{-1}) on the performance of wheat and observed that year length increased significantly at 100 kg seed ha^{-1} then at the other rates.

2.2.8 1000 grain weight

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that 1000 grains weight didn't differ significantly due to different planting densities of wheat seeds. The highest 1000 grain weight was obtained from 188 seed m^{-2} and the lowest from 500 seeds m^{-2}.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material. He found that seed rates exerted significant effect on 1000 seed weight.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat. He reported that the lowest seed rate produced the highest 1000 grain weight.

Ahmed *et al.* (1995) studied on two cultivars using seeding rates from 40 to 120 kg seed ha^{-1}. He revealed that 1000 grains weight decreased from 40.47 to 39.69 g with the corresponding sowing rates.

Torofder (1993) conducted an experiment to find out the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akber, Barkat, Ananda and Kanchan), included in the study and found that 1000 grains weight decreased with the increase of seed rate.

Mahajan *et al.* (1991) conducted an experiment with three seed rates of 100, 125 and 150 kg ha^{-1} and three seed treatments (unsoaked, water soaked or sprouted). Grain yield increased with seed sowing rate and was highest with sprouted seed. Weight of 1000 grain was highest (41 g) with 150 kg sprouted seed ha^{-1}.

sA filed experiment was under taken by Chatha *et al.* (1986) to observe the yield of wheat cultivars as affected by different seed rates (18.5, 37, 55.5, 74 and 92.5 kg seeds ha^{-1}) under irrigated conditions. They found that increasing sowing rates had no significant effect on 1000 grains weight.

Gaffer and Shahidullah (1985) conducted an experiment to study the effect of seed rates (100, 140 and 180 kg seed ha^{-1}) on the performance of wheat and observed that 1000 grains weight was significantly higher at 100 kg seed ha^{-1} than at the other rates.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plant m^{-2}) to find out the effect of planting density on the growth of yield of wheat. They reported that 1000 grains weight remain un affected by reduction in plant population.

2.2.9 Grain yield

Herbek *et al.* (2007) conducted an parameter to study the effect of different seeding rates (10, 15, 20, 25, 30, 35 and 40 seeds ft^{-2}) and established stand on the yield potential of wheat. They observed that there was no significant difference among grain yields i. e. the low seeding rate produced yields equal to higher seeding rate.

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) on the effect of spring wheat yield and yield components. They observed that productivity was highest at lowest seed rate.

Dixit and Gupta (2004) conducted an experiment to investigate the effect of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat. It was revealed that increasing the sowing rate significantly increased grain yield.

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates (125, 150 and 175 kg ha^{-1}) on growth and yield of surface seeded wheat. They reported that use of 175 kg seed ha^{-1} resulted in the highest grain yield.

A field study was undertaken by Volynkina and Volynkin (2003) in the Kurgan region to show the effect of planting density on the yield and grain quality of spring wheat. The highest grain yield was obtained at a sowing rate of 2-3 million seeds ha^{-1}.

An observation was taken by Arif *et al.* (2002) to study the effect of different swing rates (50, 100, 120 and 150 kg ha^{-1}) on yield components of wheat cultivars (Inqilab-91) and

Bakhtawar-92. Maximum grain yield (3346 kg ha^{-1}) was recorded at sowing rates of 150 kg seed ha^{-1}.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that the highest grain yield obtained from the optimum planting density of wheat (250 seed m^{-2}).

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material and concluded that seed rates exerted significant effect on seed yield.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat and revealed that 150 kg seed ha^{-1}produced the highest grain yield and 75 kg seed ha^{-1} produced the lowest grain yield and they differed significantly with each other.

Nag *et al.* (1998) carried out an experiment to investigate the response on growth and yield of wheat to different seed rates. They found that increasing seed rate resulted in increase total dry matter and leaf area index but it did not increased grain yield in wheat.

Torofder (1993) conducted an experiment to find out the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akber, Barkat, Ananda and Kanchan) were included in the study and obtained statistically similar yields with seed rate of 100 and 120 kg ha^{-1}.

Mishra (1993) conducted a field trial where 100, 125 and 150 kg seed ha^{-1} were used as experimental treatment and got the average grain yields of 1.24, 1.37 and 1.28 t ha^{-1} from 100, 125 and 150 kg seed ha^{-1} respectively.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 500 and 600 seed m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and observed that grain yield was significantly higher with 400 seeds m^{-2}.

Huel and Baker (1990) noted that grain yield increased with the increment of seed rate up to 646 seeds m^{-2} (in 1984) and up to 320 seed m^{-2} (in 1985). In other experiment it was found that sowing rate had little influence on yield and increased seeding rates did not compensate for late sowing cv. Granada in which yield increases due to increase stand density.

A field trial was undertaken by Bhatnagar *et al.* (1990) to find out the response of wheat to different seed rates. Seeds were sown in rows 15, 19 and 23 cm apart in row with seed rates of 100, 125, 150, 175 and 200 kg ha^{-1}. The highest grain yield of 4.17 t ha^{-1} in 1986-87 and 2.63 t ha^{-1} 1987-88 were obtained from 23 cm apart in row spacing with the seed rate of 200 kg ha^{-1}.

2.2.10 Straw yield

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates (125, 150 and 175 kg ha^{-1}) on growth and yield of surface seeded wheat. They reported that use of 175 kg seed ha^{-1} resulted in the highest grain yield.

Dixit and Gupta (2004) conducted an experiment to investigate the effect of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat. They found that increasing the seeding rate significantly increased straw yield. The highest straw yield (72.59 quintal ha^{-1}) was obtained at the rate of 150 kg seed ha^{-1}.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that the maximum straw yield was recorded at optimum planting density of 250 seeds m^{-2}.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material. He found highest straw yield at 130 kg seed ha^{-1}.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat. He reported that straw yield increased upto a certain level of seed rate ad there after declined. The highest straw yield was produced from seeds at the rate 125 kg ha^{-1}.

2.2.11 Harvest index

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates (125, 150 and 175 kg ha^{-1}) on growth and yield of surface seeded wheat. They reported that harvest index was unaffected by the variation of seed rates.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used 3 levels of planting density (500, 250 and 188 seeds

m^{-2}) and concluded that the highest harvest index from the optimum planting density at 250 seeds m^{-2} and the lowest harvest index were found from 500 seeds m^{-2}.

Hossain (2002) conducted field trial to find out optimum seed rate and harvesting time to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seed ha^{-1}) were used as an experimental material. In that experiment seed rates exerted significant effects on straw yield and harvest index.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rates (75, 100, 125 and 150 kg seed ha^{-1}) on the yield and yield contributing characters of wheat. He reported that harvest index significantly varied due to different seed rates. The highest harvest index was observed in seed rate at 125 kg ha^{-1}.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 500 and 600 seed m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and observed that harvest index increased up to 400 seeds m^{-2} and thereafter decreased.

Borojevic and Kraljevic (1983) studied with five wheat cv. sown at 300, 500 and 700 seeds m^{-2} the number of plant produced was 12.7, 14.4 and 15.9 % respectively. They also found that increasing the seeding rate reduced the harvest index significantly where as row spacing had no effect.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plant m^{-2}) to find out the effect of planting density on the growth of yield of wheat. They reported that harvest index remain unaffected by reduction in plant population.

2.3 Interaction effect of nitrogen and plant spacing

2.3.1 Plant height

Hossain (2005) conducted an experiment to know the effect of nitrogen level and plant spacing on the yield performance of wheat. It was observed that plant height was not significantly affected by the interaction of plant spacing and nitrogen level. Numerically the application of 90 kg seed ha^{-1} and 160 kg N ha^{-1} produced the highest plant height (92.95 cm) and the shortest plant (70.48 cm) was found from the combination of 60 kg seed ha^{-1} with control i.e. no application of nitrogen.

Pandey *et al.* (2004) conducted an experiment to study the effect of fertilizer levels and plant spacing on growth and yield of wheat under low land rice eco system. They used five levels of nitrogen fertilizer (0, 60, 90, 120 and 150 kg ha^{-1}) and three levels of seed rates (125, 150 and 175 kg seed ha^{-1}). They reported that plant height increased with sub sequent increasing fertilizer level and reported maximum value at 150 kg N ha^{-1}. But decreased non significantly with increase in seed rate.

Kumar *et al.* (2002) conducted an experiment to study the effect of seed rate (50, 75 and 100 kg ha^{-1}) and nitrogen levels (90, 120, 150 and 180 kg ha^{-1}) on biomass production in wheat. They reported that plant height enhanced significantly with enhancing both seed rates and nitrogen level.

Das (2002) reported that the combined effect of planting density and nitrogen on height of wheat plant was not statistically significant. Numerically the highest plant height (100.99 cm) was obtained in planting density 250 seed m^{-2} combined with 120 kg N ha^{-1} and the lowest (80.44 cm) was in planting density 500 seeds m^{-2} and control plot. Singh *et al.* (2002) also reported that plant height increased with increasing rate of N and decreased with increasing sowing rate.

Mozumder (2001) noticed that plant height did not respond significantly due to interaction of plant spacing and nitrogen. Even though plant height did not differ due to interaction effect of different plant spacing and levels of nitrogen the highest plant height (86.47 cm) was obtained from the interaction from 125 kg seed ha^{-1} and 90 kg N ha^{-1}.

2.3.2 Dry matter

Kumar *et al.* (2002) conducted an experiment to study the effect of seed rate (50, 75 and 100 kg ha^{-1}) and nitrogen levels (90, 120, 150 and 180 kg ha^{-1}) on biomass production in wheat. They reported that dry matter accumulation enhanced significantly with enhancing plant spacing and also registered a significant increase up to 150 kg N ha^{-1}.

Reddi and Patil (2003) carried out an experiment to study the response of wheat to different N levels (75, 100 and 125 kg ha^{-1}) and seed rates (125, 150 and 175 kg ha^{-1}) under late sown condition. They concluded that dry matter accumulation increased with the increasing levels of N coupled with seed rates.

2.3.3 Number of total tillers

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) on the effect of spring wheat yield and yield components. They observed that total tiller number was increased significantly by seed rate and N levels.

The effect of seed rate and nitrogen level on the number of total tillers $plant^{-1}$ was statistically significant. However, apparently it was found that 90 kg seed ha^{-1} in combination with 160 kg N ha^{-1} resulted the highest number of total tillers $plant^{-1}$ (6.13) and 60 kg seed ha^{-1} in combination with control i.e. without application of nitrogen showed the lowest number of total tillers $plant^{-1}$(2.98) (Hossain, 2005).

Das (2002) conducted a field trial to observe the effect of nitrogen and planting density on the yield of wheat. He found that the total number of tillers $plant^{-1}$ was non significant due to interaction between planting density and nitrogen application rate. Numerically the highest number of tillers $plant^{-1}$ (5.90) was obtained with the combination of 188 seed m^2 and 120 kg N ha^{-1} and the lowest (3.20) at 500 seeds m^{-2} with controlled nitrogen treatment.

Kumar *et al.* (2002) conducted an experiment to study the effect of seed rate (50, 75 and 100 kg ha^{-1}) and nitrogen levels (90, 120, 150 and 180 kg ha^{-1}) on biomass production in wheat. They concluded that total number of tillers per unit area enhanced significantly with enhancing seed rate. They also reported that number of tillers registered a significant increase up to 150 kg N ha^{-1}.

Mozumder (2001) studied out the response of wheat to different nitrogen levels and seed rates. He reported that the interaction of nitrogen and seed rate significantly affected number of total tillers $plant^{-1}$. The highest number of total tillers $plant^{-1}$ (5.09) was found from the combination of 75 kg seed ha^{-1} and 120 kg N ha^{-1}.

2.3.4 Number of effective tillers

Hossain (2005) concluded that the highest number of effective tillers per hill was found in combined effect of 120 kg N and 90 kg seed ha^{-1}. Das (2002) also reported that the highest number of effective tiller $plant^{-1}$ (4.53) was obtained in planting densities of 188 seeds m^{-2} combined with 120 kg N ha^{-1}.

Kumar *et al.* (2002) conducted an experiment to study the effect of seed rate (50, 75 and 100 kg ha^{-1}) and nitrogen levels (90, 120, 150 and 180 kg ha^{-1}) on biomass production in wheat. They reported that effective tillers per unit area enhanced significantly with enhancing seed rate and also with 150 kg N ha^{-1}.

Mozumder (2001) worked with different seed rates (75, 100, 125 and 150 kg ha^{-1}) and nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}). The interaction effect of seed rate and nitrogenous fertilizer was found significant in case of number of effective tillers $plant^{-1}$. It was observed that the highest number of effective tillers $plant^{-1}$ was found from the combination effect of 75 kg seed and 90 kg N ha^{-1}.

2.3.5 Spike length

Hossain (2005) conducted an experiment to study the response of wheat to different fertilizer levels and seed rates. He found that 160 kg N ha^{-1} gave the highest length (9.75 cm) of a spike but it was statistically identical with 120 kg N ha^{-1}. He also reported that 90 kg seed ha^{-1} performed the best incase of spike length but it was also statistically identical with 120 kg seed ha^{-1}.

Pandey *et al.* (2004) conducted an experiment to study the effect of fertilizer levels and plant spacing on growth and yield of wheat under low land rice eco system. They used five levels of nitrogen fertilizer (0, 60, 90, 120 and 150 kg ha^{-1}) and three levels of seed rates (125, 150 and 175 kg seed ha^{-1}). They reported that spike length increased significantly only up to 120 kg N ha^{-1} and further increase in fertilizer level had not any significant effect on this attribute. Seed rate had not any significant effect on spike length.

Das (2002) studied with three levels of seed rates (500, 250 and 188 seed m^{-2}) and four levels of fertilizer (0, 40, 80 and 120 kg N ha^{-1}). He reported that spike length was not significantly influenced by the interaction effect of nitrogen and seed rate. Mozumder (2001) reported that the longest spike length (9.66 cm) was obtained from the interaction of 75 kg seed with 90 kg N ha^{-1}.

2.3.6 1000 grain weight

Hossain (2005) stated that there were no significant responses among the combination effect of different fertilizer level and seed rate.

The 1000 grains weight was not significantly influenced by the interaction between planting density and different rates of nitrogen (Das, 2002). The highest 1000 grain weight (46.12 g) was obtained with planting density of 250 seeds m^{-2} in combination with 120 kg N ha^{-1} and the lowest (40.35 g) with planting density of 5000 seeds m^{-2} with no nitrogen treatment.

Mozumder (2001) worked with different seed rates (75, 100, 125 and 150 kg ha^{-1}) and nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}). The interaction effect of seed rate and nitrogenous fertilizer was found significant in case of number of effective tillers $plant^{-1}$. It was observed that the highest 1000 grains weight (46.80 g) from the interaction effect of 75 kg seed ha^{-1} with 120 kg N ha^{-1}.

Walli and Wahab (1987) carried out an observation with three seed rates (60, 100 and 140 kg ha^{-1}) and three levels of N (0, 40 and 80 kg ha^{-1}) and reported that increasing seed rate increased 1000 grains weight but increasing N application significantly increased 1000 grains weight.

2.3.7 Grain yield

Otteson *et al.* (2007) conducted an experiment to study the seeding rates (2.9 and 4.2 million seeds ha^{-1}) and N levels (140 and 224 kg N ha^{-1}) on the effect of spring wheat yield and yield components. They observed that productivity was highest at lowest seed rate and N level.

Hossain (2005) found that incase of grain yield ha^{-1}, the combination effect of 120 kg N ha^{-1} with 120 kg seed ha^{-1} and 160 kg N ha^{-1} with 120 kg seed ha^{-1} was statistically identical. The highest grain (3.26 t ha^{-1}) yield was obtained from the interaction effect of 120 kg N ha^{-1} with 120 kg seed ha^{-1}. Das (2002) also reported that the highest grain yield was obtained with 250 seeds m^{-2} in combination with 120 kg N ha^{-1}.

Mozumder (2001) worked with different seed rates (75, 100, 125 and 150 kg ha^{-1}) and nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}). The interaction effect of seed rate and nitrogenous fertilizer was found significant in case of number of effective tillers $plant^{-1}$. It was observed that the interaction of seed rate and nitrogen significantly affected grain yield of wheat. The combination of 150 kg seed ha^{-1} with 120 kg N ha^{-1} was found as the best treatment which obtained the highest grain yield.

2.3.8 Straw yield

Hossain (2005) conducted an experiment and found that straw yield was significantly affected by the interaction of seed rate and nitrogen levels. It was observed that the application of 90 kg seed ha^{-1} and 120 kg N ha^{-1} showed numerically the highest straw yield (4.11 t ha^{-1}) and 60 kg seed ha^{-1} and 0 kg N ha^{-1} showed the lowest straw yield.

Das (2002) reported that straw yield was not significantly influenced by the interaction between different seed rates and nitrogen levels. He used 188, 250 and 500 seeds m^{-2} and 0, 40, 80 and 120 kg N ha^{-1} as experimental treatments.

The interaction effect of seed rate and nitrogen was found significant in respect of straw yield of wheat (Mozumder, 2001). It was observed that the highest straw yield was found in the interaction of 150 kg seed ha^{-1} with 120 kg N ha^{-1}.

2.3.9 Harvest index

Hossain (2005) carried out a field trial with four levels of fertilizer (0, 80, 120 and 160 kg N ha^{-1}) and three levels of seed rates (0, 90 and 120 kg seed ha^{-1}). He found that incase of harvest index, there were no significant response among the combination effect of different fertilizer level and seed rates.

Harvest index was not significantly affected by the interaction between planting densities and different rates of nitrogen. Numerically the highest harvest index (46.53%) was obtained with optimum planting densities of 250 seeds m^{-2} in combination of 120 kg N ha^{-1} (Das, 2002).

From an experiment, Mozumder (2001) found that there was significant variation in harvest index due to interaction of different nitrogen levels and seed rates. The highest (46.33%) harvest index was obtained from the interaction of 60 kg N ha^{-1} with 75 kg seed ha^{-1}.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

A field experiment was conducted in rabi season to study the effect of nitrogen and spacing on the growth and yield of wheat. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, collections and analysis of different parameters.

3.1 Location

The experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during December 11, 2007 to March 28, 2008 to study the growth and yield of wheat as influenced by nitrogen and plant spacing.

3.2 Experimental site

The experimental field was located at 90^0 22'E longitude and 23^0 41'N latitude at an altitude of 8.6 meters above the sea level.

3.3 Soil

The land was in Agro-ecological zone of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The soil was clay loam in texture having pH 5.50. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Weather

Cold temperature and minimum rainfall is the main feature of the experimental site in Rabi season. The monthly total rainfall, temperature (Maximum and Minimum) and relative humidity during the study period (December to March) is shown in Appendix II.

3.5 Variety

Shourov (BARI Gom-19) was released for cultivation in 1998. Height of the plant ranges from 90-100 cm. It produces 5-6 tillers per plant. Leaves are flat, droopy and deep green in color. Weight of 1000-seeds is 40-45 g. It takes about 102-110 days from sowing to harvest. Average yield of this variety is 3.5 to 4.5 ton per hectare.

3.6 Layout of the experiment

The experiment was laid out in a split-plot design with three replications. The experimental area was divided into three blocks each of which representing a replication. Each block was divided into 3 main plots in which nitrogen levels were applied at random. Each main plot was further divided into 4 unit plots or sub-plots for the treatment of different plant spacing and treatments were arranged at random. So, the total number of unit plots in the entire experimental plot were 3 x 4 x 3 =36. Size of each plot was 3.5 m x 2.5 m. The distance maintained between two blocks was 1.5m and between sub-plots 1m.

3.7 Experimental treatment

There were two sets of treatments i.e. nitrogen levels and plant spacing. There were three levels of N fertilizer (120, 180 and 240 kg ha^{-1}) and four plant spacing (3, 5, 7 and 10 cm, plant to plant in 20 cm about rows). So, the treatments were as follows-

Factor A: Level of nitrogen (kg ha^{-1}): 3

N_1=120

N_2=180

N_3=240

Factor B: Plant spacing (cm):4

S_1=3

S_2=5

S_3=7

S_4=10

3.8 Details of the land operation

The particular of the cultural operations carried out during the experimentation are present below:

3.8.1 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought desirable fine tilth and levelled by laddering. The visible large clods were hammered to break into small pieces. All weeds, stubbles and crop residues were cleaned from the land. The final ploughing and land preparation were done on December 10, 2007. The layout was done as per experimental design on December 11, 2007.

3.8.2 Fertilizer application

Before final land preparation the field was fertilized with P_2O_5, K_2O and S at the rate of 68, 25 and 20 kg ha^{-1}, respectively in the form of triple super phosphate, muriate of potash and gypsum. Nitrogen was applied in main plots as urea as per experimental treatments. The whole amount of triple super phosphate (TSP), muriate of potash (MP) gypsum and two third of urea (as per treatment) were incorporated in each plot at the time of final land preparation. The remaining urea was applied at crown root initiation stage (21 days after sowing) followed by irrigation.

3.8.3 Collection and sowing of seed

The wheat seeds (cv. Sourav) were collected from Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. At a good tilth condition, furrows were made with hand rakes for sowing. Seeds were sown continuously in line on December 11, 2007 as per experimental treatment. The line to line distance was maintained 20 cm. After sowing, the seeds were covered with the soil and slightly pressed by hand.

3.8.4 Thinning

The crop was thinned 15 DAS following the treatment variables maintaining plant to plant distance as 3, 5, 7 and 10 cm in lines.

3.8.5 Weeding

Weeds infested the experimental plots. So two weeding were done manually at 25 and 50 days after sowing. Both thinning and weeding were done simultaneously during first weeding. During weeding the weeds identified were Durba (*Cynodon dactylon* L.), Shama (*Echinochloa crusgalli* L.), Arail (*Leersia bexandra*), Chelaghash (*Parapholis incurve* Linn), Mutha (*Cyperus rotundus* L.), Bathua (*Chenopodium album* L.), Banmasur (*Vicia sativa* L.), Shaknotey (*Amaranthus viridis* L.), Foskabegun (*Physalis beterophylls*) and Titabegun (*Solanum torvum*).

3.8.6 Irrigation

The experimental plot was irrigated two times. The first and second irrigation were required to be applied at crown root initiation stage and grain filling stage (20 and 70 days after sowing) and there was a rainfall at heading stage (46 days after sowing). During irrigation care was taken so that water could not flow from one plot to another or overflow the boundary of the plots. Excess water of the field was drained out.

3.8.7 Pest management

The experimental plots were sprayed with Melethion 57EC at the rate of 2ml per litre to control aphid. No infection of disease was noticed. Rat attacked the crop at 2^{nd} week of February. Zinc phosphide was applied to control rat. A guard was appointed to protect the wheat grain from bird especially Parrots from mid February to March.

3.8.8 Harvesting and sampling

The crop was harvested at maturity on March 28, 2008. Samples were collected from different places of each plot leaving undisturbed one square meter in the center. The selected sample plants were then harvested, bundled, tagged and carefully carried to the Agronomy Field Laboratory in order to collect data. Samples of one square meter square and rest crop was harvested separately plot-wise, bundled and tagged. The crop bundles were sun dried by spreading those on the threshing floor. The grains were separated from the plants by beating the bundles with bamboo sticks. The straw and grain were dried again.

3.9 Recording of data

The growth parameters during study were recorded at 15 days interval started from 27 DAS up to harvest from randomly preselected plants and the yield & following other parameters were taken at harvest from predemarked area.

1. Plant height (cm)
2. Above ground dry matter $plant^{-1}$(g)

3. Crop growth rate (CGR) (g m^{-2} day^{-1})

4. Relative growth rate (RGR) (g g^{-1} day^{-1})

5. Tillers $plant^{-1}$

6. Effective tillers $plant^{-1}$

7. Non-effective tillers $plant^{-1}$

8. Spike length (cm)

9. 1000 grain weight (g)

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

11. Straw yield (t ha^{-1})

12. Harvest index (%)

3.9.1 Plant height

The mean plant height was determined from ten plants and expressed in cm.

3.9.2 Above ground dry matter

Ten plants from each plot at each harvest were taken from ground level and was oven dried at 80^0C until a constant weight was obtained. The dry weights of plants were recorded with the help of digital balance and the mean value was determined and expressed as per plant basis.

3.9.3 Crop growth rate (g m^{-2} day^{-1})

The dry matter accumulation of the crop per unit land area in unit of time is referred to as crop growth rate (CGR), expressed as g m^{-2} day^{-1}. The mean CGR values for the crop during the sampling intervals have been computed by using the formula of Brown (1984).

$$CGR\ (g\ m^{-2}\ day^{-1}) = (W_2 - W_1)/SA\ (T_2 - T_1)$$

Where,

SA = Ground are a occupied by the plant at each sampling. W_1 and W_2 are the total dry matter production in grams at the time T_1 and T_2 respectively.

3.9.4 Relative growth rate (g g^{-1} day^{-1})

The relative growth rate at which a plant incorporates new material into its sink is measured by relative growth rate of dry matter accumulation and is expressed in g g^{-1} day^{-1}. Relative growth rate was worked out by following the formula of Radford (1967).

$$RGR\ (g\ g^{-1}\ day^{-1}) = (L_nW_2 - L_nW_1) / (T_2 - T_1)$$

Where,

W_1 and W_2 are initial and final dry matter weight at the time T_1 and T_2 respectively. L_n refers to Natural Logarithm.

3.9.5 Tillers plant^{-1}

Number of tillers from the plant was counted and mean values were recorded.

3.9.6 Effective and non effective tillers plant^{-1}

Number of effective and non effective tillers from the plants was counted and mean values were recorded.

3.9.7 Spike length (cm)

Spike lengths of the plants were taken. The measurement was taken from the base of the flag leaf to the tip of the spike lets and the mean value was determined.

3.9.8 1000 grain weight (g)

Thousand seeds were taken from the seed sample and weighed at about 12% moisture level using an electric balance.

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

Total grain weight (at 12 % moisture) was taken from pre-demarked area of each plot and converted further as t ha^{-1}.

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

Having finished the threshing, drying, weight of straw of each sample plot, was measured and converted to t ha^{-1}.

3.9.11 Harvest index (%)

Harvest index was determined with the following formula of Donald (1963) Harvest index (%) = (Grain yield / Biological yield) X100

3.10 Statistical analysis

The collected data were complied and analysed by split plot design to find out the statistical significance of experimental results. The collected data were analysed by MSTAT software (Russell, 1986). The mean differences were evaluated by least significant difference (LSD) test.

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

Results obtained from the present study regarding the effects of nitrogen and different plant spacing and their interactions on the yield and yield components of wheat have been presented, discussed and compared in this chapter.

4.1 Plant height (cm)

4.1.1 Effect of nitrogen

Results revealed that plant heights were statistically maximum at par with N_2 (180 kg N ha^{-1}) and N_3 (240 kg N ha^{-1}) at all growth stages (27, 42, 57, 72, 87 DAS and at harvest) except 87 DAS where N_3 produced significantly highest plant height (Fig. 1). Treatment N_1 (120 kg N ha^{-1}) gave lowest height of plant at all stages of crop growth. Plant height varied from 27.01 cm to 82.83 cm measured 27 DAS and harvest.

Different scientists reported that highest plant height with 160 kg N ha^{-1} (Ram *et al.*, 2004), 180 kg N ha^{-1} (Das, 2003 and Kumar *et al.*, 1999).

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

Kataria and Bassi (1999) conducted a field experiment and observed that application of 80 kg N ha^{-1} produced significantly tallest plant height than 40 kg N ha^{-1}.

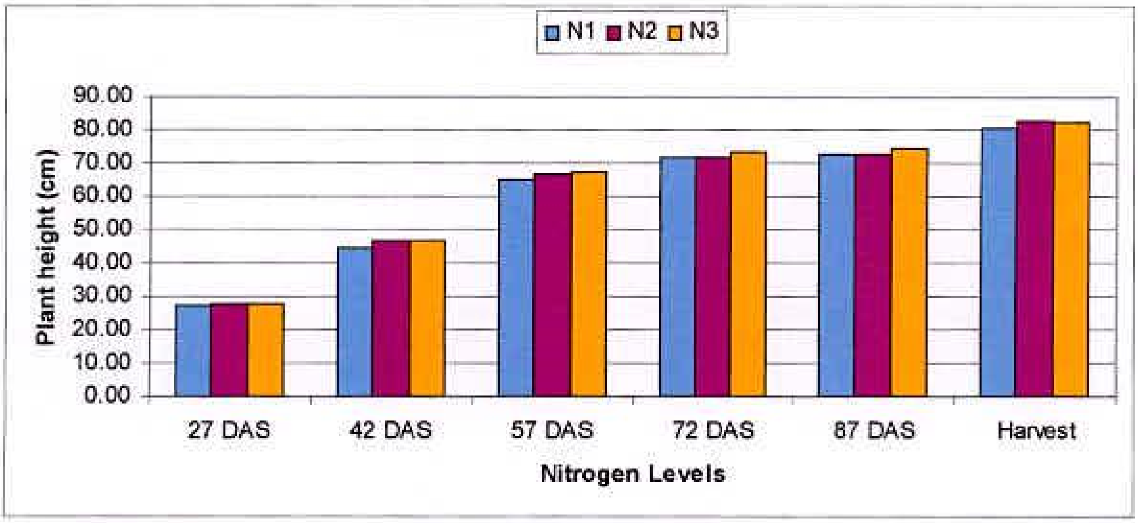

Figure 1: Plant height of wheat as affected by nitrogen levels at different days ($LSD_{0.05}$ = 0.61, 0.94, 0.90, 0.88, 0.94 and 1.22 at 27, 42, 57, 72, 87 and harvest respectively)

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

4.1.2 Effect of spacing

Significant variation of plant height was found due to different planting spacing at all growth stages (Fig. 2). The results revealed that the tallest plants (28.43, 47.02, 67.60, 73.40, 75.60 and 83.73 cm at 27, 42, 57, 72, 87 DAS and harvest, respectively) were obtained with the spacing of S_2 (5 cm) and followed by S_3 (7 cm) at 27, 72, 87 DAS and harvest. On the other hand, the lowest plant heights (26.88, 44.83, 65.80, 70.38, 70.80 and 79.34 cm) were obtained from the spacing of S_4 (10 cm) at all the sampling data. According to Gaffer and Shahidullah (1995) plant height was significantly higher at 100 kg seed ha^{-1}.

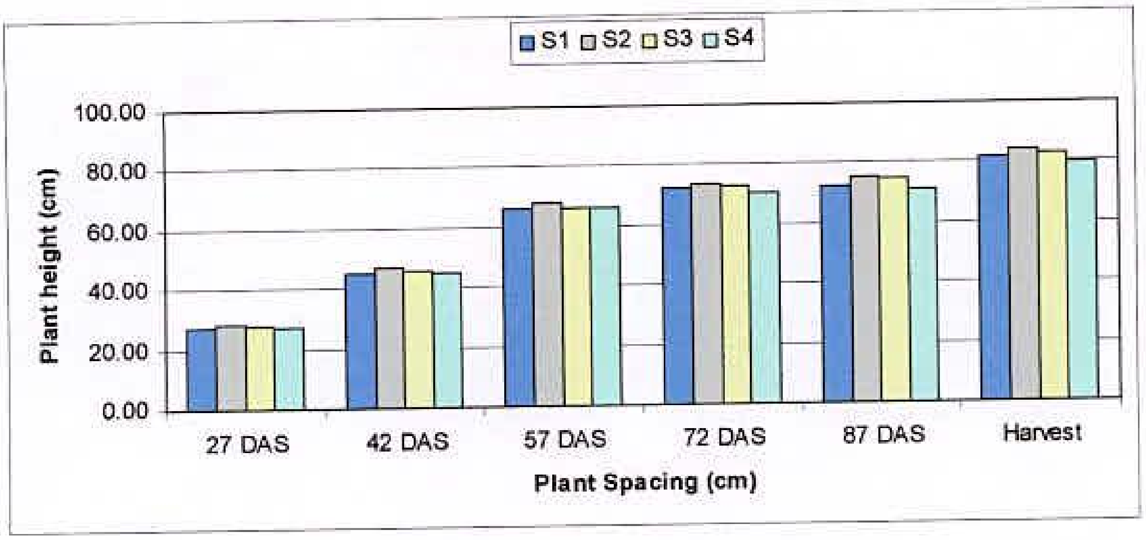

Figure 2: Plant height of wheat as affected by plant spacings at different days respectively)

$S_1 = 3$ cm, $S_2 = 5$ cm, $S_3 = 7$ cm, $S_4 = 10$ cm

4.1.3 Interaction effect of nitrogen and plant spacing

Irrespective of treatment difference, plant height of wheat increased progressively and picked at harvest. Plant height at different days after sowing (DAS) was greatly influenced by interaction effect of nitrogen and plant spacing (Table 1). It was observed that at all the stages (at 27, 42, 57, 72, 87 DAS and harvest), N_2S_2 showed the highest plant height (29.32, 48.21, 68.40, 74.33, 76.40 and 85.90 cm, respectively) which was not significantly different from N_3S_3 (85.87 cm) at harvest and significantly similar with N_1S_2, N_1S_3, N_3S_2, N_3S_4 at 27 DAS and N_3S_2 at 42, 57, 72 and 87 DAS. On the other hand the lowest plant height at 27, 42, 57, 72, 87 DAS and harvest (24.93, 41.92, 63.42, 67.33, 68.33 and 77.47 cm, respectively) was observed in N_1S_4 which was not significantly different from N_2S_4 at harvest and significantly similar with N_1S_1 at 27 DAS. Nitrogen (180 kg ha^{-1}) coupled with plant spacing (5 cm) favoured plant to have maximum cell division and cell elongation thus improved plant height at maximum from early growth stage to final harvest. Pandey *et al.* (2004) reported maximum plant height at 150 kg N ha^{-1}, Das (2002) obtained highest plant height in planting density 250 seed m^{-2} combined with 120 kg N ha^{-1} and the highest plant height (86.47 cm) was obtained from the interaction 125 kg seeds ha^{-1} and 90 kg N ha^{-1} by Mozumder (2001).

Table 1. Plant height of wheat as affected by the interaction of nitrogen levels and plant spacing at different days

Treatments	27 DAS	42 DAS	57 DAS	72 DAS	87 DAT	At harvest
N_1S_1	25.94	44.29	65.80	72.07	74.80	83.60
N_1S_2	28.86	45.41	66.67	73.27	75.53	80.93
N_1S_3	28.33	45.14	65.13	71.60	71.73	80.91
N_1S_4	24.93	41.92	63.42	67.33	68.33	77.47
N_2S_1	27.57	45.79	67.20	72.20	74.20	82.33
N_2S_2	29.32	48.21	68.40	74.33	76.40	85.90
N_2S_3	27.33	45.91	66.43	73.20	72.27	81.80
N_2S_4	27.31	46.75	67.00	70.47	69.53	77.75
N_3S_1	27.11	45.61	66.40	73.73	73.87	81.73
N_3S_2	29.09	47.45	67.27	74.07	76.20	85.87
N_3S_3	27.37	46.15	66.73	73.33	75.13	80.90
N_3S_4	28.01	45.83	65.80	71.73	71.80	82.82
$LSD_{0.05}$	**1.73**	**1.87**	**1.80**	**1.75**	**1.88**	**1.73**
CV (%)	**5.20**	**4.84**	**4.45**	**6.42**	**4.16**	**5.47**

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.2 Above ground dry weight plant^{-1}

4.2.1 Effect of nitrogen

Above ground dry weight plant^{-1} of wheat was significantly influenced by different levels of N application at 57, 72, 87 DAS and harvest except 27 and 42 DAS (Fig. 3). The result revealed that the highest above ground dry weight plant^{-1} (2.57, 3.30, 4.70 and 5.38 g) were recorded with N_2 (240 kg N ha^{-1}) at 57, 72 and 87 DAS and harvest, respectively which was statistically similar with N_3 (180 kg N ha^{-1}) at 57 and 87 DAS.

On the other hand the lowest above ground dry weight plant^{-1} (2.11, 2.82, 3.35 and 5.13 g) was recorded with N_1 (120 kg N ha^{-1}) at 57, 72, 87 DAS and harvest, respectively. Similar results were recorded by Chanda and Gunri (2004) and Khan *et al.* (2002) representing the dry matter of wheat increases with the level of nitrogen up to 200 kg N ha^{-1}.

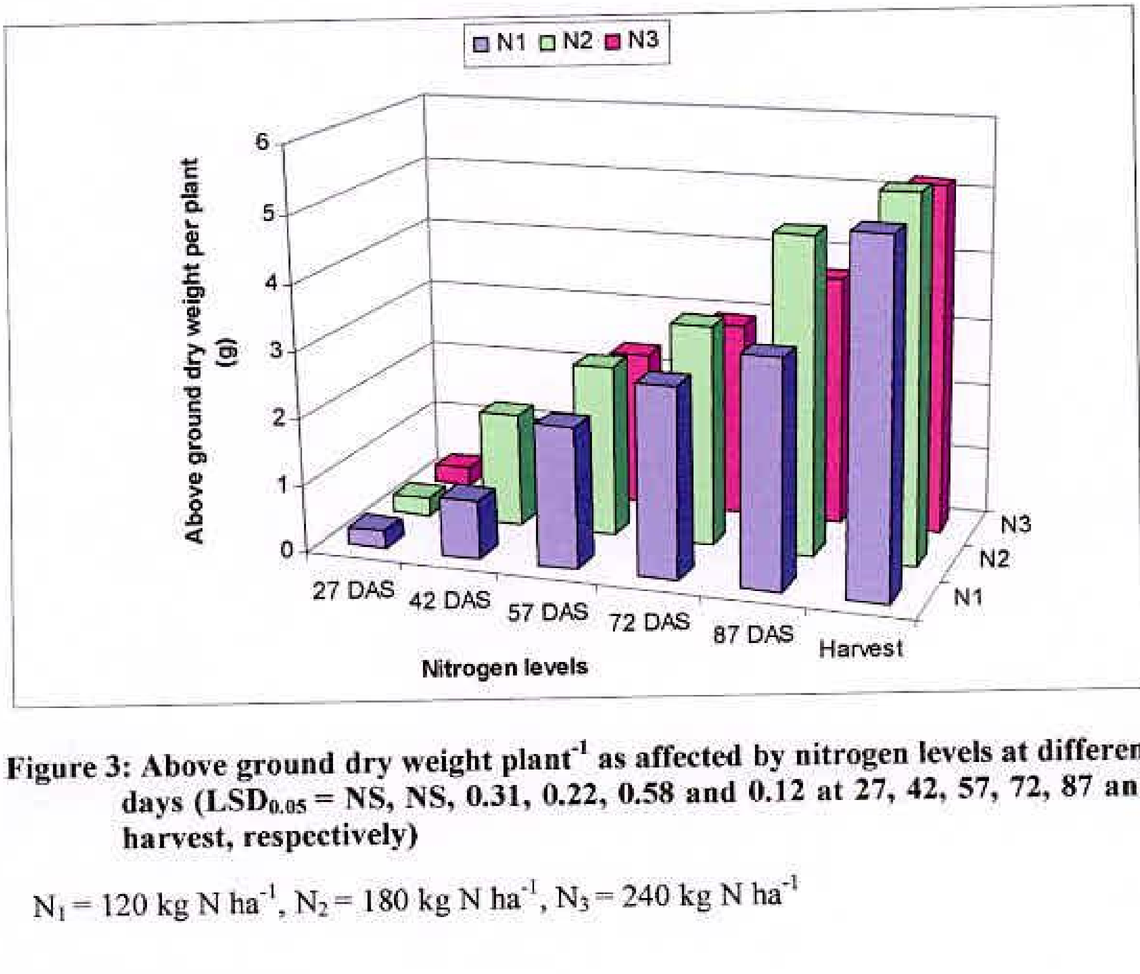

Figure 3: Above ground dry weight plant^{-1} as affected by nitrogen levels at different days ($LSD_{0.05}$ = NS, NS, 0.31, 0.22, 0.58 and 0.12 at 27, 42, 57, 72, 87 and harvest, respectively)

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

4.2.2 Effect of spacing

Significant variation at above ground dry weight plant^{-1} was found due to different plant spacing in all the studies duration except 27 and 42 DAS (Fig. 4). The results revealed that the highest above ground dry weight plant^{-1} (2.41, 3.18, 3.84 and 5.49 at 57, 72, 87

DAS and harvest, respectively) were obtained with the spacing of S_2 (5 cm) at par with S_1 (3 cm) at 57, 72, 87 DAS; S_3 (7 cm) at 57 DAS and with S_1 (3cm) at harvest. On the other hand the lowest above ground dry weight plant^{-1} (2.23, 2.87, 3.55 and 4.94 g, respectively) was obtained from the spacing of S_4 (10 cm) at 57, 72, 87 DAS and harvest. Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plants m^{-2}) and reported that dry matter production per plant was higher at the lower plant densities.

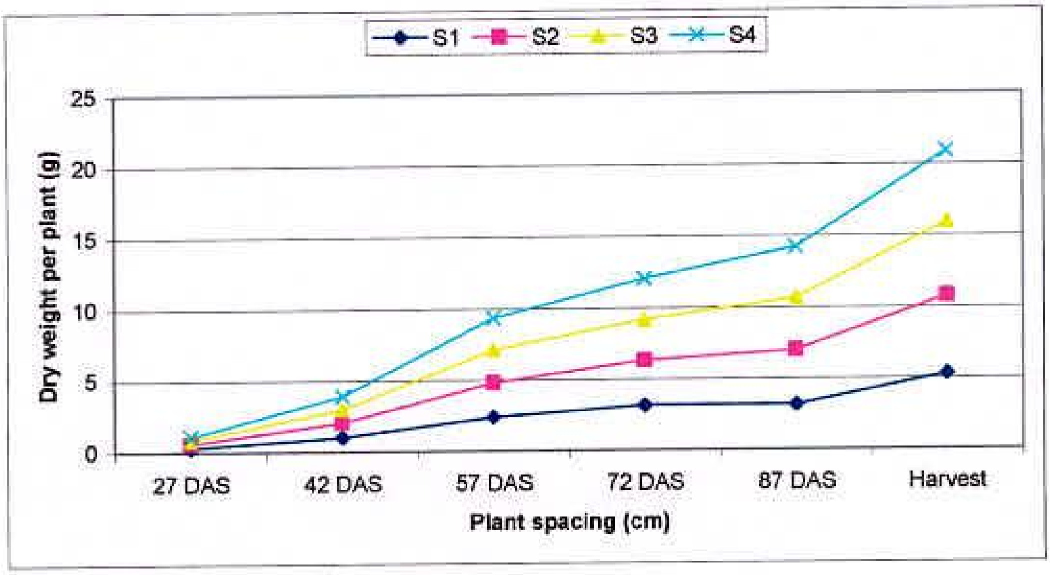

Figure 4: Above ground dry weight plant^{-1} as affected by plant spacings at different days ($LSD_{0.05}$ = NS, NS, 0.16, 0.25, 0.16 and 0.22 at 27, 42, 57, 72, 87 and harvest respectively)

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.2.3 Interaction effect of nitrogen and plant spacing

Above ground dry weight plant^{-1} at different DAS was greatly influenced by interaction effect of nitrogen and plant spacing (Table 2). It was observed that at 57, 72, 87 DAS and harvest N_2S_2 showed the highest above ground dry weight plant^{-1} (2.95, 3.87, 4.70 and 5.88 g, respectively) which was statistically similar with N_1S_4, N_3S_1, N_1S_2 & N_3S_2 at 57 DAS, N_3S_2 & N_3S_1 at 87 DAS and N_3S_2 & N_3S_1 at harvest. On the other hand the lowest above ground dry weight plant^{-1} at 57, 72, 87 DAS and harvest (2.03, 2.62, 3.24 and 4.62 g, respectively) was observed in N_3S_4. Kumar *et al.* (2002) conducted an experiment to study the effect of seed rate (50, 75 and 100 kg ha^{-1}) and nitrogen levels (90, 120, 150 and 180 kg N ha^{-1}) on biomass production in wheat. They reported that dry matter accumulation enhanced significantly with enhancing plant spacing and also registered a significant increase up to 150 kg N ha^{-1}. Reddi and Patil (2003) carried out an experiment to study the response of wheat to different N levels (75, 100 and 125 kg N ha^{-1}) and seed rates (125, 150 and 175 kg ha^{-1}) under late sown condition. They concluded that dry matter accumulation increased with the increasing levels of N coupled with seed rates.

Table 2. Above ground dry weight plant^{-1} of wheat as affected by the interaction of nitrogen levels and plant spacings at different days

Treatments	27 DAS	42 DAS	57 DAS	72 DAS	87 DAT	At harvest
N_1S_1	0.27	0.89	2.19	2.81	3.39	5.03
N_1S_2	0.30	1.06	2.48	3.22	3.91	5.43
N_1S_3	0.24	0.87	2.09	2.70	3.35	4.92
N_1S_4	0.24	0.86	2.08	2.69	3.28	4.80
N_2S_1	0.28	0.98	2.23	3.05	3.50	5.32
N_2S_2	0.33	1.19	2.95	3.87	4.70	5.88
N_2S_3	0.29	1.01	2.47	3.07	3.88	5.40
N_2S_4	0.21	0.85	2.06	2.66	3.27	4.80
N_3S_1	0.31	1.17	2.73	3.34	4.29	5.73
N_3S_2	0.31	1.07	2.62	3.31	4.28	5.66
N_3S_3	0.28	0.96	2.22	2.87	3.46	5.11
N_3S_4	0.18	0.85	2.03	2.62	3.24	4.62
$LSD_{0.05}$	**NS**	**NS**	**0.63**	**0.44**	**0.86**	**0.82**
CV (%)	**9.24**	**7.48**	**7.55**	**6.51**	**8.08**	**6.90**

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.3 Crop growth rate (g m^{-2} day^{-1})

4.3.1 Effect of nitrogen

Crop growth rate of wheat was significantly influenced by different levels of N application during 27-57 DAS, 57-87 DAS and 87 DAS to harvest (Table 3). The result revealed that the highest crop growth rate, 0.92, 1.41 and 1.04 were recorded with N_2 (180 kg N ha^{-1}) during 27-57 DAS, 57-87 DAS and 87 DAS to harvest. The lowest crop growth rate 0.75, 1.16 and 0.90 respectively were recorded with N_1 (120 kg N ha^{-1}) during 27-57 DAS, 57-87 DAS and 87 to harvest respectively.

4.3.2 Effect of spacing

Significant variations of crop growth rate were found due to different plant spacing during 27-57 DAS, 57-87 DAS and 72 DAS to harvest (Table 3). The results revealed that the highest crop growth rate (2.26 and 1.45) was obtained with the spacing of S_2 (5 cm x 20 cm) during 57-87 DAS and 87 DAS to harvest, respectively. But during 27-57 DAS the highest crop growth rate (1.47) was found with the spacing of S_1 (3 cm x 20 cm). On the other hand the lowest crop growth rate (0.45, 0.72 and 0.53) was obtained from the spacing of S_4 (10 cm) during 27-57 DAS, 57-87 DAS and 87 DAS to harvest, respectively.

4.3.3 Interaction effect of nitrogen and plant spacing

Crop growth rates were greatly influenced by interaction effect of nitrogen and plant spacing (Table 3). It was observed that during 27-57 DAS, 57-87 DAS and 87 DAS to harvest; N_2S_1, N_2S_2 and again N_2S_2 respectively showed the highest crop growth rate (1.58, 2.59 and 1.57 respectively) which was not significantly different from N_1S_1 at 87 DAS to harvest. On the other hand the lowest crop growth rate during 27-57 DAS, 57-87 DAS and 87 DAS to harvest (0.33, 0.61 and 0.65 respectively) was observed in N_1S_4, N_3S_4 and N_2S_4, respectively.

Table 3: Crop growth rate (g m^{-2} day^{-1}) of wheat as affected by nitrogen levels, plant spacing and their interaction effect at different days

Treatments	27 – 57 DAS	57 – 87 DAS	87 DAS – harvest
Nitrogen (N)			
N_1	0.75	1.16	0.90
N_2	0.92	1.41	1.04
N_3	0.90	1.31	0.96
$LSD_{0.05}$	0.04	0.03	0.03
CV (%)	4.06	3.07	3.37
Spacing (S)			
S_1	1.47	1.22	1.22
S_2	0.93	2.26	1.45
S_3	0.58	0.98	0.67
S_4	0.45	0.72	0.53
$LSD_{0.05}$	**0.04**	**0.03**	**0.03**
CV (%)	**4.06**	**3.07**	**3.37**
Interaction (N×S)			
N_1S_1	1.35	1.94	1.54
N_1S_2	0.73	1.20	1.28
N_1S_3	0.60	0.84	0.70
N_1S_4	0.33	0.67	0.65
N_2S_1	1.58	2.26	1.17
N_2S_2	1.09	2.59	1.57
N_2S_3	0.48	1.03	0.65
N_2S_4	0.44	0.89	0.47
N_3S_1	1.48	1.36	1.23
N_3S_2	0.98	1.09	1.22
N_3S_3	0.67	1.06	0.67
N_3S_4	0.57	0.61	0.56
$LSD_{0.05}$	**0.08**	**0.05**	**0.05**
CV (%)	**4.04**	**3.07**	**3.37**

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg Nha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.4 Relative growth rate (g g^{-1} day^{-1})

4.4.1 Effect of nitrogen

Relative growth rate of wheat during 27-57 DAS, 57-87 DAS and 87 DAS to harvest were not significantly influenced by different levels of nitrogen(Table 4). But the result revealed that numerically the maximum relative growth rate, 0.12, 0.016 and 0.006 respectively were recorded with N_1 (120 kg N ha^{-1}) at 27-57 DAS, 57-87 DAS and 87 DAS to harvest, respectively. On the other hand the minimum relative growth rate, 0.12, 0.016 and 0.005 respectively were recorded with N_2 (180 kg N ha^{-1}) and N_3 (240 kg N ha^{-1}) during 27-57 DAS, 57-87 DAS and 87 DAS to harvest respectively.

4.4.2 Effect of spacing

Non-significant variation on relative growth rate was found due to different plant spacing during 27-57 DAS, 57-87 DAS and 87 DAS to harvest (Table 4). But the result revealed that numerically the maximum relative growth rate (0.14, 0.017 and 0.007) was obtained with the spacing of S_4 (10 cm), S_3 (7 cm) and S_2 (5 cm) respectively during 27-57 DAS, 57-87 DAS and 87 DAS to harvest respectively. On the other hand the minimum crop growth rate (0.10, 0.015 and 0.004) was obtained from the spacing of S_1 (3 cm), S_2 (5 cm) and S_1 (3 cm) respectively during 27-57 DAS, 57-87 DAS and 87 DAS to harvest respectively.

4.4.3 Interaction effect of nitrogen and plant spacing

Relative growth rate was not influenced by interaction effect of nitrogen and plant spacing (Table 4). But it was observed that at 27-57 DAS, 57-87 DAS and 87 DAS to harvest; N_1S_3, N_2S_3 and N_1S_2 showed the maximum relative growth rate (0.166, 0.018 and 0.007 respectively). On the other hand the minimum relative growth rate at 27-57

DAS, 57-87 DAS and 87 DAS to harvest (0.098, 0.013 and 0.003) was observed in N_1S_2, N_3S_2 and N_3S_1 respectively.

Table 4: Relative growth rate (g g^{-1} day^{-1}) of wheat as affected by nitrogen levels, plant spacing and their interaction effect at different days

Treatments	27 – 57 DAS	57 – 87 DAS	87 DAS – harvest
Nitrogen (N)			
N_1	0.12	0.016	0.006
N_2	0.12	0.016	0.005
N_3	0.12	0.016	0.005
$LSD_{0.05}$	NS	NS	NS
CV (%)	4.14	3.19	3.56
Spacing (S)			
S1	0.10	0.017	0.004
S2	0.11	0.015	0.007
S3	0.13	0.017	0.005
S4	0.14	0.016	0.006
LSD0.05	NS	NS	NS
CV (%)	4.14	3.19	3.56
Interaction (N×S)			
N_1S_1	0.108	0.016	0.005
N_1S_2	0.098	0.015	0.007
N_1S_3	0.166	0.016	0.006
N_1S_4	0.113	0.017	0.006
N_2S_1	0.105	0.016	0.005
N_2S_2	0.109	0.014	0.005
N_2S_3	0.107	0.018	0.005
N_2S_4	0.141	0.015	0.005
N_3S_1	0.103	0.017	0.003
N_3S_2	0.110	0.013	0.006
N_3S_3	0.119	0.016	0.004
N_3S_4	0.148	0.017	0.004
$LSD_{0.05}$	**NS**	**NS**	**NS**
CV (%)	**4.14**	**3.19**	**3.56**

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.5 Tillers plant^{-1}

4.5.1 Effect of nitrogen

Number of tillers plant^{-1} of wheat was not significantly influenced by different levels of N application at 27, 42, 57, 72, 87 DAS and harvest (Table 5). But the result revealed that numerically maximum number of tillers plant^{-1} (1.43, 2.17, 3.67, 3.33, 3.17 and 3.18) were recorded with N_3 (application of 240 kg N ha^{-1}) at 27, 57, 72, 87 DAS and harvest, respectively and the minimum number of tillers plant^{-1} (1.30, 1.92, 3.53, 2.98, 3.02 and 3.03) were recorded with N_1 (application of 120 kg N ha^{-1}) at all the stages (27, 42, 57, 72, 87 DAS and harvest, respectively). Different scientist observed highest number of tillers (6.43) at 140 kg N ha^{-1} (Alam *et al.*, 2007), 180 kg N ha^{-1} (Hossain, 2006).

4.5.2 Effect of spacing

Significant variation of number of tillers plant^{-1} was found due to different planting spacing in all the stages of crop growth (Table 5). The results revealed that the highest number of tillers plant^{-1} (1.66, 2.27, 3.83, 3.34, 3.22 and 3.28 at 27, 42, 57, 72, 87 DAS and harvest, respectively) were obtained with the spacing of S_4 (10 cm) which was not significantly different from S_2 (5 cm) at 27, 57, 87 DAS and harvest and with S_3 (7 cm) at 57 and 87 DAS. On the other hand the lowest number of tillers plant^{-1} (1.03, 1.76, 3.07, 3.13, 2.91 and 2.93) were obtained from the spacing of S_1 (3 cm) at 27, 42, 57, 72, 87 DAS and harvest, respectively which was not significantly different from S_2 (5 cm) and S_3 (7 cm) 72 DAS. Dixit and Gupta (2004) observed that 100 kg seed ha^{-1} gave highest tiller number and increasing the seeding rate significantly reduced the number of tillers. Again Mozumder (2001) obtained the highest tiller plant^{1} from the lowest seed rate (75 kg seeds ha^{-1}).

4.5.3 Interaction effect of nitrogen and plant spacing

Irrespective of treatment difference, tiller production increased with time and picked of 57 DAS then reduced little mortality up to harvest. Number of tillers plant^{-1} at different days after sowing (DAS) was greatly influenced by interaction effect of nitrogen and plant spacing (Table 5). It was observed that at 27 DAS the highest tiller plant^{-1} (2.03) was obtained from N_2S_4 and followed by N_3S_3 (1.73), N_2S_2 (1.67), N_3S_4 & N_1S_2 (1.60), N_2S_3 (1.47), N_1S_4 (1.33) and N_3S_2 (1.20). At 42 DAS, N_3S_3 was the highest (2.53) and followed by N_3S_4 (2.47), N_2S_4 (2.33), N_2S_2 (2.13), N_1S_3 (2.07) and N_1S_2, N_1S_4 & N_3S_2 (2.00). At 57 DAS, N_2S_2 was greater (4.13) and at par with N_3S_3 (4.07), N_1S_4 (4.00), N_1S_2 & N_3S_4 (3.87), N_1S_3 (3.73), N_2S_3 (3.67) & N_3S_2 (3.47). At 72 DAS, N_2S_2 was highest (3.61) and similar with N_3S_4 (3.60). At 87 DAS, N_2S_2 was highest (3.40) and followed by N_1S_4, N_3S_3 (3.27) & N_2S_4, N_3S_4 (3.20). At harvest, N_2S_2 was maximum (3.44) and at par with N_1S_4 (3.29), N_3S_3 (3.28), N_3S_4 (3.23), N_2S_4 (3.22) and N_3S_2 (3.15). On the other hand the lowest number of tillers plant^{-1} (0.57, 1.60, 3.00, 2.87, 2.67 and 2.69 at 27, 42, 72, 87 and harvest, respectively) was obtained by N_1S_1. Different scientist obtained the highest tillers plant^{-1} at 90 kg seeds ha^{-1} in combination with 160 kg N ha^{-1} (Hossain, 2005), 75 kg seeds ha^{-1} in combination with 120 kg N ha^{-1} (Mozumder, 2001).

Table 5: Tillers $plant^{-1}$ of wheat as affected by nitrogen levels, plant spacing and their interaction effect at different days

Treatments	27 DAS	42 DAS	57 DAS	72 DAS	87 DAT	At harvest
Nitrogen (N)						
N_1	1.30	1.92	2.66	2.98	3.02	4.56
N_2	1.35	1.93	3.60	3.05	3.03	4.98
N_3	1.43	2.17	3.67	3.33	3.17	4.77
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
CV (%)	6.11	7.94	9.99	8.36	8.22	7.98
Spacing (S)						
S_1	1.03	1.76	3.07	3.13	2.91	2.93
S_2	1.49	1.93	3.82	3.00	3.20	3.26
S_3	1.26	2.09	3.69	3.11	2.96	2.98
S_4	1.66	2.27	3.83	3.34	3.22	3.28
$LSD_{0.05}$	0.43	0.42	0.36	0.24	0.16	0.15
CV (%)	6.11	7.94	9.99	8.36	8.22	7.98
Interaction (N×S)						
N_1S_1	0.57	1.60	3.00	2.87	2.67	2.69
N_1S_2	1.60	2.00	3.87	3.13	3.07	3.05
N_1S_3	1.00	2.07	3.73	3.07	2.93	2.95
N_1S_4	1.33	2.00	4.00	3.00	3.27	3.29
N_2S_1	0.93	1.67	3.13	2.88	2.87	2.86
N_2S_2	1.67	2.13	4.13	3.61	3.40	3.44
N_2S_3	1.47	1.67	3.67	2.93	2.80	2.79
N_2S_4	2.03	2.33	3.20	3.33	3.20	3.22
N_3S_1	1.17	1.67	3.07	2.93	3.07	3.06
N_3S_2	1.20	2.00	3.47	3.00	3.13	3.15
N_3S_3	1.73	2.53	4.07	3.13	3.27	3.28
N_3S_4	1.60	2.47	3.87	3.60	3.20	3.23
$LSD_{0.05}$	0.75	0.72	0.62	0.16	0.24	0.27
CV (%)	6.11	7.94	9.99	8.36	8.22	7.98

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.6 Effective tillers $plant^{-1}$

4.6.1 Effect of nitrogen

Number of effective tillers $plant^{-1}$ of wheat was significantly influenced by different levels of N application at 72, 87 DAS and harvest except 57 DAS (Table 6). The result revealed that the highest number of effective tillers plant^{-1} (2.78, 2.53 and 4.38) were recorded with N_2 (180 kg N ha^{-1}) at 72, 87 DAS and at harvest, respectively and was not significantly different from N_3 (240 kg N ha^{-1}) at 87 DAS. On the other hand the lowest number of effective tillers plant^{-1} (2.53, 2.28 and 4.13) was recorded with N_1 (120 kg N ha^{-1}) at 72, 87 DAS and harvest, respectively. The highest effective tiller number obtained from 140 kg N ha^{-1} (Alam *et al.*, 2007), 150 kg N ha^{-1} (Akter, 2005), 180 kg N ha^{-1} (Das, 2003).

4.6.2 Effect of spacing

Significant variation of number of effective tillers plant^{-1} was found due to different plant spacing at 57, 72, 87 DAS and harvest (Table 6). It was noted that S_4 gave maximum effective tillers plant^{-1} (2.38, 2.71 & 2.53) at 57, 72 and 87 DAS, respectively and followed by S_2 and S_3 in almost all these days of samplings. At harvest, S_2 gave maximum (4.64) and at par with S_4 (4.44). On the other hand the lowest number of effective tillers plant^{-1} (1.93, 2.56, 2.38 and 3.56) were obtained from the spacing of S_1 (3 cm) at 57, 72, 87 DAS and harvest, respectively. Mahajan *et al.* (1991) got the highest tiller number from 100 kg seeds ha^{-1}.

4.6.3 Interaction effect of nitrogen and plant spacing

Number of effective tillers plant^{-1} at different days after sowing (DAS) was greatly influenced by interaction effect of nitrogen and plant spacing (Table 6). It was observed that at 57, 72, 87 DAS and harvest; N_2S_2 showed the highest number of effective tillers plant^{-1} (2.53, 3.07, 2.93 and 5.47, respectively). Almost all the combinations except N_1S_1 showed very closer results to that of N_2S_2 at 57, 72 and 87

DAS. No treatment combination was at par with N_2S_2 at harvest. On the other hand the lowest number of effective tillers plant^{-1} at 57, 72, 87 DAS and harvest (1.80, 2.33, 2.13 and 3.33) was obtained in N_1S_1. Hossain (2005) concluded that the highest number of effective tillers per hill was found in combined effect of 120 kg N and 90 kg seeds ha^{-1} and Mozumder (2001) got it from the combination of 75 kg seeds and 120 kg N ha^{-1}.

4.7 Non-effective tillers plant^{-1}

Irrespective of treatment variable, almost 25% non effective tillers plant^{-1}was observed at harvest (Table 6). Any treatment factor (Nitrogen or spacing) or their combination could not reduce the non effectiveness of plant remarkably.

Table 6. Effective and non-effective tillers plant^{-1} as affected by nitrogen levels, plant spacings and their interaction effect at different days

Treatments	Number of effective tiller plant^{-1}				Number of non effective tiller plant^{-1}
	57 DAS	72 DAS	87 DAT	At harvest	At harvest
Nitrogen (N)					
N_1	2.13	2.53	2.28	4.13	1.41
N_2	2.27	2.78	2.53	4.38	1.26
N_3	2.10	2.60	2.47	4.17	1.28
$LSD_{0.05}$	NS	0.15	0.14	0.20	NS
CV (%)	8.57	8.14	5.41	7.17	5.01
Spacing (S)					
S_1	1.93	2.56	2.38	3.56	1.33
S_2	2.27	2.60	2.47	4.64	1.32
S_3	2.09	2.69	2.33	4.27	1.31
S_4	2.38	2.71	2.53	4.44	1.29
$LSD_{0.05}$	0.40	0.14	0.14	0.24	NS
CV (%)	8.57	8.14	5.41	7.17	5.01
Interaction (N×S)					
N_1S_1	1.80	2.33	2.13	3.33	1.60
N_1S_2	2.27	2.47	2.20	4.20	1.26
N_1S_3	2.07	2.80	2.27	4.27	1.26
N_1S_4	2.33	2.47	2.53	3.53	1.26
N_2S_1	2.13	2.40	2.33	3.73	1.43
N_2S_2	2.53	3.07	2.93	5.47	1.13
N_2S_3	2.13	2.47	2.27	4.87	1.27
N_2S_4	2.27	2.73	2.60	3.80	1.33
N_3S_1	1.87	2.80	2.67	4.53	1.26
N_3S_2	2.00	2.53	2.27	4.27	1.26
N_3S_3	2.07	2.73	2.47	4.20	1.33
N_3S_4	2.54	2.87	2.47	4.53	1.33
$LSD_{0.05}$	0.43	0.45	0.44	0.48	NS
CV (%)	8.57	8.14	5.41	7.17	5.01

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.8 Length of spike (cm)

4.8.1 Effect of nitrogen

Spike length of wheat was significantly influenced by different levels of N application at 72, 87 DAS and harvest except 57 DAS (Fig. 5). The result revealed that the highest spike length plant^{-1} (10.01, 11.16 and 11.21 cm) were recorded with N_2 (180 kg N ha^{-1}) at 72 and 87 DAS and harvest which was similar with N_3 (240 kg N ha^{-1}) at 72 DAS. On the other hand the lowest spike length plant^{-1} (9.93, 9.96 and 10.00 cm) was recorded with N_1 (120 kg N ha^{-1}) at 72, 87 DAS and harvest. Hossain (2006) observed that spike length significantly increased with N levels.

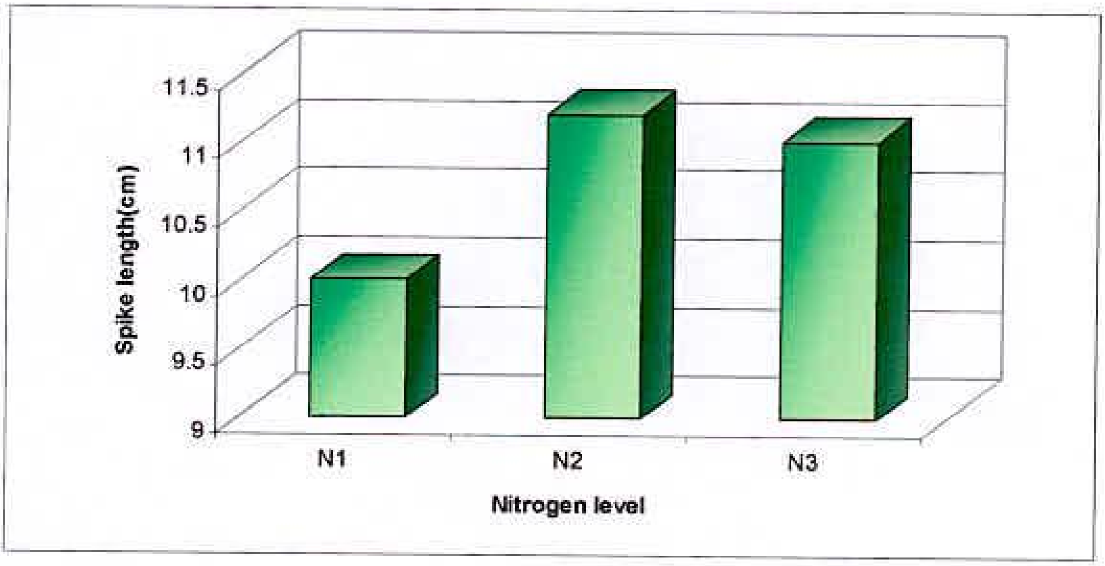

Figure 5: Spike length of wheat as affected by nitrogen levels at harvest ($LSD_{0.05}$ = 0.13 at harvest)

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

4.8.2 Effect of spacing

Significant variation on spike length plant^{-1} was found due to different plant spacing at 72, 87 DAS and harvest accept 57 DAS (Fig. 6). The results revealed that the highest spike length plant^{-1} (10.14, 11.31 and 11.35 cm) was obtained with the spacing of S_2 (5 cm). On the other hand the lowest spike length plant^{-1} (9.28, 10.33 and 10.35) was obtained from the spacing of S_4 (10 cm) at 72, 87 DAS and harvest respectively. Mozumder (2001) reported the longest spike of 8.98 cm with 75 kg seeds ha^{-1} which was followed by 8.76 and 8.4 cm obtained from the seed rate of 100 and 125 kg ha^{-1}. Torofder (1993) found that length of spike decreased with the increase of seed rate.

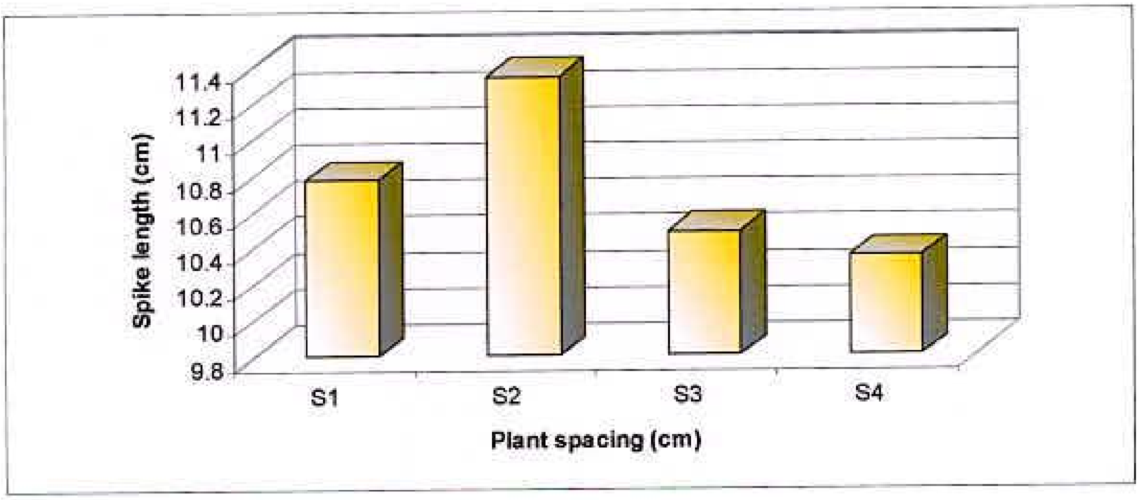

Figure 6: Spike length of wheat as affected by plant spacings at harvest ($LSD_{0.05}$ = 0.14 at harvest)

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.8.3 Interaction effect of nitrogen and plant spacing

Spike length plant^{-1} at different days after sowing (DAS) was greatly influenced by interaction effect of nitrogen and plant spacing (Table 7). It was observed that at 57, 72, 87 DAS and at harvest; N_2S_2 showed the highest spike length plant^{-1} (5.25, 10.53, 11.95 and 12.07 cm, respectively) which was at par with N_2S_1, N_3S_1 and N_2S_3 at 57 DAS; N_3S_1 at 72 DAS. On the other hand the lowest spike length plant^{-1} at 57, 72, 87 DAS and harvest (4.67, 8.48, 9.51 and 9.62 cm) was observed in N_1S_1. Mozumder (2001) reported that the longest spike length (9.66 cm) was obtained from the interaction of 75 kg seed with 90 kg N ha^{-1}.

Pandey *et al.* (2004) reported that spike length increase significantly only up to 120 kg N ha^{-1} and further increase in fertilizer level had not any significant effect on this attribute. Seed rate had not any significant effect on spike length.

Table 7. Spike length of wheat as affected by interaction effect of nitrogen levels and plant spacings at different days

Treatments	57 DAS	72 DAS	87 DAT	At harvest
N_1S_1	4.67	8.48	9.51	9.62
N_1S_2	5.03	9.88	10.89	10.93
N_1S_3	4.80	8.67	9.70	9.68
N_1S_4	4.85	8.71	9.74	9.77
N_2S_1	5.16	10.11	11.24	11.21
N_2S_2	5.25	10.53	11.95	12.07
N_2S_3	4.93	9.78	10.80	10.86
N_2S_4	4.81	9.60	10.65	10.70
N_3S_1	5.20	10.40	11.44	11.50
N_3S_2	5.09	10.00	11.09	11.06
N_3S_3	4.89	9.71	10.88	10.94
N_3S_4	4.92	9.54	10.60	10.58
$LSD_{0.05}$	0.19	0.25	0.25	0.25
CV (%)	5.98	4.35	6.42	7.30

4.9 1000-seed weight (g)

4.9.1 Effect of nitrogen

Weight of 1000-seeds of wheat was significantly influenced by different levels of N application (Table 8). The results revealed that the highest 1000 seed weight (42.53 g) was recorded with N_2 (180 kg N ha^{-1}) and at par with N_3 (240 kg N ha^{-1}). On the other hand the lowest 1000-seed weight (40.06 g) was recorded with N_1 (120 kg N ha^{-1}).

4.9.2 Effect of spacing

Significant variation on 1000-seed weight was found due to different plant spacing (Table 8). The results revealed that the highest 1000-seed weight (43.41 g) was obtained with the spacing of S_2 (5 cm). On the other hand the lowest 1000-seed weight (40.12 g) was obtained from the spacing of S_4 (10 cm).

4.9.3 Interaction effect of nitrogen and plant spacing

Weight of 1000-seeds was greatly influenced by interaction effect of nitrogen and plant spacing (Table 8). It was observed that the highest 1000-seed weight (44.73 g) was recorded from N_2S_2 which was similar with N_3S_1 (43.81 g). On the other hand the lowest 1000-seed weight (38.56 g) was observed in N_1S_4 which was not significantly different from N_1S_3 and N_1S_1.

Table 8: 1000 grain weight of wheat as affected by nitrogen levels, plant spacings and their interaction effect at different days

Treatment	Weight of 1000 seeds
Nitrogen (N)	
N_1	40.06
N_2	42.53
N_3	42.10
$LSD_{0.05}$	0.87
Spacing (S)	
S_1	42.25
S_2	43.41
S_3	40.47
S_4	40.12
$LSD_{0.05}$	1.01
Interaction (N×S)	
N_1S_1	39.98
N_1S_2	42.91
N_1S_3	38.78
N_1S_4	38.56
N_2S_1	42.94
N_2S_2	44.73
N_2S_3	41.44
N_2S_4	41.01
N_3S_1	43.81
N_3S_2	42.60
N_3S_3	41.20
N_3S_4	40.78
$LSD_{0.05}$	1.75
CV (%)	7.07

N_1 = 120 (kg ha^{-1}), N_2 = 180 (kg ha^{-1}), N_3 = 240 (kg ha^{-1})

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

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

4.10.1 Effect of nitrogen

Grain yield of wheat was significantly influenced by different levels of N application (Fig. 7). The results revealed that the highest grain yield (3.46 t ha^{-1}) was recorded with N_2 (180 kg N ha^{-1}) and statistically similar with N_3 (240 kg N ha^{-1}). On the other hand the lowest grain yield (3.22 t ha^{-1}) was recorded with N_1 (120 kg N ha^{-1}). Das (2003) reported 3.13 t ha^{-1} grain yield of wheat with 180 kg N ha^{-1}.

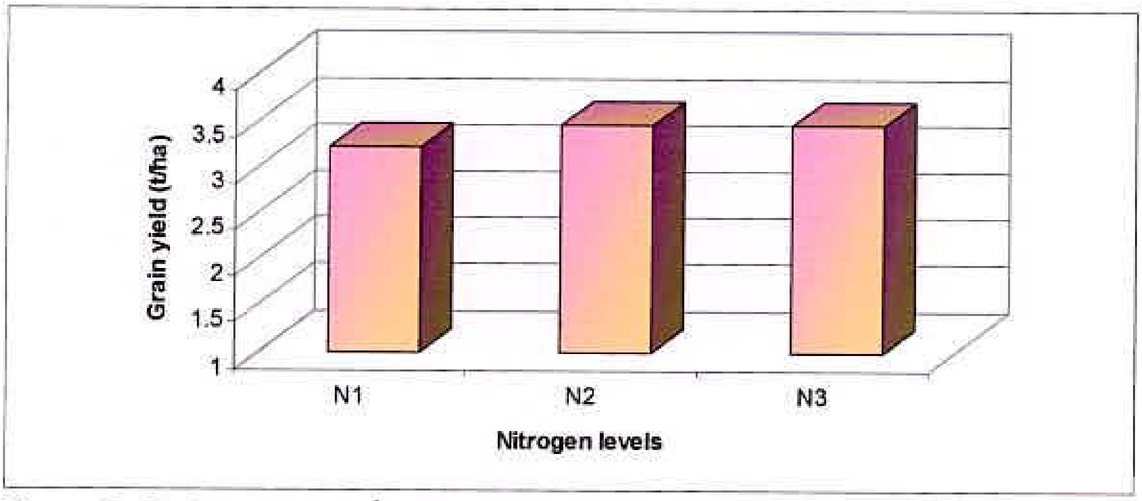

Figure 7: Grain yield (t ha^{-1}) of wheat as affected by nitrogen levels ($LSD_{0.05}$ = 0.13)

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

4.10.2 Effect of spacing

Significant variation on grain yield was found due to different plant spacing (Fig. 8). The results revealed that the highest grain yield (3.76 t ha^{-1}) was obtained with the spacing of S_2 (5 cm). On the other hand the lowest grain yield (2.87 t ha^{-1}) was obtained from the spacing of S_4 (10 cm).

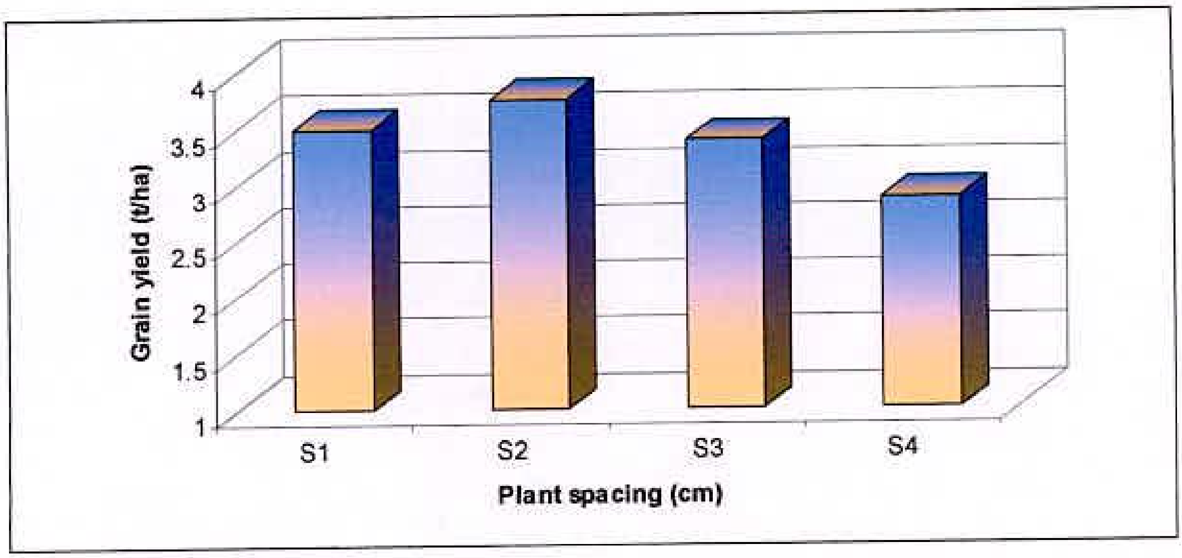

Figure 8: Grain yield of wheat as affected by plant spacings ($LSD_{0.05}$ = 0.16)

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

4.10.3 Interaction effect of nitrogen and plant spacing

Grain yield was greatly influenced by interaction effect of nitrogen and plant spacing (Fig. 9). It was observed that the highest grain yield (3.94 t ha^{-1}) was recorded from N_2S_2 which was statistically similar with N_3S_1 (3.83 t ha^{-1}), N_3S_2 (3.69 t ha^{-1}) and N_1S_2 (3.65 t ha^{-1}). On the other hand the lowest grain yield (2.81 t ha^{-1}) was observed in N_3S_4. Grain yield was attributed due to increased effective tillers $plant^{-1}$, No. of grains $spike^{-1}$ and 1000 grain weight. Different scientist reported maximum grain yield with 120 kg N ha^{-1} X 120 kg seeds ha^{-1} (Hossain, 2005 and Mozumder, 2001).

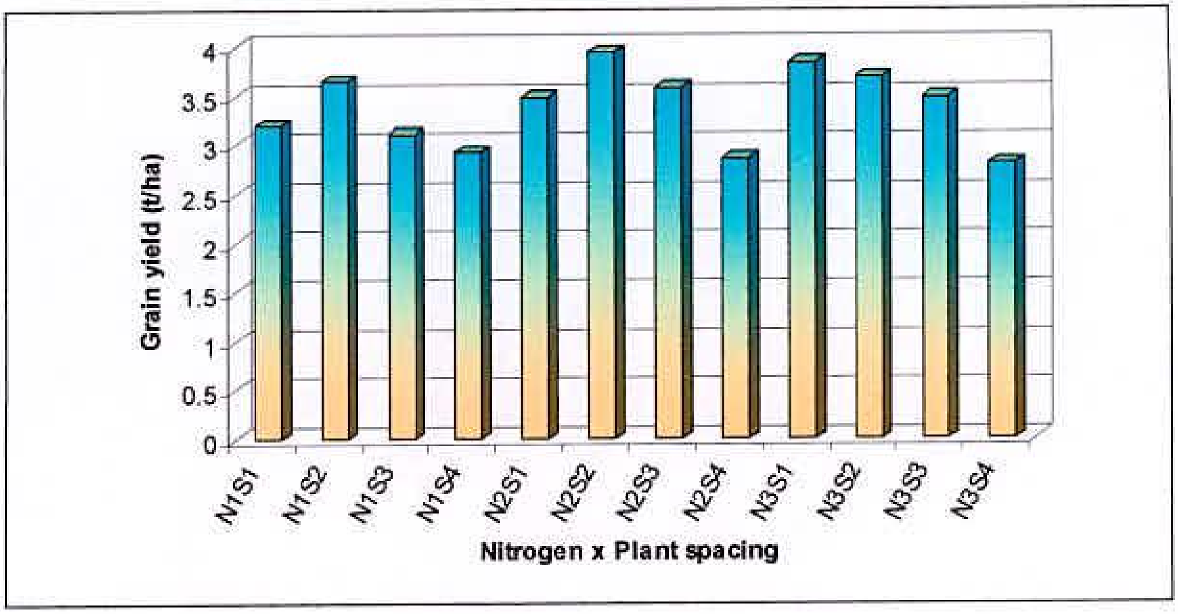

Figure 9: Grain yield (t ha^{-1}) of wheat as affected by nitrogen levels and plant spacings ($LSD_{0.05}$ = 0.28)

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

4.11.1 Effect of nitrogen

Straw yield of wheat was significantly influenced by different levels of N application (Table 9). The result revealed that the highest straw yield (6.15 t ha^{-1}) was recorded with N_2 (180 kg N ha^{-1}). On the other hand the lowest straw yield (5.16 t ha^{-1}) was recorded with N_1 (120 kg N ha^{-1}). Das (2003) reported 4.17 t ha^{-1} straw yield of wheat with 180 kg N ha^{-1}.

4.11.2 Effect of spacing

Significant variation on straw yield was found due to different plant spacing (Table 9). The results revealed that the highest straw yield (6.38 t ha^{-1}) was obtained with the spacing of S_2 (5 cm). On the other hand the lowest straw yield (5.21 t ha^{-1}) was obtained from the spacing of S_4 (10 cm).

4.11.3 Interaction effect of nitrogen and plant spacing

Straw yield was greatly influenced by interaction effect of nitrogen and plant spacing (Table 9). It was observed that the highest straw yield (7.16 t ha^{-1}) was recorded from N_2S_2. On the other hand the lowest straw yield (4.58 t ha^{-1}) was observed in N_3S_4. Straw yield was attributed due to increased effective tillers $plant^{-1}$, spike length and 1000 grain weight. Different scientist reported maximum straw yield with 120 kg N ha^{-1} X 120 kg seed ha^{-1} (Hossain, 2005 and Mozumder, 2001).

4.12 Harvest index (%)

4.12.1 Effect of nitrogen

Harvest index of wheat was significantly influenced by different levels of N application (Table 9). The result revealed that the highest harvest index (40.14%) was recorded with N_2 (180 kg N ha^{-1}). On the other hand the lowest harvest index (34.36%) was recorded with N_1 (120 kg N ha^{-1}).

4.12.2 Effect of spacing

Significant variation on harvest index was found due to different plant spacing (Table 9). The results revealed that the highest harvest index (41.93%) was obtained with the spacing of S_2 (5 cm). On the other hand the lowest harvest index (33.20%) was obtained from the spacing of S_4 (10 cm).

4.12.3 Interaction effect of nitrogen and plant spacing

Harvest index was greatly influenced by interaction effect of nitrogen and plant spacing (Table 9). It was observed that the highest harvest index (46.27%) was recorded from N_2S_2. On the other hand the lowest harvest index (30.23%) was observed in N_3S_4 which was not significantly different from N_1S_3 (30.28%).

Table 9: Straw yield and harvest index of wheat as affected by nitrogen levels, plant spacings and interaction of nitrogen levels and plant spacings

Treatments	Straw yield (t ha^{-1})	Harvest index (%)
Nitrogen (N)		
N_1	5.16	34.36
N_2	6.15	40.14
N_3	5.70	37.72
$LSD_{0.05}$	0.13	1.01
Spacing (S)		
S_1	5.77	39.81
S_2	6.38	41.93
S_3	5.29	34.70
S_4	5.21	33.20
$LSD_{0.05}$	0.16	1.18
Interaction (N×S)		
N_1S_1	5.44	33.03
N_1S_2	6.14	39.12
N_1S_3	5.44	30.28
N_1S_4	4.85	35.02
N_2S_1	5.68	42.29
N_2S_2	7.16	46.27
N_2S_3	5.93	37.66
N_2S_4	4.75	34.33
N_3S_1	6.49	44.10
N_3S_2	6.49	40.40
N_3S_3	5.48	36.16
N_3S_4	4.58	30.23
$LSD_{0.05}$	0.28	2.03
CV (%)	4.75	3.16

N_1 = 120 kg N ha^{-1}, N_2 = 180 kg N ha^{-1}, N_3 = 240 kg N ha^{-1}

S_1 = 3 cm, S_2 = 5 cm, S_3 = 7 cm, S_4 = 10 cm

Chapter 5
Summary and Conclusion

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during December 2007 to March 2008 to study the response of wheat to nitrogen levels and plant spacing under the Modhupur Tract (AEZ-28). The experiment consisted of two factors with different levels viz. A. Nitrogen levels (3): N_1 (120 kg N ha^{-1}), N_2 (180 kg N ha^{-1}) & N_3 (240 kg N ha^{-1}) and B. Plant spacing (4): S_1 = (3 cm), S_2 = (5 cm), S_3 = (7 cm) & S_4 = (10 cm). The experiment was laid out in a split-plot design with three replications. The nitrogen levels were in main plot and plant spacing in sub-plot.

All management practices and intercultural operations such as weeding, irrigation and pest management were done as and when necessary. The data were collected on plant height, above ground dry weight $plant^{-1}$, tillers $plant^{-1}$, effective tillers $plant^{-1}$, non-effective tillers $plant^{-1}$, spike length (cm), weight of 1000 seeds, grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%).

The data on crop growth parameters like plant height, above ground dry weight $plant^{-1}$, tillers $plant^{-1}$, effective tillers $plant^{-1}$, non-effective tillers $plant^{-1}$ and spike length were recorded at 15 days interval starting from 27 days after sowing (DAS) upto harvest. The 1000-grain weight, grain yield, straw yield and harvest index were recorded at harvest. Data were analyzed using MSTAT package program. The mean values were separated using least significant difference (LSD) test at 5% level of significance.

Results showed that different levels of nitrogen and different plant spacing had significant effect on growth parameters and yield parameters.

The different levels of nitrogen application significantly differed the plant height, above ground dry weight plant^{-1}, effective tillers plant^{-1} and spike length. The highest plant height (82.83 cm), above ground dry weight plant^{-1} (5.38 g), effective tillers plant^{-1} (4.38) and spike length (11.21 cm) at harvest were found with the application of 180 kg N ha^{-1}. The lowest results (80.61 cm, 5.13g, 4.13 and 10 cm, respectively) were observed with the application of 120 kg N ha^{-1}. It was also observed that different nitrogen levels had no significant effect on tillers plant^{-1}. Yield performance differed significantly at different nitrogen levels. The highest 1000 seed weight (42.53 g), grain yield (3.46 t ha^{-1}), straw yield (6.15 t ha^{-1}) and harvest index (40.14%) were found with the application of 180 kg N ha^{-1} and the lowest performance (40.06 g, 3.22 t ha^{-1}, 5.16 t ha^{-1} and 34.36%, respectively) were observed with the application of 120 kg N ha^{-1}.

Different spacing significantly differed the plant height, above ground dry weight plant^{-1}, effective tillers plant^{-1} and spike length. The highest plant height (83.73 cm), above ground dry weight plant^{-1} (5.49 g), effective tillers plant^{-1} (4.64) and spike length (11.35 cm) at harvest were found with 20 cm × 5 cm spacing at harvest. The lowest plant height (79.34 cm), above ground dry weight plant^{-1} (4.94 g) and spike length (10.35 cm) were observed with 20 cm × 10 cm spacing and effective tillers plant^{-1} (3.56) was observed with 20 cm × 3 cm spacing. Yield performance differed significantly at different spacing. The highest 1000 seed weight (43.41g) was found with the spacing of S_2 and the lowest performance (40.12g) was observed with S_4. The highest grain yield (3.76 t ha^{-1}), straw yield (6.38 t ha^{-1}) and harvest index (41.93%) were found with the S_4 and the lowest performance (2.87 t ha^{-1}, 5.21 t ha^{-1} and 33.20%, respectively) were observed with S_4.

Interaction effect of different levels of nitrogen and plant spacing had an impact on plant height, above ground dry weight plant^{-1}, effective tillers plant^{-1}, spike length, 1000 seed weight, grain yield, straw yield and harvest index. The highest plant height (85.90 cm), above ground dry matter (5.88 g), effective tillers plant^{-1} (5.47), spike length (12.07 cm) and 1000 seed weight (44.73 g) at harvest were found with the combined effect of 180 kg N ha^{-1} with 20 cm× 5 cm spacing and the lowest results 77.47 cm plant height with 120 kg N ha^{-1} with 20 cm × 10 cm and above ground dry weight plant^{-1} (4.62 g) in N_3S_4, effective tillers plant^{-1} (3.33) in N_1S_4, spike length (9.62 cm) in N_1S_4 and 1000 seed weight (38.56 g) were observed with the combination of 120 kg N ha^{-1} and 20 cm × 3 cm spacing. The highest grain yield (3.94 t ha^{-1}), straw yield (7.16 t ha^{-1}) and harvest index (46.27%) were found with the combined effect of 180 kg N ha^{-1} with 20 cm × 5 cm spacing and the lowest grain yield (2.81 t ha^{-1}), straw yield (4.58 t ha^{-1}) and harvest index (30.23%) were observed with the combined effect of 240 kg N ha^{-1} with 20 cm × 10 cm spacing.

However, considering all these factors studied, it is concluded that the present wheat variety could be cultivated with nitrogen @ 180 kg ha^{-1} along with 20 cm × 5 cm spacing for optimum yield. The result could be further tested under different agro climatic conditions of Bangladesh.

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Appendices

APPENDICES

Appendix I. Morphological, physical and chemical characteristics of initial soil (0-15 cm depth)

A. Physical composition of the soil

Soil separates	(%)	Methods employed
Sand	26.90	Hydrometer method (Day, 1995)
Silt	27.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

B. Chemical composition of the soil

Sl.	Soil characteristics	Analytical data	Methods employed
1.	Organic carbon (%)	0.82	Walkley and Black, 1947
2.	Total N (kg ha^{-1})	1790.00	Bremmer and Mulvaney, 1982
3.	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4.	Total P (ppm)	840.00	Olsen and Sommers, 1982
5.	Available N (kg ha^{-1})	54.00	Bremmer, 1965
6.	Available P (kg ha^{-1})	69.00	Olsen and Dean, 1965
7.	Exchangeable K (kg ha^{-1})	89.50	Pratt, 1965
8.	Available S (ppm)	16.00	Hunter, 1984
9.	pH (1:2.5 soil of water)	5.50	Jackson, 1958
10.	CEC	11.23	Chapmen, 1965

Appendix II. Monthly average Temperature, Relative Humidity and Total rainfall of the experimental site during the period from December 2007 to March 2008.

Year	Month	Air temperature (^0c)			Relative Humidity (%)		Rainfall
		Maximum	Minimum	Mean	3 PM	12 AM	(mm)
2007	Dec.	24.6	15.3	19.95	82.19	73.91	0
2008	Jan.	21.1	13.7	17.4	72.1	64.16	22
	Feb.	28.5	16.8	22.65	63	50.83	112
	Mar.	31.8	23.7	27.75	72.29	55.13	78

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

Appendix III. Source of variation, degree of freedom and mean square for plant height and dry matter

Source of variation	d.f.	Mean square											
		Plant height						Dry matter					
		27 DAS	42 DAS	57 DAS	72 DAS	87 DAS	At harvest	27 DAS	42 DAS	57 DAS	72 DAS	87 DAS	At harvest
R	2	9.95	7.83	106.31	54.49	60.46	131.59	0.017	0.09	1.52	3.14	4.94	3.05
N	2	3.06**	20.63*	10.93*	8.11*	9.17*	15.27*	0.002^{NS}	0.12^{NS}	0.65**	0.78*	1.56*	0.22**
Error I	4	3.32	4.49	24.81	20.86	10.44	50.87	0.003	0.06	0.17	0.10	0.39	1.65
S	3	4.32**	8.18*	0.27**	44.86*	16.18*	31.11*	0.009^{NS}	0.03^{NS}	0.06**	0.26**	0.17**	0.48**
N X S	6	5.70**	2.74*	4.78*	12.05*	9.36*	17.08*	0.005^{NS}	0.03^{NS}	0.25**	0.37*	0.72**	0.60*
Error II	18	1.01	1.19	1.10	1.20	1.04	1.01	0.003	0.02	0.13	0.17	0.25	0.23
Total	35												

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS = Not significant, R = Replication, N = Nitrogen and S = Plant spacing.

Appendix IV. Source of variation, degrees of freedom and mean square for CGR and RGR

Source of variation	Degrees of freedom	Mean square					
		Crop growth rate (CGR)			Relative growth rate (RGR)		
		27 – 57 DAS	57 – 87 DAS	87 DAS – Harvest	27 – 57 DAS	57 – 87 DAS	87 DAS – Harvest
R	2	0.006	0.002	0.004	0.001	0.000	0.002
N	2	0.103**	0.184**	0.063**	0.002^{NS}	0.001^{NS}	0.004^{NS}
Error I	4	0.002	0.003	0.002	0.000	0.000	0.000
S	3	1.875**	4.116**	1.728**	0.002^{NS}	0.002^{NS}	0.001^{NS}
N X S	6	0.037**	0.099**	0.029**	0.001^{NS}	0.001^{NS}	0.001^{NS}
Error II	18	0.002	0.001	0.001	0.000	0.000	0.000

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS = Not significant, R = Replication, N = Nitrogen and S = Plant spacing.

Appendix V. Source of variation, degree of freedom and mean square for yield attributes

Source of variation	d.f.	Mean square			
		Total tiller $plant^{-1}$	Effective tiller $plant^{-1}$	Non effective tiller $plant^{-1}$	Spike length
R	2	0.18	1.54	0.02	0.01
N	2	0.08**	0.22**	0.08^{NS}	5.08*
Error I	4	0.12	0.59	0.04	0.00
S	3	0.23**	2.02**	0.01^{NS}	1.76**
N X S	6	0.11**	0.83*	0.04^{NS}	0.47**
Error II	18	0.02	0.65	0.05	0.02
Total	35				

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS = Not significant, R = Replication, N = Nitrogen and S = Plant spacing.

Appendix VI. Source of variation, degree of freedom and mean square for 1000 grain weight, grain yield and harvest index of wheat

Source of variation	d.f.	Mean square		
		1000 grain weight	Grain yield	Harvest index
R	2	0.001	0.04	4.51
N	2	20.88*	0.23**	100.97*
Error I	4	0.001	0.02	0.08
S	3	21.48*	1.28*	153.89*
N X S	6	2.38*	0.12**	38.08*
Error II	18	1.04	0.03	1.40
Total	35			

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. R = Replication, N = Nitrogen and S = Plant spacing.