GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.) AS INFLUENCED BY NITROGEN AND SEED RATE

BY

KAKALI ROY

REGISTRATION NO. 25224/00345

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

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JANUARY-JUNE, 2006

Approved by:

....	....
(Prof. Dr. Md. Hazrat Ali)	**(Dr. Parimal Kanti Biswas)**
Supervisor	Co-Supervisor

....
(Dr. Parimal Kanti Biswas)
Chairman, Examination Committee
Department of Agronomy, SAU

CERTIFICATE

This is to certify that the thesis entitled **"Growth and yield of wheat (*Triticum aestivum* L.) as influenced by nitrogen and seed rate"** 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 **Kakali Roy, Registration No. 25224/00345** 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 26.06.06
Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)
Supervisor

Dedicated to
My
Beloved Parents

ACKNOWLEDGEMENT

All praises are due to Almighty God, the most gracious and merciful. Lord of the universe, who enabled the author to conduct and complete this work with the stipulated period of time.

I express my deepest sense of gratitude, profound and ever indebtedness to my academic supervisor Dr. Md. Hazrat Ali, Professor, Department of Agronomy, Sher-e- Bangla Agricultural University, Dhaka-1207, for his sincere supervision, untiring guidance, constant encouragement, valuable suggestions, and constructive comments throughout the period of research work and preparation of manuscript of the thesis.

I express my sincere appreciation, profound sense, respect and immense indebtedness to the co-supervisor Dr. Parimal Kanti Biswas, Chairman, Examination Committee, 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 the manuscript of the thesis.

I would like to express my deepest respect and boundless gratitude to all the respected teachers of the department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for the valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and research work.

I appreciate 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 my period of study and research.

I would like to express cordial thanks to my senior brother Mirza Hasanuzzaman and dear friends Sanjit, Motin, Tuly and Main for their heartiest assistance in my research period. I am very gratified especially to Rumana Momotaz and Asaduzzaman (Asad) for their blessing, inspiration and encouragement during the period of study.

I would like to express my last but not least profound gratitude to my beloved father, mother, sisters, and brother who scarified all their happiness during the whole study period.

The author

GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.) AS INFLUENCED BY NITROGEN AND SEED RATE

ABSTRACT

An experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka. during November to March, 2005-2006 to investigate the effect of nitrogen and seed rate on the growth, yield attributes and yield of wheat cv. Shourav. The treatment consists of four nitrogen levels (0, 60, 100 and 140 kg ha^{-1}) and four seed rates (80, 100, 120 and 140 kg ha^{-1}). The experiment was laid out in a split-plot design with three replications. Experiment results showed that nitrogen had significant effect on plant height, dry matter accumulation, crop growth rate, relative growth rate, number of total tillers per m^2, number of effective tillers per m^2, spike length, number of fertile spikelets $spike^{-1}$, number of unfertile spikelets $spike^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index. The results revealed that nitrogen at the rate of 100 kg ha^{-1} showed the best performance in all the parameters studied. The highest grain yield (3.3 t ha^{-1}) and straw yield (4.36 t ha^{-1}) was obtained from 100 kg N ha^{-1} while control treatment gave the lowest grain and straw yield of 2.19 and 3.1 ton ha^{-1} respectively. The grain and straw yields increased correspondingly with the increase of N from 0 to 100 kg ha^{-1} and decreased thereafter. Seed rate of 120 kg ha^{-1} gave the highest grain yield (3.08 t ha^{-1}) and seed rate of 140 kg ha^{-1} gave the highest straw yield (4.27 t ha^{-1}) of wheat. Among the various interactions, nitrogen at the rate of 100 kg ha^{-1} along with 120 kg seed ha^{-1} produced the highest grain yield of 3.65 t ha^{-1}.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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 Logarithum
m^2	=	meter square
mg	=	mili gram
mm	=	millimeter
N	=	Nitrogen
NS	=	Non significant
P_2O_5		Phosphorus penta oxide
PK	=	Phosphorus, Potassium
ppm	=	Parts per million
RGR	=	Relative Growth Rate
S	=	Sulpher
S	=	Seed
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. 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). The crop is grown under different environmental condition ranging from humid to arid, subtropical to temperate zone (Saari, 1998).

In Bangladesh, it is the second most important staple food crop after rice. It covers 7,41,830 hectares of land with an annual production of 16,05,760 metric tons (BBS. 2004).

Though wheat is an important cereal crop in Bangladesh but the average yield is very low compared to that in the advanced countries. In order to meet the ongoing food deficit and to cope with the food demand for the increasing population, wheat production needs to be increased in Bangladesh. The scope of increasing the cultivated land is limited in Bangladesh due to occupation of land for accommodating the ever-growing population. The only option is to increase the total production and to find out the ways and means to increase the yield per unit area.

In Bangladesh, wheat is grown during the dry winter months from November to March (Rabi season). The yield of wheat in the farmers' field is much lower than that of the research farm. The low yield of wheat in Bangladesh may be due to various factors such as lack of quality seeds, untimely seeding, imbalanced fertilization and seed rate and lack of proper agronomic management practices. Among them nitrogen fertilization and seed rate are the important factors which influence the yield of wheat (Mozumder, 2004).

Among the fertilizers, 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). Application of nitrogen above the optimum dose decrease grain and straw yields (Gehl *et al.*, 1990). Nitrogen fertilizer should be applied at a right dose for increasing its agronomic efficiency. 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 facility and plant protection (Pasricha and Brar, 1999).

Establishment of plant population through optimum seed rate is another important factor for securing good yield of wheat. Seed rate influences yield and yield contributing characters of wheat (Singh and Singh, 1987). Higher seed rate than the recommended one generally increases plant population resulting intra-crop competition thereby affecting the yield. Tiller mortality is greater at high planting density, and the number of fertile spikelets spike^{-1}; along with the yield components are mostly affected by planting 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 decreased rate of leaf photosynthesis, increased total photosynthetic assimilation and increased sink effect on grain yield (Zhenhua *et al.*, 1995). ~~Seed rate influence yield and yield contributing characters of wheat (Singh and Singh, 1987).~~

Optimum seed rate ensures proper growth of the aerial and underground part of the plant through efficient utilization of solar radiation, nutrient uptake as well as air, space and water. The vital research work has not yet been done for optimum seed rate and there may be a positive response between optimum nitrogen and seed rate in order to get high grain yield. Therefore, a problem-oriented research such as seed rate and nitrogen effects 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 study the influence of different seed rate on growth, yield and yield components of wheat
2. To determine the effect of different levels of N fertilizer on the growth, yield contributing characters and yield of wheat
3. To assess the interaction effects of seed rate and applied nitrogen on the growth and yield of wheat.

Chapter 2
Review of literature

REVIEW OF LITERATURE

As wheat is a leading cereal crop in the world, a good number of researches have been done 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 seed rate. Therefore, for having a clear understanding on the effect of different nitrogen levels and seed rate on the yield of wheat, many research works have been carried out throughout the world. Some of the research works are reviewed in this chapter.

2.1 Effect of nitrogen

2.1.1 Plant height

An experiment was conducted by Rahman (2005) to find out the effect of nitrogen, sulpher and boron fertilizers under irrigated and rainfed condition on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen viz. 75, 100, 125, and 150 kg N ha^{-1}. He observed that there were no significant responses of different levels of nitrogen in case of both plant height and number of effective spikelets $spike^{-1}$.

An observation was preformed by Akter (2005) to examine the effect of nitrogen levels under rainfed and irrigated conditions on yield and seed quality of wheat. The experiment was involved with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1}. She 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 observed that plant height increased with increasing rate of nitrogen.

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 heights were found positively correlated with N levels up to 125 kg ha^{-1}.

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 the 180 kg N ha^{-1}.

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

Kumar *et al.* (1999) conducted a field experiment on sandy loam soils of Kukumseri (Lahaul valley) of dry temperate high hills of Himachal Pradesh during 1993-94 and 1994-95. The experiment consisting of 5 levels of nitrogen (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting management practices. It was observed that plant height increased with increasing rates of nitrogen up to 180 kg ha^{-1} during both the years.

Kataria *et al.* (1999) conducted a field experiment at Palampur during winter (Rabi) seasons of 1990-91 and 1991-92. The treatments consist of 3 levels of Nitrogen (40, 80 and 120 kg ha^{-1}) and 2 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 to 150 kg ha^{-1}. Plant height increased significantly with 0 to 200 N kg ha^{-1} (Meneses and Ivan, 1992).

Ahmed and Hossain (1992) observed that plant heights of wheat were 79.9 cm, 82.3 cm, and 84.4 cm with 45, 90, and 135 kg N ha^{-1} respectively. Plant height progressively increased with the increase of nitrogenous fertilizer. Dhuka *et al.* (1991) reported that wheat provided highest plant height with 120 kg N ha^{-1}.

2.1.2 Dry matter

Chanda and Gunri (2004) was working to study the 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 increased 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 attributes 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 *et al.* (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 the effects of CO_2 enrichment on the shoot and total mass depended largely on soil nitrogen level, and the shoot and total mass increased significantly in the moderate to high N treatments but did not 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 3 levels of nitrogen (80, 120 or 160 kg ha^{-1}) 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 a field trial in the winter season of 1990/91 to evaluate the response of wheat to different levels 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 DM yield increased up to 100 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 3 levels of nitrogen (40, 80, 120 kg ha^{-1}) and found that nitrogen increased the dry matter production by keeping the plants green thus delaying maturity.

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 3 levels of nitrogen to see the response of wheat to CGR and noticed that variation in N level did not 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

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}.

Akter (2005) worked with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1} and she 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 in the experiment. They said that there was significant effect of nitrogen rate on tiller number $plant^{-1}$ at 25, 45, 65, and 85 DAS. Tiller number per plant increased 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 biofertilizers 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 per m^2 was increased with increasing levels of nitrogen.

Ayoub *et al.* (1994) conducted an experiment with 4 doses of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that increasing nitrogen fertilizer level significantly increased the number of tillers $plant^{-1}$.

Patel and Upadhyay (1993) reported that number of tillers $plant^{-1}$ of wheat increased significantly with increasing rates of N up to 150 kg ha^{-1}.

A field experiment was carried out by Roy *et al.* (1991) at 2 ecologically different regions, at Hathazari (22.5^0 N, 92^0 E) and Dinajpur (26^0 N, 88^0 E) to find out the response of wheat to nitrogen fertilizer. They showed that nitrogen application increased the total number of tillers $plant^{-1}$.

Pandey *et al.* (1986) fertilized wheat plants with different levels of nitrogen and found that number of tillers per m^2 increased with the increasing rate of nitrogen application from 0 to 200 kg N ha^{-1}

2.1.6 Number of effective tillers

An experiment was conducted by Rahman (2005) including four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. He reported that number of effective tillers $hill^{-1}$ 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 to 100 kg N ha^{-1}. The highest number of effective tillers $plant^{-1}$ was recorded from 100 kg N ha^{-1} which was statistically identical with 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 per m^2 increased significantly only up to 120 kg N ha^{-1} and further increase in fertilizer levels did not show significant effect.

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}.

Das (2002) conducted an experiment with four level of nitrogen (0, 40, 80, and 120 kg ha^{-1}) to evaluate the effect of planting density and rate of nitrogen application on the yield of wheat cv. Kanchan. He reported that maximum number of effective tillers plant^{-1} was obtained at 120 kg N ha^{-1} that was statistically similar to that of 80 kg N ha^{-1}.

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

Kataria and Bassi (1999) carried out a field experiment with 3 levels of N (40, 80 and 120 kg N ha^{-1}) and 2 levels of mulch (no mulch and mulched). They concluded that number of effective tillers per m^2 increased significantly at the N application of 80 kg N ha^{-1}.

Kumar *et al.* (1995) conducted a field experiment with 4 levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that productive tillers increased significantly with the increase of N levels from 0 to 120 kg ha^{-1}, but differences in productive tillers between 120 and 180 kg N ha^{-1} were not significant.

Singh *et al.* (1992) reported that nitrogen fertilization showed marked improvement in yield attributes of wheat. Number of effective tillers per m^2 was highest at 120 kg N ha^{-1}. Effective tillers increased significantly with the increase in the level of N up to 80 kg N ha^{-1} (Singh *et al.*, 1991)

Baten and Islam (1983) carried out an experiment on a medium high silty loam soil of Bangladesh Agricultural University Farm, Mymensingh during 1981-82 with Sonalika wheat applying 4 levels of N (0, 60, 120 and 180 kg/ ha). They reported that the effect of N application was positively significant on effective tiller plant^{-1}.

2.1.7 Spike length

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 viz. 75, 100, 125, and 150 kg N ha^{-1}. He reported that length of spike was significantly increased 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 viz. 0 (control), 50, 100 and 150 kg ha^{-1} and found that spike length increased with the increasing rate of nitrogen up to 100 kg N 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 obtained 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 level of nitrogen (0, 40, 80, and 120 kg ha^{-1}) and found that spike length increased with the increasing rate of nitrogen up to 120 kg N ha^{-1}.

Mozumder (2001) performed an experiment to investigate the effect of different levels of nitrogen and seed rate on the yield and yield contributing characters of wheat. Treatments of nitrogen in that experiment were 0, 30, 60, 90, and 120 kg ha^{-1}. He reported that spike length increased with increasing rate of nitrogen. The results indicated that the highest spike length was recorded when 120 kg N ha^{-1} was applied.

Sushila and Giri (2000) conducted an experiment with 3 levels of nitrogen (0, 45 and 90 kg ha^{-1}) to see the influence of farmyard manure, nitrogen and biofertilizers on growth, yield attributes and yield of wheat. They found that spike length was increased with increasing levels of nitrogen.

A field experiment was conducted at the Institute Farm of Janagadh, during winter (Rabi) season of 1991-92 with 3 levels of N (90, 120 and 150 kg N ha^{-1}) and it was reported that significantly increased in spike length of wheat was observed only up to the application of 120 kg N ha^{-1} (Patel *et al.*, 1995).

Patel and Upadhyay (1993) examined that spike length of wheat increased significantly with increasing rates of N up to 150 kg ha^{-1}.

Singh *et al.* (1992) reported that spike length of wheat respondent significantly to application of nitrogen. Maximum spike length was obtained with 120 kg N ha^{-1}.

Bhagawati *et al.* (1992) carried out an experiment on 'WH283' wheat with 0, 40, 80 and 120 kg N ha^{-1} and reported that spike length of wheat were significantly increased by nitrogen application. Maximum spike length was obtained at 120 kg N ha^{-1}.

Spike length of wheat responded significantly to the application of N fertilizer. Spike length of wheat increased significantly with increasing rates of nitrogen up to 80 kg N ha^{-1} (Singh *et al.*, 1991).

A field trial was conducted at Institute of Agricultural Sciences, Banaras Hindhu University during 1979-81 with wheat cv. HD 1553 under 3 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 to 120 kg ha^{-1} (Singh and Singh, 1987).

2.1.8 Number of fertile spikelets

An experiment was carried out by Rahman (2005) to investigate the effect of nitrogen, sulpher and boron fertilizers on the yield and quality of wheat. The experiment included four levels of nitrogen viz. 75, 100, 125, and 150 kg nitrogen ha^{-1}. He observed that there was no significant response of different levels of nitrogen in case of number of effective spikelets $spike^{-1}$.

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 conditions on yield and seed quality of wheat. She found that seed $spike^{-1}$ increased with the increasing rate of nitrogen up to 100 kg N ha^{-1} and decline thereafter.

Das (2002) used four level of nitrogen (0, 40, 80 and 120 kg ha^{-1}) in an experiment and found that fertile spikelets $spike^{-1}$ increased with the increasing rate of nitrogen up to 120 kg N ha^{-1}.

Mozumder (2001) reported that number of total filled grains $spike^{-1}$ increased with the gradual increase of nitrogen from 0 to 120 kg N ha^{-1}.

Singh and Uttam (1993) stated that application of 120 kg N ha^{-1} gave significantly higher number of spike per m^2 as well as seeds $spike^{-1}$ over 60 kg N ha^{-1} and other doses.

Patel and Upadhyay (1993) conducted that number of seeds spike^{-1} of wheat increased significantly with increasing rates of N up to 150 kg ha^{-1}.

Awasthi and Bhan (1993) conducted a field experiment at the soil conservation winter (Rabi) seasons of 1986-87 and 1987-88. The treatments consisted of five varieties of wheat K65, K78, K72, K8430 and K306 and 4 levels of nitrogen (0, 20, 40 and 60 kg N ha^{-1}). They observed that number of seeds spike^{-1} of wheat increased significantly with the increasing rates of nitrogen up to 60 kg ha^{-1}.

An experiment was conducted during the winter season of 1985-86 and 1986-87 at Shalimar, Shrinagar consisting of 3 wheat verities (VL 142, HS 86 and HD 2009) and 4 levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and it was reported that number of seeds spike^{-1} increased with the increasing rates of nitrogen up to 80 kg N ha^{-1} (Singh *et al.*, 1992). Singh *et al.* (1991) reported that application of nitrogen increased seeds spike^{-1} significantly with the increase in level of N up to 40 kg ha^{-1}.

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

Singh *et al.* (1987) carried out a field experiment at the Institute of Agricultural Sciences, Banaras Hindu University in Rabi seasons of 1978-80 and 1980-81 with 3 levels of nitrogen (40, 80 and 120 kg ha^{-1}), 3 levels of P_2O_5 (0, 40 and 80 kg ha^{-1}) and 2 levels of K_2O (0 and 40 kg ha^{-1}). The experiment result showed that number of seeds spike^{-1} increased with the increasing rates of N up to 120 kg ha^{-1}.

2.1.9 Number of unfertile spikelets

An observation was performed by Rahman (2005) to investigate the effect of nitrogen, sulpher and boron fertilization under irrigated and rainfed condition on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen viz. 75, 100, 125 and 150 kg ha^{-1}. He reported that number of unfertile spikelets $spike^{-1}$ was higher at 150 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 characters of wheat. Nitrogen treatments were 0, 30, 60, 90 and 120 kg ha^{-1}. He reported that nitrogen showed no significant response in respect of number of unfertile spikelets $spike^{-1}$. He also showed that although nitrogen did not show significant effect on number of unfertile spikelets $spike^{-1}$, the highest number of unfertile spikelets $spike^{-1}$ (4.05) was obtained from the nitrogen application of 30 kg ha^{-1}.

1000 grain weight

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

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} in that experiment. They found that differentiation of the level of nitrogen fertilization did not significantly influence the mass of 1000 grain.

Das (2003) showed that nitrogen had significant effect on 1000 grains 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 level 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 thousand-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 see 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 to 45 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 splikelets $spike^{-1}$ 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, Camada in 1990 and 1991 on 4 cultivars (Columbus, Max, Katepwa and Hege) with 4 doses of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that increasing nitrogen fertilizer level significantly increased 1000 grain weight.

Patel and Upadhyay (1993) conducted an experiment with 3 levels of N (0, 120 and 150 kg ha^{-1}) and reported that 1000 grain weight of wheat increased significantly with increasing rates of N up to 150 kg N ha^{-1}.

Patra (1990) conducted a field experiment with two wheat varieties (Sonalika and Sagarika) under varied levels of nitrogen fertilizer (40, 80 & 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 on wheat (Sonalila) with 4 doses of N (0, 60, 120 & 180 kg ha^{-1}) and observed that 1000 seed weight of wheat increased with the increasing rate of nitrogen from 40 to 120 kg N ha^{-1}.

2.1.11 Grain yield

Rahman (2005) reported that most of the yield components and grain yield of wheat were significantly higher at 125 kg N ha^{-1}.

An experiment was conducted by Akter (2005) to study the effect of nitrogen levels under rainfed and irrigated conditions on yield and seed quality of wheat. The experiment was involved with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1}. From the experiment, it was noted that increasing N levels also 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}.

A field experiment was performed in 1998-2003 in Poland to determine the influence of different rates of N (0, 80, 120 and 160 kg ha^{-1}) on grain yield and technological quality of two winter wheat cultivars (Begra and Korweta). An increase of grain yield of winter wheat was recorded with the application of N at 120 kg ha^{-1} (Knapowski and Ralcewicz, 2004).

Das (2003) showed that nitrogen had significant effect on grain yield. Nitrogen application at the rate of 180 kg ha^{-1} produced the highest grain yield (3.13 ton ha^{-1}). The grain and straw yield increased gradually with the increase of nitrogen dose.

Bellido *et al.* (2000) carried out a field experiment during 1986 in Cordoba Southern Spain, on a vertisol (Typic Haploxerent) with 4 levels of N (0, 50, 100 and 150 kg N ha^{-1}). They observed that grain yield of wheat increased significantly at the nitrogen rate of 150 kg N ha^{-1}.

Halvorson *et al.* (2000) carried out a field experiment during 1984 on a Temvik-eilton silt loam soil located near Mandan, on spring wheat with 3 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 3 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}.

Application of fertilizer had marked effect on various plant characters and seed yield. Wheat crop without fertilizers produced significantly lower yield due to poor development of yield components than with fertilizers. The seed yield of wheat was most dependent on N, then P and very little on K (Curic, 1982). Split application of nitrogen gave significantly higher seed yield of wheat (Rajput *et al.*, 1995).

Singh and Singh (1995) carried out a field trial during the winter season of 1990-91 at research station, Majhera with 3 levels of N (0, 40 & 80 kg N ha^{-1}), applied with 3 method. The experimental result showed that the rate of 80 kg N ha^{-1} increased the seed yield by 15.6% over 40 kg N ha^{-1}.

Prasad and Singh (1995) conducted an experiment with 4 levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and reported that seed yield increased with the increasing 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 basal 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 at the Lods Agronomy Research Centre, McGill University, Macdonald Campus and at the crop Federee Research farm. Ste-Rosalie, Camada in 1990 and 1991 on 4 cultivars (Columbus, Max, Katepwa and Hege) with 4 doses of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported increasing 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 of120 kg N ha^{-1} gave the highest seed yield.

Singh *et al.* (1992) found that the seed yield of wheat increased with the increase of N from 40 to 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 to 50 kg N ha^{-1} as urea. Seed yield was highest with 100 kg N ha^{-1} and further dose decreased the seed yield.

Kumar (1985) carried out an experiment on a strongly alkaline (p^H 9.2) clay loam soil at IARI, regional station, Pusa with 4 cultivars of wheat (HP 1267, HW 135, HP 1379 and HP 1207) applying 4 levels of N (0, 60, 120 and 180 kg ha^{-1}). He reported that increasing levels of N up to 120 kg ha^{-1} increased the grain and straw yields of wheat significantly.

2.1.12 Straw yield

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 and 150 kg ha^{-1} to evaluate the effect of nitrogen levels under rainfed and irrigated conditions 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 ton 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 that 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 4 levels of N (0, 3, 4 and 8.7 g N per m^2) until anthesis. It was observed that nitrogen application near anthesis of 3.4 g N per m^2 gave highest straw yield.

Sushila and Giri (2000) conducted an experiment to find out the effect of farmyard manure, nitrogen and biofertilizers 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 3 levels of nitrogen (40, 80 and 120 kg ha^{-1}) and reported that straw yield of wheat increased significantly with increasing rates of N up to 120 kg N ha^{-1}.

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

Sharma and Dhillon (1993) reported that applications of nitrogen remarkably improve the straw yield of wheat and application of 120 kg N ha^{-1} gave the highest straw yield. Patel and Upadhyay (1993) examined that straw yield of wheat increased significantly with increasing rates of N up to 150 kg ha^{-1}.

Awasthi and Bhan (1993) conducted a field experiment with five varieties of wheat K65, K78, K72, K8430 and K306 and 4 levels of nitrogen (0, 20, 40 & 60 kg N ha^{-1}). They observed that straw yield of wheat increased significantly with the increasing rates of nitrogen up to 60 kg ha^{-1}.

Tomar *et al.* (1993) conducted an experiment to observe the response of wheat (Triticum aestivum L.) varieties to irrigation under different fertility levels and reported that wheat seed and straw yield increased with increasing rates of N fertilizer.

Rathore and Patel (1991) carried out an experiment in Rabi season of 1987-88 and 1988-89 with 3 levels of nitrogen (40, 80 and 120 kg N ha $^{-1}$) using a seed rate of 120 kg ha^{-1} and reported that increasing rate 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 3 levels of nitrogen (40, 80 and 120 kg 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 nitrogen as urea. Urea was applied in split doses at various stages, which increased seed yield, by 48-82%. Straw yield of wheat was remarkably influenced with different levels of N application. Split application of N gave significantly higher straw yield of wheat

Kumar (1985) conducted an experiment with 4 cultivars of wheat (HP 1267, HW 135, HP 1379 and HP 1207) applying 4 levels of N (0, 60, 120 and 180 kg ha^{-1}). He reported that increasing levels of N 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 Bangladesh Agricultural University, Mymensingh on wheat cultivar Sonalika with 4 doses of N (40, 60, 80 and 100 kg ha^{-1}) and reported that N application at early tillering stage tended to give higher straw yield.

2.1.13 Harvest index

Rahman (2005) worked with four levels of nitrogen viz. 75, 100, 125 and 150 kg ha^{-1} to evaluate the effect of nitrogen on the yield and quality of wheat. He reported that harvest index was significantly higher at 125 kg N ha^{-1}.

Akter (2005) carried out an experiment to examine the effect of nitrogen levels under rainfed and irrigated conditions on yield and seed quality of wheat. The experiment was involved with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1}. In that experiment, the highest harvest index was observed at 100 kg N ha^{-1}

Pandey *et al.* (2004) set an experiment with 0, 60, 90, 120 and 150 kg N ha^{-1} to find out the effect of fertilizer levels and seed rate on growth and yield of wheat. They 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 from the 180 kg nitrogen ha^{-1}.

Das (2002) found that harvest index increased with the increasing rate of nitrogen application. The highest harvest index was produced by the application of 120 kg N ha^{-1}.

Mozumder (2001) set up an experiment to evaluate the effect of different levels of nitrogen on the yield and yield contributing characters of wheat. There were 0, 30, 60, 90 and 120 kg N ha^{-1}. He reported that nitrogenous fertilizer exhibited significant effect on harvest index. The highest harvest index (37.04%) was observed in N @ 60 kg ha^{-1} which was followed by 36.53% and 36.50% from N at the rate of 30 and 90 kg ha^{-1} respectively. But the difference among them was not significant.

Sushila and Giri (2000) conducted an experiment to find out the influence of farmyard manure, nitrogen and biofertilizers on growth, yield attributes and yield of wheat under limited water supply. They used three levels of nitrogen fertilizer viz. 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) observed that harvest index of wheat increased significantly with the increasing rates of nitrogen up to 60 kg ha^{-1}.

Bhagawati *et al.* (1992) carried out an experiment on 'WH283' wheat with 0, 40, 80 and 120 kg N ha^{-1} and reported that harvest index of wheat was increased significantly with the increasing rate of nitrogen.

2.2 Effect of seed rate

2.2.1 Plant height

Dixit and Gupta (2004) conducted an experiment to investigate the effects of seed rate (100, 125 or 150 kg ha^{-1}) on the growth and yield of wheat cv. HUW-234 in Varanasi, Uttar Pradesh, India, during rabi 1995/96. 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 on growth and yield of surface-seeded wheat. They used three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1}.they reported that in case of plant height, there were no significant different among the seed rates.

An observation was taken by Arif *et al.* (2002) to study the effect of different sowing rates on yield and yield components of wheat cultivars (Inqilab-91 and Bakhtawar-92). They used four seed rates (50, 100, 120 and 150 kg ha^{-1}) in the experiment. Maximum plant height (97 cm) was recorded at sowing rates of 150 kg seed ha^{-1}. Inqilab-91 produced the highest plant height (97 cm).

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used three levels of planting density (500, 250 and 188 seeds per m^2). He concluded that planting density did not significantly influence plant height. The highest plant height was observed in planting density of 188 seeds per m^2.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Treatments of seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. 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 per m^2 to study the effect of population on tillering, growth, yield components and yield of wheat and they observed that there were no significant difference among the seed rate in case of plant height.

Gaffer and Shahidullah (1985) conducted an experiment at Mymensingh to study the effect of seed rates on the performance of wheat cv. Inia-66. They used four levels of seed rates such as 100, 140 or 180 kg seeds ha^{-1}. Plant height was significantly higher at 100 kg seeds ha^{-1} than the other rates.

2.2.2 Dry matter

Nag *et al.* (1998) conducted an experiment during winter, 1994-95 at Regional Agricultural Research Station, Rahmatpur, Barisal to investigate the response on growth and yield of wheat to different seed rates. It appeared that increasing seed rate resulted in increased total dry matter in wheat. They also found that per plant dry matter production decreased with increasing the seed rate.

The effects of crop density (300, 450 or 600 plants per 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 per m^2, spring triticale showed greater dry matter accumulation in shoots than spring wheat; however, at 600 plants per m^2, spring wheat exhibited greater dry matter accumulation in shoots than spring triticale. Spring wheat recorded greater dry matter accumulation in well-developed shoots (4, 5, and 6 levels) than in non-productive shoots (1, 2 and 3 levels).

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

Saradon *et al.* (1988) reported that wheat cv. Klein Toledo, San Agustin and Marcos Juarez were sown to give plant densities of 120-360 plants per m^2 in field experiment at Mianmar. They found that at higher plant densities translocation of DM to the ear began earlier and was greater than in plants grown at lower densities. Dry matter distribution at harvest was not affected by plant density.

Bagga and Tomar (1981) conducted an experiment with 3 levels of planting densities (200, 250 and 300 plants per m^2) to find out the effect of planting density on the growth and yield of wheat. They reported that DM production $plant^{-1}$ was higher at the lower plant densities.

2.2.3 Crop growth rate (CGR)

Nag *et al.* (1998) carried out an experiment during winter, 1994-95 at Regional Agricultural Research Station, Rahmatpur, Barisal to investigate the response on growth and yield of wheat to different seed rates. They found that crop growth rate differed significantly by the different growth stage of wheat but did not influence significantly due to seed rates. They also observed that CGR increased very slowly with increasing the seed rates.

2.2.4 Relative growth rate (RGR)

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

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

2.2.5 Number of total tillers

Dixit and Gupta (2004) carried out an experiment to investigate the effects of seeding rate (100, 125 or 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) set up an experiment to evaluate the effect of planting density on tiller production of wheat cv. Kanchan. He used three levels of planting density (500, 250 and 188 seeds per m^2) and found that total number of tillers $plant^{-1}$ was significantly influenced by planting density. The lowest planting density of 188 seeds per m^2 produced highest number of total tillers $plant^{-1}$.

Hossain (2002) conducted a field trial to find out optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three level of seed rate (110, 120, 130 kg seed ha^{-1}) were used as an experimental material. 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 tillers $plant^{-1}$ 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 in the 1988-89 winter season, 4 high-yielding recommended wheat cultivars and 4 new cultivars with longer spikes and more grains $spike^{-1}$ (but low tillering) were sown at 100, 125 and 150 kg seeds ha^{-1} in rows 22.5, 18 and 15 cm apart, respectively . Higher seed sowing rates coupled with decrease in row spacing increased the number of tillers per m^2 and grain yields.

Saradon *et al.* (1988) found that wheat cv. Klein Toledo, San Agustin and Marcos Juarez were sown to give plant densities of 120-360 plants per m^2 in field experiment at Mianmar, Argentina. They commented that tiller mortality was greater at high plant density and in the tall cultivar (Ktein Toledo).

A field experiment was undertaken by Chatha *et al.* (1986) to observe the yield of wheat cultivars as affected by different seed rates under irrigated conditions. In that experiment, seed rates were 18.5, 37.0, 55.5, 74.0 & 92.5 kg seeds ha^{-1}. They found that increasing sowing rates had no significant effect on 1000 grains wt but they increased emergence and tillers $unit^{-1}$ area and grain yields.

Gaffer *et al.* (1985) used 4 levels of seed rates such as 100, 140 or 180 kg seeds ha^{-1} and observed that tillers $plant^{-1}$ was significantly higher at 100 kg seeds ha^{-1} in an experiment than the other rates, but grain yield was highest at 140 kg seed ha^{-1} and straw yield was also highest at 180 kg seed ha^{-1}.

Borojevic and Kraljevic (1983) studied with 5 wheat cv. Sown at 300, 500 and 700 seeds per 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 rate than at the intermediate rate and was most intensive at the low sowing rate in 6 cm rows.

Smocek *et al.* (1982) conducted in thin stands; grain yield was most influenced by plant number and uniformity of production. In dense stands by the number of secondary tillers and their grain number and uniformity of production. In dense stands an increase of 1 grain ear^{-1} of a secondary productive tiller increased-total yield by138 kg ha^{-1}.

In a field trial to find out the seed rate, Black and Aase (1982) sown 3 wheat cv. At high and low sowing rates @ 148-480 plants per 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 per m^2 than low density.

Bagga and Tomar (1981) reported that, 2-dwarf and 4 semi-dwarf wheat varieties when grown at densities of 200, 250 and 300 plants per m^2 under field conditions were favorable for high yields. 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) carried out an experiment to study the effect of different levels of seed rate on growth and yield of surface-seeded wheat. They used three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1}. In that examination seed rate of 175 kg ha^{-1} recorded significantly higher effective tillers per m^2.

Hossain (2002) conducted an experiment to find out the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate viz.110, 120, 130 kg seed ha^{-1} were involved in the study and noticed significant effect on effective tillers per m^2.

Sun yuanmin *et al.* (1996) showed that reducing plant density coupled with early sowing, and increased fertilizer application at middle and late growth stages, increased number of tillers per m^2, percentage of fertile tillers and biomass at maturity.

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

Sharar *et al.* (1987) observed that increasing the sowing density of wheat cv. Chenab-70, Lyallpur-73 and Yecora from 125 to 313 seeds per m^2 increased stand densities from 44.7 to 100.4 plants/3600 cm^2 and fertile tiller number from 146.0 to 182.9/3600 cm^2 and fertile tiller number from 146.0 to 182.9/3600 cm^2, and decreased average grain number/ear from 56.0 to 44.5.

2.2.7 Spike length

Dixit and Gupta (2004) carried out an experiment to find out the effects of seed rates (100, 125 or 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) set up an experiment to examine the effect of planting density on the yield of wheat cv. Kanchan. He used three levels of planting density (500, 250 and 188 seeds per m^2) and noticed that planting density frequencies differed significantly in respect of spike length of wheat.

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

Mozumder (2001) carried out an experiment to study the effect of different levels of seed rates on the yield and yield contributing characters of wheat. Treatments of seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1} and revealed 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 8.40 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 (Akbar, Barkat, Ananda and Kanchan) were included in the study. He found that length of spike decreased with the increase of seed rate.

Gaffer *et al.* (1985) observed an experiment to study the effect of seed rates on the performance of wheat. They used four levels of seed rates such as 100, 140 or 180 kg seeds ha^{-1} and found that ear length increased significantly at 100 kg seeds ha^{-1} than at the other rates.

2.2.8 Number of fertile spikelets $spike^{-1}$

Dixit and Gupta (2004) conducted an experiment to find out the effects of seed rate (100, 125 or 150 kg ha^{-1}) on growth and yield of wheat. It was found that increasing the seed rates significantly reduced the number of fertile spikelets $spike^{-1}$.

Hossain (2002) carried out an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three level of seed rate (110, 120, 130 kg seed ha^{-1}) were used as an experimental material. In that experiment, seed rates exerted significant effect on effective spikelets $spike^{-1}$.

Mozumder (2001) reported that the highest number of fertile spikelets $spike^{-1}$ was obtained from the seed rate of 125 kg ha^{-1}. Seed rate of 75 and 100 kg ha^{-1} produced statistically similar number of fertile spikelet $spike^{-1}$.

Torofder (1993) performed an experiment to study the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study. He found that no of fertile spikelets $spike^{-1}$ decreased with the increase of seed rate.

Zhang *et al.* (1991) reported in a trial with two cultivars grown at 3000 - 15000 plants/mu that number of spikes and spikelets $plant^{-1}$, number of grains $spike^{-1}$ and 1000 grains weight and number of fertile spikelets $spike^{-1}$ decreased as the number of degenerating spikelets $spike^{-1}$ increased.

Roy and Biswas (1991) observed that number of fertile spikelets per ear was the highest with 300 seeds per m^2, which was not significantly differed with 400 seeds per m^2.

Krept and Spiss (1988) reported that wheat cv. Liwilla was sown on 9 Oct. 1985 at densities of 300-500 seeds per m^2 in rows 15 cm apart. Stand densities were maintained constant by the removal of tillers. They found that the numbers of grains per m^2 were highest at the highest stand density where as the number of fertile spikelets ear^{-1} and 1000 grains weight was reduced.

Chatha *et al.* (1986) conducted an experiment to observe the yield of wheat cultivars as affected by different seed rates. In that experiment seed rates were 18.5, 37.0, 55.5, 74.0 and 92.5 kg seeds ha^{-1}. They found that increasing sowing rates decreased fertile spikelets ear^{-1}.

Gaffer and Shahidullah (1985) used four levels of seed rates such as 100, 140 or 180 kg seeds ha^{-1} in an experiment and found that fertile spikelets $spike^{-1}$ was significantly higher at 100 kg seeds ha^{-1} than the other rates.

Mazurek (1984) investigated the effects of five different seed rates up to 900 seed per m^2 in 17 varieties of wheat. He found that denser sowing reduced the emergence percentage but increased the number of ears per m^2, though the ears tended to be shorter bearing fewer productive spikelets, and grain yield was lower in consequence.

2.2.9 Number of unfertile spikelets

Mozumder (2001) induced an experiment to recognize the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. In that experiment it was revealed that number of unfertile spikelets $spike^{-1}$ (5.42) was found in the highest seed rate (150 kg ha^{-1}) and the lowest number of unfertile spikelets $spike^{-1}$ (2.50) was recorded from 75 kg seed ha^{-1}.

An observation was taken by Chatha *et al.* (1986) to study the yield of wheat cultivars as affected by different seed rates under irrigated conditions. In that experiment, seed rates were 18.5, 37.0, 55.5, 74.0 and 92.5 kg seeds ha^{-1}. They found that increasing sowing rates increased unfertile spikelets $spike^{-1}$.

Nourafza and Langer (1979) conducted an experiment with 5 densities of wheat (170 to 580 seeds per m^2) and reported that sowing rate of 375 seeds per m^2 was optimum for grain yield. At higher rates the increase in ear population was affected by reduced grain set.

Krept and Spiss (1988) noticed that wheat cv. Liwilla was sown on 9 oct. 1985 at densities of 300-500 seeds per m^2 in rows 15 cm apart. Stand densities were maintained constant by the removal of tillers. From the result it was revealed that the number of unfertile spikelets ear^{-1} was increased with the increasing plant density.

2.2.10 1000 grain weight

Das (2002) set up an experiment on wheat cv. Kanchan and used three levels of planting density (500, 250 and 188 seeds per m^2). He concluded that 1000 grains weight did not differ significantly due to different planting densities of wheat seeds. The highest 1000-grain weight was obtained from 188 seed per m^2 and the lowest from 500 seeds per m^2.

Hossain (2002) carried out an experiment to evaluate optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120, 130 kg seed ha^{-1}) were used and found that seed rates exerted significant effect on 1000 seed weight.

Mozumder (2001) conducted a field trial to investigate the effect of different seed rate on the yield and yield contributing characters of wheat. Treatments of seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1} and revealed that the lowest seed rate produced the highest 1000 grains weight.

Ahmad *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.

Ionescu (1994) observed with winter wheat cv. Albota and Fundulea-4 at 100-500 plants per m^2 in rows (a) 12.5 and (b) 25 cm apart. He found that grain yield were higher in (b) than in (a). It was affected by plant density in (a) but decreased with increased in plant density in Albota and increased in Fundulea-4 in (b) and 1000-grain weight was unaffected there.

Torofder (1993) worked with three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) to observe the effect of seed rate on yield of wheat. He 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 or 150 kg ha^{-1}. Grain yield increased with seed sowing rate and was highest with sprouted seed (av. 3.51 t ha^{-1}). 1000 grains weight was highest (41 g) with 150 kg sprouted seed ha^{-1}.

Krept and Spiss (1988) also reported that 1000 grains weight was reduced at the highest stand density.

Chatha *et al.* (1986) used 18.5, 37.0, 55.5, 74.0 and 92.5 kg seeds ha^{-1} as experimental treatment and found that increasing sowing rates had no significant effect on 1000 grains weight.

Gaffer *et al.* (1985) conducted an experiment to study the effect of seed rates on the performance of wheat. They used four levels of seed rates such as 100, 140 or 180 kg seeds ha^{-1} and found that 1000 grains weight was significantly higher at 100 kg seeds ha^{-1} than at the other rates.

Bagga and Tomar (1981) found that, 2-dwarf and 4 semi-dwarf wheat variety when grown at densities of 200, 250 and 300 plants per m^2 under field conditions 1000 grains weight remained unaffected by reduction in plant population.

2.2.11 Grain yield

Dixit and Gupta (2004) investigated the effects of seed rate (100, 125 or 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) investigated an experiment to know the effect of seed rates on growth and yield of surface-seeded wheat. They used three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} and 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}.

Arif *et al.* (2002) conducted an experiment to study the effect of seeding rates on yield and yield components of wheat. Four seed rates viz. 50, 100, 120 and 150 kg ha^{-1} were used in the experiment. Maximum grain yield (3346 kg ha^{-1}) was recorded at sowing rates of 150 kg seed ha^{-1}.

Das (2002) used three levels of planting density (500, 250 and 188 seeds per m^2) as experimental treatment and observed that grain yield varied significantly due to planting densities. It was found that the highest grain yield obtained from the optimum planting density of wheat (250 seed per m^2).

Hossain (2002) conducted an observation to find out optimum seed rate and harvesting time for wheat to obtain maximum seed yield as well as quality seed. Three level of seed rate (110, 120, 130 kg seed ha^{-1}) were used, seed rates exerted significant effect on seed yield.

Mozumder (2001) investigated the effect of different levels of seed rate on the yield of wheat. Treatments of seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1} and revealed that 125 kg seeds 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) studied an experiment during winter, 1994-95 at Regional Agricultural Research Station, Rahmatpur, Barisal to investigate the response of growth and yield of wheat to different seed rates. It appeared that increasing seed rate resulted in increase total dry matter and leaf area index but it did not increased grain yield in wheat.

Ionescu (1994) studied with winter wheat cv. Albota and Fundulea-4 were at 100-500 plants per m^2 in rows (a) 12.5 or (b) 25 cm apart. He observed that the grain yield were higher in (b) than in (a). It was affected by plant density in (a) but decreased with increased in plant density in Albota and increased in Fundulea-4.

Torofder (1993) examined an observation to study the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akbar, 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) studied 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 per m^2 to evaluate yield of wheat where they observed that grain yield was significantly higher with 400 seeds per m^2.

Huel and Baker (1990) noted that grain yields increased with the increment of seed rate up to 640 seeds per m^2 (in 1984) and up to 320 seeds per m^2 (in 1985). In another 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 were due to increased 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 or 23 cm apart in row with seed rates of 100, 125, 150, 175 or 200 kg ha^{-1}. The highest grain yield of 4.17 t ha^{-1} in 1986-87 and 2.63 t ha^{-1} in 1987-88 were obtained from 23 cm apart in row spacing with the seed rate of 200 kg ha^{-1}.

Endres and Joba (1989) observed that grain yield of wheat was the highest (5.2 t ha^{-1}) with the closest row-to-row spacing (10 cm) and was lowest (3.3 t ha^{-1}) with the widest row-to-row spacing (40 cm). Yield increased from 3.5 t ha^{-1} with 150 plants per m^2 to 3.8 t $ha^{-1}$with 450 plants per m^2. In experiment wheat sown at 2.25, 4.50 and 6.75 million germinable seeds ha^{-1}, they found that the highest grain yield was achieved at the highest sowing rate (Dotlacil and Holubova, 1988).

Andersson and Larsson (1989) found that increased seed rates increased the number of plants per m^2but also increased lodging. Increasing the seed rate to 420 seeds per m^2 gave a moderate increase in grain yield. The optimum seed rate was about 15% lower at low N than at higher N levels.

In 1981-85, wheat cv. Sonalika gave average grain yields of 1.82, 2.35 and 1.99 t ha^{-1} when sown at 100, 150 and 200 kg ha^{-1}, respectively, and 1.51, 2.08, 2.44 and 2.18 t ha^{-1} with 0, 30, 60 and 90 kg N ha^{-1}, respectively. Crops sown at 150 kg ha^{-1} and given 60 kg N ha^{-1} gave the highest yield of 2.96 t ha^{-1} (Gupta, 1989).

2.2.12 Straw yield

Pandey *et al.* (2004) investigated the effect of seed rate on growth and yield of surface-seeded wheat. They used three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} and noticed that use of 175 kg seed ha^{-1} resulted in the highest grain yield.

Dixit and Gupta (2004) used 100, 125 or 150 kg ha^{-1} seed ha^{-1} as experimental treatment to find out the effect of seed rate on 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 with @ 150 kg seed ha^{-1}.

Das (2002) concluded that straw yield varied significantly due to planting densities. It was found that the maximum straw yield was recorded at optimum planting density of 250 seeds per m^2.

Hossain (2002) performed an experiment to find out optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three level of seed rate (110, 120, 130 kg seed ha^{-1}) were used, seed rates exerted significant effect on straw yield and harvest index. He found the highest straw yield at 130 kg seed ha^{-1}.

Mozumder (2001) conducted an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. 75, 100, 125 and 150 kg seed ha^{-1} were used as experimental treatment. Result revealed that straw yield increased up to a certain level of seed rate and there after declined. The highest straw yield was produced from seeds @ 125 kg ha^{-1}.

Torofder (1993) conducted an experiment to evaluate the optimum seed rate of different high yielding varieties of wheat. Three seed rates (80, 100 and 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study. He found that yield of straw increased significantly with higher seed rate as compared to that with the lower seed rates. Paul (1992) noted that sowing rates (120, 140 or 160 kg seed ha^{-1}) did not significantly affect grain or straw yield.

2.2.13 Harvest index

Pandey *et al.* (2004) worked with three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} and reported that harvest index was unaffected by the variation of seed rates.

Das (2002) carried out an experiment to evaluate the effect of planting density and rate of nitrogen application on the yield of wheat cv. Kanchan. He used three levels of planting density (500, 250 and 188 seeds per m^2 and obtained the highest harvest index from the optimum planting density at 250 seeds per m^2 and the lowest harvest index were found from 500 seed per m^2.

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

From an experiment Mozumder (2001) investigated the effect of different seed rate on the yield of wheat. Treatments of seed rates in that experiment were 75, 100, 125 and 150 kg seed ha^{-1} and it was revealed that harvest index significantly varied due to different seed rates. The highest harvest index was observed in seed rate at 125 kg /ha.

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. They observed that harvest index increased up to 400 seed per m^2 and there after decreased.

Borojevic and Kraljevic (1983) examined with 5 wheat cv. sown at 300, 500 and 700 seeds per m^2 the number of plant produced was 12.7, 14.4 and 15.9% respectively. They found that increasing the seeding rate reduced the harvest index significantly whereas row spacing had no effect.

Bagga and Tomar (1981) reported that 2 dwarf and 4 semi-dwarf wheat varieties when grown at densities of 200, 250 and 300 plants per m^2under field conditions were favorable for high yields. They reported that harvest index remained unaffected by reduction in plant population.

2.3 Interaction effect of nitrogen and seed rate

2.3.1 Plant height

Hossain (2005) conducted an experiment to know the effect of nitrogen level and seed rate on the yield performance of wheat. In was observed that plant height was not significantly affected by the interaction of seed rate 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.

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 per m^2 combined with 120 kg N ha^{-1} and the lowest (80.44 cm) was in planting density 500 seeds per m^2 and control plot.

Singh *et al.* (2002) conducted that a field experiment in Kampur, Uttar Pradesh, India during 1997-98. Plant height increased with increasing rate of N and decreased with increasing sowing rates.

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

An experiment was conducted by Pandey *et al.* (2004) to study the effect of fertilizer levels and seed rates on growth and yield of wheat under lowland rice ecosystem of north Bihar. They used five levels of nitrogen fertilizer (0, 60, 90, 120 & 150 kg ha^{-1}) and three level of seed rates (125, 150, 175 kg ha^{-1}). They reported that plant height increased with subsequent increase in fertilizer level and recorded maximum value at 150 kg N ha^{-1}. But decrease non-significantly with increase in seed rate.

2.3.2 Dry matter accumulation

Kumar *et al.* (2002) studied with three levels of seed rate (50, 75 and 100 kg ha^{-1}) along with four levels of nitrogen fertilizer and reported that dry matter accumulation enhanced significantly with enhancing seed rate 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 rate.

2.3.3 Number of total tillers

The effect of seed rate and nitrogen level on the number of total tillers $plant^{-1}$ was not 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 per m^2 and 120 kg N ha^{-1} and the lowest (3.20) at 500 seeds per m^2 with control nitrogen treatment.

Kumer *et al.* (2002) examined an observation with three levels of seed rate (50, 75 and 100 kg ha^{-1}) and four levels of nitrogen (90, 120, 150 and 180 kg ha^{-1}). 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 and 120 kg N ha^{-1}.

2.3.4 Number of effective tillers

Hossain (2005) concluded that the highest number of effective tillers $hill^{-1}$ was found in combined effect of 120 kg N and 90 kg seed ha^{-1}.

Das (2002) reported that the highest number of effective tillers $plant^{-1}$ (4.53) was obtained in planting densities of 188 seeds per m^2 combined with 120 kg N ha^{-1}.

Kumer *et al.* (2002) conducted an experiment with different seed rates (50, 75 and 100 kg ha^{-1}) and fertilizer levels (90, 120, 150 and 180 kg ha^{-1}). They observed 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 ha^{-1}). The interaction effect of seed rate and nitrogenous fertilizer was found significant in case of number of effective tillers per plant. It was observed that the highest number of effective tillers $plant^{-1}$ was found from the combination effect of 75 kg seed with 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 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 also statistically identical with 120 kg seed ha^{-1}.

Pandey *et al.* (2004) found 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. They used five fertilizer levels (0, 60, 90, 120 and 150 kg N ha^{-1}) and three seed rate (125, 150, 175 kg ha^{-1}) in their experiment.

Das (2002) studied with three levels of seed rates (500, 250 and 188 seed per m^2) and four level of fertilizer (0, 40, 80 and 120 kg ha^{-1}). He reported that spike length was not significantly influenced by the interaction effect of nitrogen and seed rate.

There were a significant variation in spike length observed due to the interaction between seed rate and nitrogen (Mozumder, 2001). He reported that the longest spike length (9.66 cm) was obtained from the interaction of 75 kg seed with 90 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 rates increased spike length but increasing N rates significantly increased spike length.

2.3.6 Number of fertile spikelets

Hossain (2005) found that 160 kg N and 90 kg seed ha^{-1} was very conducive to increase unfertile spikelets $spike^{-1}$. The combination effect between 160 kg N and 90 kg seed ha^{-1} produced 27.08 unfertile spikelets $spike^{-1}$ which was also statistically identical with the interaction effect of 120 kg N with 120 kg seed ha^{-1}.

Das (2002) examined that number of fertile spikelets $spike^{-1}$ was not however significantly influenced by the interaction between planting density and different rates of nitrogen. The highest number of unfertile spikelets $spike^{-1}$ (48.25) was obtained with low planting density of 188 seed per m^2 in combination with high rate of nitrogen application (120 kg ha^{-1}).

Mozumder (2001) carried out an experiment to investigate the response of wheat to different level of nitrogen and seed rates. Five levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and four level of seed rates (75, 100, 125 and 150 kg ha^{-1}) were used in that experiment. He reported that number of unfertile spikelets $spike^{-1}$ showed significant variation due to the interaction between seed rate and nitrogen. The highest number of unfertile spikelets spike^{-1} (18.84) was obtained from the interaction between 125 kg seed ha^{-1} and 90 kg N ha^{-1}.

2.3.7 Number of unfertile spikelets

Mozumder (2001) conducted a field trial and reported that number of unfertile spikelets spike^{-1} did not responded significantly due to interaction of seed rate and nitrogen. The highest (5.56) and the lowest (2.48) number of unfertile grain spike^{-1} were obtained from the interaction of 150 kg seed ha^{-1} with control nitrogen and 75 kg seed with 30 kg N ha^{-1}, respectively.

2.3.8 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 grains weight (46.12 g) was obtained with planting density of 250 seeds per m^2 in combination with 120 kg N ha^{-1} and the lowest (40.35 g) with planting density of 5000 seeds per m^2 with no nitrogen treatment.

An observation was carried out by Mozumder (2001) to examine the effect of nitrogen levels and seed rate on yield and seed quality of wheat. He obtained the highest 1000 grains weight (46.80 g) from the interaction effect of 75 kg seed with 120 kg N ha^{-1}.

An experiment was carried out by Walli and Wahab (1987) with three seed rates (60, 100 and f140 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.

2.3.9 Grain yield

Hossain (2005) found that in case of grain yield ha^{-1}, the combination effect of 120 kg N with 120 kg seed ha^{-1} and 160 kg N 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 with 120 kg seed ha^{-1}.

Das (2002) reported that the highest grain yield was obtained with 250 seed per m^2 in combination with 120 kg N ha^{-1}.

A field experiment was performed by Mozumder (2001) to determine the influence of different nitrogen level (0, 30, 60, 90 and 120 kg ha^{-1}) and seed rates (75, 100, 125 and 150 kg ha^{-1}) on the yield performance of wheat. He reported that the interaction of seed rate and nitrogen significantly affected grain yield of wheat. The combination of 150 kg seed with 120 kg N ha^{-1} was found as the best treatment which obtained the highest grain yield.

2.3.10 Straw yield

Hossain (2005) conducted an experiment and found that straw yield was not significantly affected by the interaction of seed rate and nitrogen levels. It was observed that the application of 90 kg seed and 120 kg N ha^{-1} showed numerically the highest straw yield (4.11 t ha^{-1}) and 60 kg seed and zero kg N ha^{-1} showed the lowest straw yield.

Das (2002) reported that straw yield was not significantly influenced by the interaction between seed rate and different rates of nitrogen. He used 188, 250 and 500 seed per 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 with 120 kg N ha^{-1}.

2.3.11 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}). But 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 N. Numerically, the highest harvest index (46.53 %) was obtained with optimum planting densities of 250 seed per 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 with 75 kg seed ha^{-1}.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, collection and preparation of plant samples, analytical methods followed in the determination of physical properties of samples.

Description of the experimental site

3.1 Location

The experiment was conducted at the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2005 to March 2006 to study the growth and yield of wheat as influenced by nitrogen and seed rate.

3.2 Site selection

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. 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 sandy loam in texture having P^H range from 5.47 to 5.63. The physical and chemical characteristics of the soil have been presented in Appendix i.

3.3 Climate

Cold temperature and minimum rainfall is the main feature of the Rabi season. The monthly total rainfall, average sunshine hour, temperature during the study period (November to February) are shown in Appendix ii.

3.4 Variety

Shourav (BARI Gom -19) was released for cultivation in 1998. Height of the plant range from 90-100 cm. It produces 5-6 tillers plant^{-1}. Leaves are flat, droopy and deep green in color. Weight of 1000-seed 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 ha^{-1}.

3.5 Layout of the experiment

The experiment was laid out in a split-plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into 4 main plots in which nitrogen levels were applied at random. Each main plot was further divided into 4 unit plots or sub-plots and different rates of seeds were sown at random. So, the total number of unit plots in the entire experimental plot was 3 X 4 X 4 = 48. Size of each unit plot was 4 m X 3 m = 12 m^2. The distance maintained between two sub-plots was 1 m and between blocks 1.5 m.

3.6 Experimental treatments

There were two sets of treatments i.e. nitrogen levels and seed rates. There were 4 fertilizer treatments in the experiment. The standard rate of phosphate, potash and sulpher at the rate of 70, 30 and 20 kg ha^{-1} respectively in form of triple super phosphate, muriate of potash and gypsum were applied (Razzaque *et al.* 2000). There were four levels of N fertilizer (0, 60, 100 and 140 kg ha^{-1}) and four rates of seed (80, 100, 120 and 140 Kg ha^{-1}).

3.7 Treatments factors:

Factor A: Level of nitrogen (kg ha^{-1}): 4

N_1 = 0 (control)

N_2 = 60

N_3 = 100

N_4 = 140

Factor B: Seed rates (kg ha^{-1}): 4

S_1 = 80

S_2 = 100

S_3 = 120

S_4 = 140

3.8 Details of the field operations

The particular of cultural operations carried out during the experimentation are presented below.

3.8.1 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought into desirable fine tilth and leveled by four of ploughing operations followed by repeated laddering. The corners of the land were spaded and visible larger clods were hammered to break into small pieces. After removing the weeds, stubbles and crop residues were cleaned from the land. The final ploughing and land preparation were done on November 24, 2005. The layout was done as per experimental design on November 26, 2005.

3.8.2 Fertilizer application

Each main plot was fertilized with triple super phosphate, muriate of potash and gypsum at the rate of 140, 50 and 145 kg ha^{-1}, respectively. Nitrogen was applied in main-plots as urea at random as per experimental treatments. The whole amount of triple super phosphate (TSP), muriate of potash (MP), gypsum and one third of urea (as per treatment) were incorporated in each plot (except control treatment) at the time of final land preparation. The remaining urea was applied in two installments, 1/3 at crown root initiation stage (21 days after sowing) and rest 1/3 at prior to spike initiation stage (53 days after sowing) of the seedling as top dressing.

3.8.3 Collection and sowing of seeds

The wheat seeds (cv. Sourav) were collected from Wheat Reasearch 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 November 26, 2006 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. Two guards were appointed from early morning to evening to protect the wheat seeds from birds especially pigeons.

3.8.4 Weeding

Weeds infested the experimental plots. So two weeding were done manually at 20 and 50 days after sowing. Both thinning and weeding were done simultaneously during first weeding. During weeding the weeds identified were-Kakpaya ghash (*Dactyloctenium aegyptium* L.), Shama (*Echinochloa crusgalli* L.), Durba (*Cynodon dactylon* L.), Chelaghash (*Parapholis incurva* Linn), Arail (*Leersia bexandra*), Mutha

(*Cyperus rotundus* L.), Bathua (*Chenopodium album* L.), Banmasur (*Vicia sativa* L.), Shaknatey (*Amaranthus viridis* L.), Foskabegun (*Physalis beterophylls*), Titabegun (*Solanum torvum*), Shetlomi (*Gnaphalium luteolabum* L.) and Keshuti (*Eclipta prostrata*).

3.8.5 Irrigation

The experimental plot was irrigated three times. The first, second and third irrigation were required to be applied at crown root initiation stage, heading stage and grain filling stage (21, 55 and 70 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.

3.8.6 Pest management

The experimental plots were sprayed at 35 days after sowing with insecticide 100 E.C. at the rate of 0.84 litre to control the termite. No infestation of disease was found. Two guards were appointed to protect the wheat grain from birds especially pigeons from mid February to harvest.

3.8.7 Harvesting and sampling

The crop was harvested at maturity on March 26, 2006. Samples were collected from different places of each plot leaving undisturbed one-meter square 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-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 grain and straw were dried again.

3.9 Recording of data

The following data were collected during the study period:

1. Plant height from 30 DAS to harvest (cm)
2. Total dry matter accumulation from 30 DAS to harvest (g per m^2)
3. Crop growth rate (CGR)
4. Relative growth rate (RGR)
5. Number of total tillers per m^2
6. Number of effective tillers per m^2
7. Spike length (cm)
8. Number of fertile spikelets $spike^{-1}$
9. Number of unfertile spikelets $spike^{-1}$
10. 1000 grains weight (g)
11. Grain yield ($t\ ha^{-1}$)
12. Straw yield ($t\ ha^{-1}$)
13. Harvest index (%)

3.9.1 Plant height from 30 DAS to harvest (cm)

To measure plant height from 30 DAS to harvest, 10 plants were selected and tagged at 30 DAS. Plant height was measured always on those plants from the base to the tip of the spike at 30 DAS, 50 DAS, 70 DAS, 90 DAS and at harvest and mean plant height was determined in cm.

3.9.2 Total dry matter from 30 DAS to harvest (g per m^2)

The plants with in 10 cm with the help of hand weeder were uprooted and cleaned with water. Plants were oven dried at 80 ^{0}c until a constant weight was obtained. The dry weight of plants were recorded in gram and converted into 1 m^2 of the test area. Data were collected at 30, 50, 70, 90 and 120 DAS (at harvest).

3.9.3 Crop growth rate (g/m^2/day)

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. The mean CGR values for the crop during the sampling intervals have been computed by using the formula of Brown (1984).

$$CGR = \frac{W_2 - W_1}{SA\ (t_2 - t_1)} \quad g/m^2/day$$

Where,

SA = Ground area 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. CGR values were calculated for the periods of 30-50, 50-70, 70-90 DAS and 90 DAS to harvest (crop duration).

3.9.3 Relative Growth Rate (g/g/day)

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/day. Relative Growth Rate was worked out by following the formula of Radford (1967).

$$RGR = \frac{L_nW_2 - L_nW_1}{T_2 - T_1} \quad g/g/day$$

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 Number of total tillers per m^2

Number of total tillers of 15 cm was counted and converted into $1m^2$ and the mean values were recorded.

3.9.6 Number of effective tillers per m^2

Number of effected tillers of 15 cm was counted at harvest and converted into $1m^2$ and mean values were computed.

3.9.7 Spike length (cm)

Spike length of the plant from the base of the flag leaf to the tip of the spikelets were measured and recorded.

3.9.8 Number of fertile spikelets spike^{-1}

Fertile spikelets of each of the spike were recorded and mean values were calculated later on.

3.9.9 Number of unfertile spikelets spike^{-1}

Unfertile spikelets from each spike also counted and mean value was also calculated.

3.9.10 1000 grain weight (g)

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

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

After threshings, proper drying (12% moisture level) and cleaning yield of each sample plot was weighed and values were converted to t ha^{-1}.

3.9.12 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}.

3.9.13 Harvest index (%)

Harvest index was determined by diving the economic (grain) yield from the net plot by the total biological yield (grain + straw) from the same area (Donald, 1963) and multiplying by 100.

$$\text{Harvest index} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \text{X } 100$$

3.10 Statistical analysis

The collected data were complied and analyzed by split plot design to find out the statistical significance of experimental results. The collected data were analyzed by MSTAT soft ware (Russell, 1986). The means for all recorded data were calculated and the analyses of variance for all characters were performed. The mean differences were evaluated also by least significant difference (LSD) test.

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. Experimental results pertaining to the effect of different treatments viz. nitrogen and seed rate levels on growth and yield of wheat are presented here. The parameters considered were plant height (cm), dry matter accumulation (g), number of total tillers per m^2, number of effective tillers per m^2, spike length (cm), number of fertile spikelets $spike^{-1}$, number of unfertile spikelets $spike^{-1}$, 1000 grains weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%). Results of the experiments have been presented in tables 1 to 16 and Figure 1 to 8. The mean square values of the said parameters together with the sources of variation and their corresponding degrees of freedom have been shown in Appendix iii to vi.

4.1 Plant height (cm)

4.1.1 Effect of nitrogen

Nitrogen had significant effect on plant height of wheat (Appendix-iii and Table 1) It was observed from Table1. that plant height varied due to variation of nitrogen at different growth stages. Application of 140 kg N ha^{-1} (N_4) produced the tallest plant height in 33.03 cm, 48.24 cm, 77.54 cm, 84.81 cm, and 88.24 cm at 30, 50, 70 90 DAS and at harvest, respectively but those plant heights were statistically identical with the corresponding plant heights obtained from 100 kg N ha^{-1} (27.44 cm, 33.54 cm, 56.88 cm, 73.47 cm and 75.59 cm at 30, 50, 70, 90 DAS and at harvest, respectively). The corresponding plant heights obtained from 60 kg N ha^{-1} were significantly lower then those obtained from 100 kg N ha^{-1} but significantly higher than those obtained from the control (N_1). The corresponding plant heights obtained from the control treatment were 27.44 cm, 33.54 cm, 56.88 cm, 73.47 cm and 75.59

cm, respectively. These findings were in agreement with the results of Gurdip *et al.* (2001), who reported that plant height increased with the increased levels of nitrogen. But Sarker *et al.* (1997) found no significant difference among the nitrogen levels (100, 120 and 160 kg ha^{-1}) for incase of plant height. Akter (2005) found that N @ 100 kg ha^{-1} increased the plant height of wheat.

Table 1. Plant height (cm) of wheat at different growth stages as influenced by different nitrogen levels

Treatment	*30 DAS*	*50 DAS*	*70 DAS*	*90 DAS*	*At harvest*
N_1	27.44	33.54	56.88	73.47	75.59
N_2	30.52	42.72	71.14	79.80	83.19
N_3	32.46	47.14	76.48	84.55	86.25
N_4	33.03	48.24	77.54	84.81	88.24
LSD (0.05)	0.28	1.61	2.55	1.92	1.77
CV (%)	3.01	3.58	3.75	4.11	3.79

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.1.2 Effect of seed rates

Application of different seed rate had a significant effect on plant height at all growth stages except 70 DAS (Appendix iii and Table 2). It was revealed from the Table 2 that the tallest plant height (31.47 cm and 86.32 cm at 30 DAS and at harvest respectively) was obtained from the seed rate at 140 kg ha^{-1}(S_4). That was statistically similar with 120 kg (S_3) and 100 kg ha^{-1}(S_2). Plant height increased at 50 and 90 DAS with 140 kg seed ha^{-1}. The shortest plant height 30.09 cm, 40.62 cm, 69.54 cm, 77.43 cm and 80.95 cm were produced at 30, 50, 70, 90 DAS and at harvest, respectively due to 80 kg seed ha^{-1}. The higher plant height with high seed rate might be due to high competition of large number plants per unit area. Roy and Biswas (1991) found that plant height increased with the increasing seed per m^2 but there was no significant difference among the seed rates. Mozumder (2001) and Das (2002) reported that plant height decreased with the increasing seed rate.

Table 2. Plant height (cm) of wheat at different growth stages as influenced by different seed rates

Treatment	*30 DAS*	*50 DAS*	*70 DAS*	*90 DAS*	*At harvest*
S_1	30.09	40.62	69.54	77.43	80.95
S_2	30.83	42.08	70.26	80.47	82.08
S_3	31.06	43.24	70.57	80.76	83.93
S_4	31.47	45.70	71.66	83.97	86.32
LSD (0.05)	0.78	1.29	2.23	1.43	2.66
CV (%)	3.01	3.58	3.75	4.11	3.79

S_1 = 80 (Kg ha^{-1}), S_2 = 100 (Kg ha^{-1}), S_3 = 120 (Kg ha^{-1}), S_4 = 140 (Kg ha^{-1})

4.1.3 Interaction effect of nitrogen and seed rate

The interaction effects of nitrogen level and seed rate on plant height was significantly influenced (Appendix iii and Figure 1). It was found from Figure1 that the interaction of 140 kg nitrogen ha^{-1} with 140 kg seed ha^{-1} (N_4S_4) gave the tallest plant height (33.48 cm, 51.50 cm, 78.87 cm, 89.30 cm and 91.12 cm) at 30, 50, 70 and 90 DAS and at harvest, respectively. This was statistically similar with the 100 kg N ha^{-1} and 140 ka N ha^{-1} along with different seed rates at 30 and 70 DAS. All the interaction treatments showed more or less similar values with each other considering all growth stages. The results revealed that combination of 100 kg N ha^{-1} and 100 kg seed ha^{-1} (N_3S_3) performed better than others. The shortest plant was found from the combination of 80 kg seed ha^{-1} with control i.e. without application of nitrogen (N_1S_1). Similar trend was also observed by Singh *et al.* (2002).

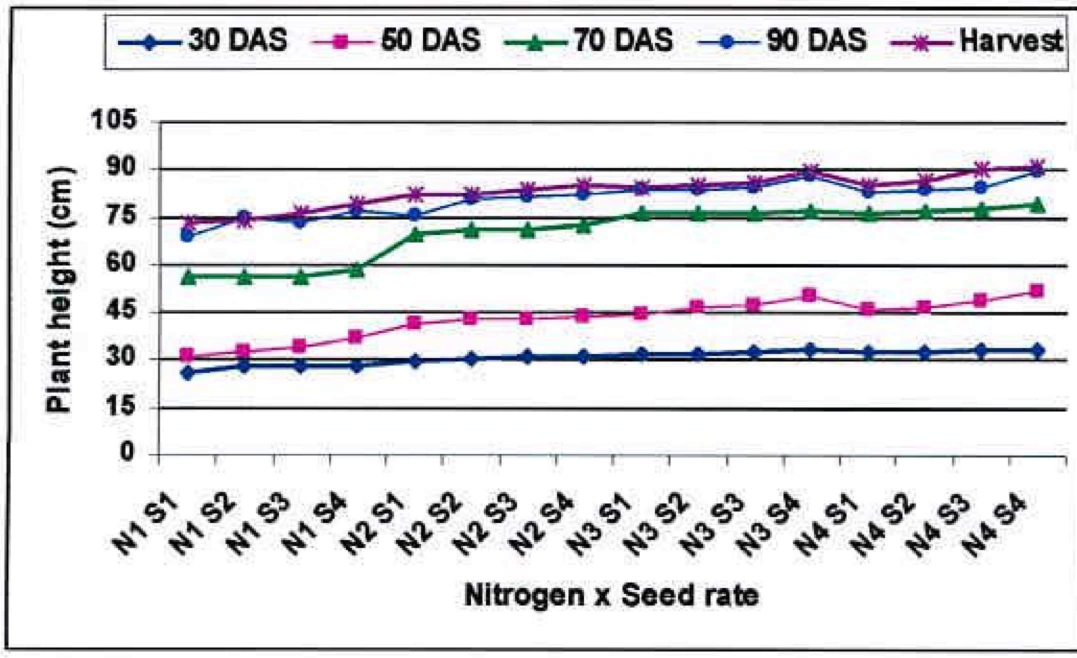

Figure1. Plant height (cm) of wheat at different growth stages as influenced by interaction between nitrogen and seed rate

4.2 Total dry matter accumulation (g per m²)

4.2.1 Effect of nitrogen

Total dry matter per m^2 at 30, 50, 70, 90 DAS and at harvest was affected due to nitrogen application (Appendix iii Table 3). Each level of nitrogen significantly increased the dry matter over preceding level up to 100 kg ha^{-1} (Table 3). Nitrogen at 100 kg ha^{-1} produced the highest dry matter per m^2 (92.82, 248.03, 481.60, 628.40 and 736.80 g per m^2 at 30, 50, 70, 90 DAS and at harvest, respectively) than 60 and 140 kg N ha^{-1} and also control. This result might be due to the contribution of nitrogen which promotes vigorous growth of plant and contributed higher dry matter production. Khan *et al.* (2002) obtained similar response of nitrogen up to 200 kg ha^{-1} on dry matter production. In an experiment Roy *et al.* (1991) also found the similar performance of dry matter production of wheat with varying nitrogen levels.

Table 3. Total dry matter (g per m²) of wheat at different growth stages as

influenced by different nitrogen levels

Treatment	*30 DAS*	*50 DAS*	*70 DAS*	*90 DAS*	*At harvest*
N_1	58.99	153.12	285.65	355.40	408.72
N_2	68.43	195.13	379.90	477.44	556.08
N_3	92.82	248.03	481.60	628.40	736.80
N_4	76.86	206.81	406.70	542.00	635.38
LSD (0.05)	2.63	4.83	6.47	8.53	19.79
CV (%)	4.20	4.70	4.60	4.46	3.75

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.2.2 Effect of seed rate

Seed rates as revealed from the table 4 exhibited significant difference on dry matter production at different growth stages (30, 50, 70, 90 DAS and at harvest). Application of 140 kg seed ha^{-1} recorded significantly higher dry matter production per m^2 (90.42g and 232.10g per m^2 at 30 and 50 DAS, respectively) over other seed rates e.g. 120, 100, 80 kg seed ha^{-1} (Table 4). But 120 kg seed ha^{-1} gave higher dry matter (440.60, 564.83 and 658.58 g per m^2 at 70, 90 DAS and at harvest) than any other treatments. These results clearly indicated that total dry matter increased at a certain limit. Nag *et al.* (1998) also reported that increasing seed rate, resulted in increase dry matter production. They also found that dry matter production increased up to a certain limit of seed rate and thereafter decreased with the increase of seed rate.

Table 4. Total dry matter (g per m^2) of wheat at different growth stages as influenced by different seed rates

Treatment	*30 DAS*	*50 DAS*	*70 DAS*	*90 DAS*	*At Harvest*
S_1	63.43	164.32	317.30	421.90	500.82
S_2	70.96	183.59	366.18	483.29	569.10
S_3	72.31	223.08	440.60	564.83	658.58
S_4	90.42	232.10	429.77	533.25	608.48
LSD (0.05)	2.63	7.94	8.51	10.39	13.53
CV (%)	4.20	4.70	4.60	4.46	3.75

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.2.3 Interaction effect of nitrogen and seed rate

It was revealed from Figure 2 that the combined effect of 100 kg N with 120 kg seed ha^{-1} gave significantly the highest dry matter per m^2 (285.30, 535.50, 695.30 and 812.00 g per m^2 at 50, 70, 90 and at harvest, respectively) except 30 DAS. But incase of 30 DAS interaction of 100 kg N with 140 kg seed ha^{-1} gave higher dry matter (115.60 g per m^2). Control treatment of nitrogen with 80 kg seed ha^{-1} gave the lowest dry matter production (54.20, 121.97, 240.50, 300.50 and 350.36 g per m^2 at 30, 50, 70 90 DAS and at harvest, respectively).

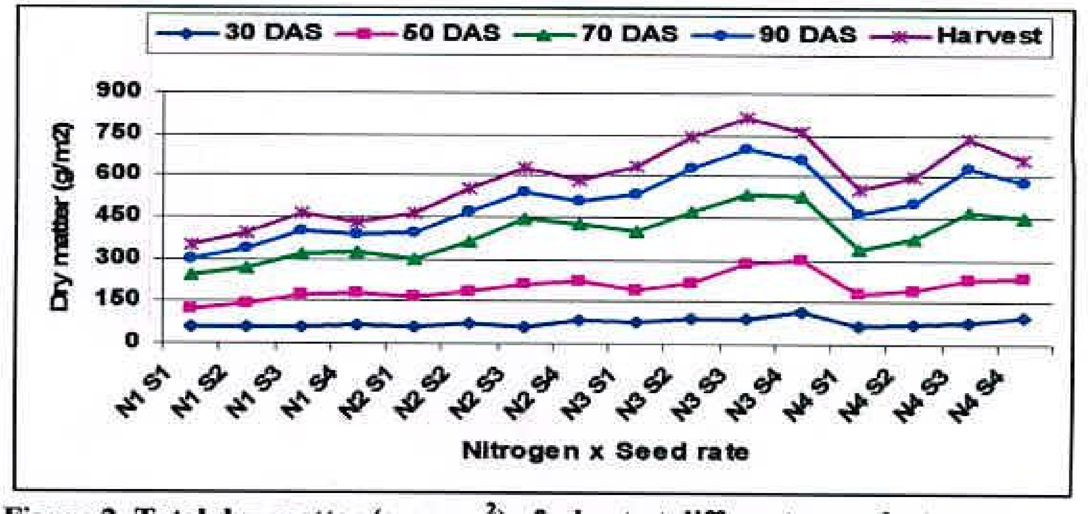

Figure 2. Total dry matter (g per m^2) of wheat at different growth stages as influenced by interaction between nitrogen and seed rate

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})
S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.3 Crop growth rate (g/m^2/day)

4.3.1 Effect of nitrogen

Table shows that crop growth rate was significantly affected by the different levels of nitrogen. At all growth stages, successive increase in the rate of nitrogen up to 100 kg ha^{-1} progressively increased CGR values 7.76, 11.68, 7.34 and 5.35 g/m^2/day at 30-50, 50-70, 70-90 DAS and 90 DAS to harvest, respectively as compared to control (Table 5). Crop growth rate was maximum in the beginning, increased with the advancement of crop growth and became declined at 70-90 DAS and 90- harvest irrespective to nitrogen levels. Khan *et al.* (2002) reported that CGR values significantly increased at 200 kg N ha^{-1} up to 65- 85 DAS.

Table 5. Crop growth rate (g/m^2/day) of wheat at different growth stages as influenced by different nitrogen levels

Treatment	*30 -50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 DAS-Harvest*
N_1	4.71	6.63	3.49	2.67
N_2	6.34	9.24	4.97	3.94
N_3	7.76	11.68	7.34	5.35
N_4	6.50	10.00	6.77	4.67
LSD (0.05)	0.21	0.23	0.30	0.24
CV (%)	4.48	5.05	7.19	6.93

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.3.2 Effect of seed rate

Seed rate had a significant effect on CGR values up to 50-70 DAS. CGR values increased with the increase of seed rate and with 120 kg seed ha^{-1} they reached maximum at 50-70 days and after that found they declined (Table 6). Higher CGR values observed at 50-70 DAS (7.65, 9.13, 10.88 and 9.89 g/ m^2/ day at the rate of 80, 100, 120 and 140 kg seed ha^{-1}). Nag *et al.* (1998) found that crop growth rate differed significantly at different growth stages of wheat but did not influence significantly due to seed rates. They also observed that CGR increased very slowly with the increasing seed rate.

Table 6. Crop growth rate (g/m^2/day) of wheat at different growth stages as influenced by different seed rates

Treatment	*30-50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 DAS-Harvest*
S_1	5.05	7.65	5.24	3.95
S_2	5.64	9.13	5.86	4.22
S_3	7.54	10.88	6.30	4.69
S_4	7.09	9.89	5.18	3.76
LSD (0.05)	0.24	0.40	0.34	0.31
CV(%)	4.48	5.05	7.19	6.93

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.3.3 Interaction effect of nitrogen and seed rate

All the combination of nitrogen and seed rate showed significant differences on CGR values at all growth stage (Table 7). Higher CGR (12.51 g/m^2/day) value found at 50-70 DAS with 100 kg N ha^{-1} in combination with 120 kg seed ha^{-1} (Table 7). lower CGR value found at late growth stage obtained from the interaction effect of control nitrogen with different levels of seed rates.

Table 7. Interaction effect of nitrogen and seed rate on Crop growth rate ($g/m^2/day$)

Treatment	*30-50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 DAS - Harvest*
$N_1 S_1$	3.39	5.93	3.00	2.49
$N_1 S_2$	4.23	6.21	3.47	2.78
$N_1 S_3$	5.55	7.27	4.23	3.08
$N_1 S_4$	5.66	7.11	3.25	2.32
$N_2 S_1$	5.39	6.44	4.78	3.71
$N_2 S_2$	5.83	8.60	5.60	3.93
$N_2 S_3$	7.40	11.63	5.22	4.34
$N_2 S_4$	6.73	10.28	4.26	3.76
$N_3 S_1$	5.88	10.23	6.86	5.02
$N_3 S_2$	6.50	12.49	7.87	5.50
$N_3 S_3$	9.69	12.51	7.99	5.84
$N_3 S_4$	8.98	11.49	6.65	5.03
$N_4 S_1$	5.52	7.99	6.30	4.57
$N_4 S_2$	5.98	9.23	6.49	4.67
$N_4 S_3$	7.52	12.10	7.74	5.50
$N_4 S_4$	6.97	10.67	6.54	3.94
LSD (0.05)	0.48	0.80	0.68	0.63
CV (%)	4.48	5.05	7.19	6.93

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.4 Relative growth rate (g/g/day)

4.4.1 Effect of nitrogen

Nitrogen application influenced RGR significantly at 30-50 and 50-70 DAS and showed no significant response at 70-90 DAS and 90 DAS-harvest (Table 8). At early stage of growth, RGR was maximum and gradually declined with the advancement of crop age. Khan *et al.* (2002) 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. They also found that the effect of nitrogen was significant on relative growth rate.

Table 8. Relative growth rate (g/g/day) of wheat at different growth stages as affected by different nitrogen levels

Treatment	*30-50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 DAS to Harvest*
N_1	0.048	0.031	0.011	0.017
N_2	0.052	0.033	0.012	0.018
N_3	0.049	0.033	0.013	0.018
N_4	0.050	0.034	0.025	0.018
LSD (0.05)	0.003	0.001	ns	ns
CV(%)	3.83	4.10	8.32	9.31

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.4.2 Effect of seed rate

Different seed rate showed significant response on RGR values at all growth stages except 70-90 DAS (Table 9). With all seed rates maximum RGR was found at early growth stage (30-50) DAS and there after declined. Nag *et al.* (1998) reported that seed rates significantly influenced the RGR and was obtained at maximum tillering stage.

Table 9. Relative growth rate (g/g/day) of wheat at different growth stages as influenced by different seed rates

Treatment	*30-50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 - Harvest*
S_1	0.048	0.033	0.014	0.009
S_2	0.048	0.034	0.014	0.008
S_3	0.057	0.034	0.012	0.008
S_4	0.047	0.031	0.011	0.007
LSD (0.05)	0.003	0.001	ns	0.001
CV (%)	3.83	4.10	8.32	9.31

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.4.3 Interaction effect of nitrogen and seed rate

It was observed that interaction effect of nitrogen and seed rate had significant effect on RGR values at different growth stage except 70-90 DAS. (Table 10). RGR values as influenced by the interaction of nitrogen and seed rate was maximum at early stage (30-50 DAS) of crop growth and thereafter they declined successively at every growth stage.

Table 10. Interaction effect of nitrogen and seed rate on Relative growth rate (g/g/day)

Treatment	*30-50 DAS*	*50-70 DAS*	*70-90 DAS*	*90 DAS-Harvest*
$N_1 S_1$	0.041	0.034	0.011	0.008
$N_1 S_2$	0.046	0.031	0.012	0.008
$N_1 S_3$	0.053	0.031	0.012	0.007
$N_1 S_4$	0.050	0.029	0.009	0.006
$N_2 S_1$	0.052	0.029	0.014	0.009
$N_2 S_2$	0.049	0.033	0.014	0.008
$N_2 S_3$	0.062	0.038	0.010	0.007
$N_2 S_4$	0.047	0.033	0.009	0.007
$N_3 S_1$	0.047	0.036	0.015	0.009
$N_3 S_2$	0.045	0.038	0.014	0.008
$N_3 S_3$	0.57	0.031	0.013	0.008
$N_3 S_4$	0.047	0.029	0.011	0.007
$N_4 S_1$	0.050	0.032	0.016	0.009
$N_4 S_2$	0.050	0.034	0.015	0.009
$N_4 S_3$	0.054	0.036	0.014	0.008
$N_4 S_4$	0.045	0.032	0.013	0.006
LSD	0.006	0.002	ns	0.002
CV	3.83	4.10	8.32	9.31

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.5 Number of total tillers per m²

4.5.1 Effect of nitrogen

Nitrogen fertilization exerted significant effect on number of total tillers per m^2. The highest number of total tillers per m^2 (572.6) which was recorded from 100 kg N ha^{-1} significantly differed from 475.1 and 471.9 obtained from 140 and 60 kg N ha^{-1}, respectively (Table 11). The lowest number of total tillers per m^2 (400.2) was obtained from control. The results showed that tiller number increased with increasing levels of nitrogen. This finding was probably due to higher nitrogen levels that encouraged the tiller production of plants. Rahman (2005) showed that number of tillers $plant^{-1}$ was significantly higher with 125 kg ha^{-1} over 150 kg N ha^{-1}. Similar findings were also reported by Akter (2005), Das (2003), Singh *et al.* (1996), Patel and Upadhaya (1993) who reported that N @ 120 kg ha^{-1} improved number of tillers per m^2. Ayoub *et al.* (1994) also observed that tillers per m^2 increased with increasing N rate.

Table .11 Effect of nitrogen on yield attributes of wheat

Treatment	*Total tillers per m^2*	*Effective tillers per m^2*	*Fertile spikelets $spike^{-1}$*	*Unfertile spikelets $spike^{-1}$*
N_1	400.2	336.7	33.79	5.77
N_2	471.9	408.5	40.44	4.19
N_3	572.6	487.7	44.36	3.97
N_4	475.1	412.0	44.84	4.53
LSD (0.05)	25.00	23.96	0.80	0.65
CV (%)	5.37	6.19	2.05	7.91

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.5.2 Effect of seed rate

Increasing seed rate showed significant effect regarding total tiller per m^2 (Table 12). The highest number of total tillers per m^2 (537.4) was obtained from the lowest seed rate (80 kg per ha) followed by 493.1 and 490.1 with the seed rate of 100 and 120 kg ha^{-1}, respectively (Table 12). On the other hand the lowest number of total tillers per m^2 (399.1) was achieved from the seed rate 140 kg ha^{-1}. It was observed that, the lowest seed rate produced the highest number of total tiller per m^2. This might be due to the production of minimum numbers of plants per unit area resulting in the maximum number of total tillers per m^2 due to maximum utilization of space, nutrients, light and moisture. The results were agreement with the findings of Hossain (2005). Azimzadeh and Koocheki (1999) stated that number of tillers $plant^{-1}$ was decreased with increasing seed rate.

Table 12. Effect of seed rate on yield attributes of wheat

Treatment	*Total tillers per m^2*	*Effective tillers per m^2*	*Fertile spikelets $spike^{-1}$*	*Unfertile spikelets $spike^{-1}$*
S_1	537.4	388.3	39.03	3.770
S_2	493.1	410.0	40.81	3.885
S_3	490.1	465.0	42.77	4.005
S_4	399.1	381.5	40.82	6.795
LSD (0.05)	21.71	21.45	0.7039	0.3073
CV (%)	5.37	6.19	2.05	7.91

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.5.3 Interaction effect of nitrogen and seed rate

The interaction of nitrogen and seed rate significantly affected the number of total tillers per m^2. Apparently it was found from Table 13 that 100 kg N ha^{-1} in combination with 80 kg seed ha^{-1} resulted the highest number of total tillers per m^2 (633.2) and control i. e. with out application of nitrogen in combination with 140 kg seed ha^{-1} showed the lowest number of total tillers per m^2 (325.4). This result was in conformity with the findings of Mozumder (2001).

Table 13. Interaction effect of nitrogen and seed rate on yield attributes of wheat

Treatment	*Total tillers per m^2*	*Effective tillers per m^2*	*Fertile spikelets spike^{-1}*	*Unfertile spikelets spike^{-1}*
$N_1 S_1$	460.0	306.7	33.33	4.00
$N_1 S_2$	390.2	346.6	33.00	4.20
$N_1 S_3$	425.3	380.3	34.87	4.27
$N_1 S_4$	325.4	313.3	33.97	10.60
$N_2 S_1$	546.3	413.4	39.27	3.71
$N_2 S_2$	500.0	423.5	39.03	3.80
$N_2 S_3$	490.2	506.6	43.07	3.90
$N_2 S_4$	351.1	326.5	40.40	5.33
$N_3 S_1$	633.2	446.7	42.00	3.51
$N_3 S_2$	592.1	463.3	45.83	3.62
$N_3 S_3$	570.2	593.3	45.80	3.75
$N_3 S_4$	495.0	486.7	43.80	5.00
$N_4 S_1$	510.2	386.7	41.53	3.86
$N_4 S_2$	490.3	406.7	45.40	3.92
$N_4 S_3$	450.2	486.7	47.33	4.10
$N_4 S_4$	425.0	399.6	45.10	6.25
LSD (0.05)	43.41	44.76	1.41	0.615
CV (%)	5.37	6.36	2.05	7.91

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.6 Number of effective tillers per m^2

4.6.1 Effect of nitrogen

From the results (Table 11), it was found that different levels of nitrogen had significant effect on the production of number of effective tillers per m^2. It was found that the highest number of effective tillers per m^2 (487.7) was obtained when N @ 100 kg ha^{-1} was applied. 487.7 was followed by 412.0, 408.5 and 336.7 obtained from 140, 60 and 0 kg N ha^{-1} respectively. The lowest number of effective tillers per m^2 (336.7) was observed in control. The results revealed that N application encouraged production of effective tiller per m^2. This finding might be due to increase in cellular activity of plants following higher levels of N application. Similar effects of nitrogen on effective tillers $plant^{-1}$ were reported by Das (2002), Mozumder (2001), and Pandey *et al.* (1986).

4.6.2 Effect of seed rate

Number of effective tillers per m^2 was significantly influenced by the seed rate. It was revealed from Table 12 that number of effective tillers per m^2 increased with the increasing rate of seed upto a certain level and there after declined. The highest number of effective tillers per m^2 (465.0) was obtained from the seed rate of 120 kg ha^{-1}. This might be due to the fact that the plants got sufficient space and utilized more nutrients, light and moisture while the highest seed rate (140 kg ha^{-1}) produced the lowest number of effective tillers (381.5). In this case, it might be due to a large population of plant per m^2 those couldn't grow normally due to stress from space, nutrient, air, light or moisture condition of the soil. This finding was supported by Turley (1999), who conducted a field trials using seed rate of 80 to 200 seed per m^2 and reported that effective tillers decreased with the decreasing of seed rate. Das

(2002), Mozumder (2001) and Mahajan *et al.* (1991) found that lower seed rate increased the effective tillers plant^{-1}.

4.6.3 Interaction effect of nitrogen and seed rate

The interaction of nitrogen and seed rate significantly affected number of effective tillers per m^2. It was observed from Table 13 that the highest number of effective tillers per m^2 (554.0) was found from 100 kg N ha^{-1} in combination with 120 kg seed ha^{-1}. The lowest number of effective tillers (306.7) was recorded from the interaction of control i. e. with out application of nitrogen with 80 kg seed ha^{-1}. This result was similar with the findings of Mozumder (2001).

4.7 Spike length (cm)

4.7.1 Effect of nitrogen

Length of spike was significantly influenced by the use of varying levels of nitrogen. Spike length increased with the increasing rate of nitrogen (Figure 3). Maximum spike length (17.25 cm) was obtained from the plants where N was applied at 140 kg ha^{-1} which was also statistically similar with 120 kg N ha^{-1}. The lowest spike length (14.83 cm) was obtained at 0 kg N ha^{-1} (control).

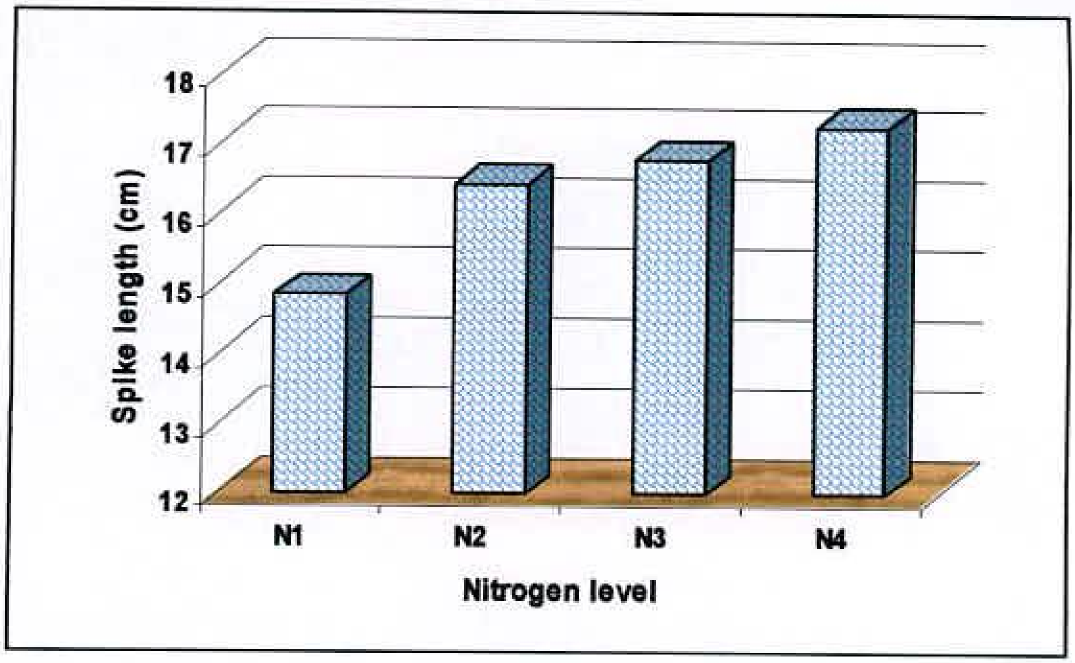

Figure 3. Spike length (cm) of wheat as influenced by different nitrogen levels ($LSD_{0.05}$ = 0.54)

Nitrogen nutrient takes part in better growth and spike formation as well as spike elongation which might be the reason of increased spike length with the increase of nitrogen supply. Similar result was obtained by Das (2002), Mozumder (2001) Kumar *et al.* (1999) where they observed increased spike length with the increase of the rate of nitrogen application.

4.7.2 Effect of seed rate

Seed rate frequencies significantly differed the spike length of wheat. The spike length of 16.38 cm and16.32 cm was produced from 120 kg and 100 kg seed ha^{-1}, respectively though these two seed rate were statistically similar (Figure 4). The lowest length of spike (15.41 cm) was produced from seed rate of 140 kg ha^{-1}. The reason of maximum length of spike with minimum seed rate might be due to the influence of minimum number of plants per unit area and consequently, more vegetative growth having maximum light and nitrogen. Markovic (1983) supported this results, he observed that increasing the sowing density tended to raise the number of ears per m^2 but reduced ear length , Das (2002) and Mozumder (2001) also support this finding.

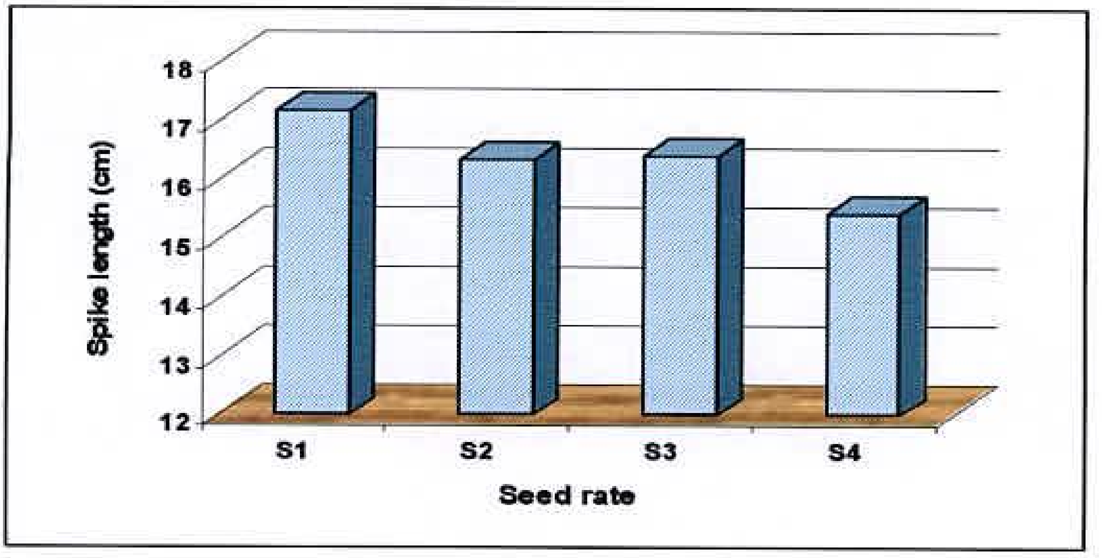

Figure 4. Spike length (cm) of wheat as influenced by different seed rates ($LSD_{0.05}$ = 0.69)

4.7.3 Interaction effect of nitrogen and seed rate

Spike length showed significant variation due to the interaction between nitrogen fertilization and seed rate (Figure 5). The longest spike length (18.17 cm) was obtained from the interaction of 160 kg N with 80 kg seed ha^{-1} (N_4S_1). Most of the interaction treatment showed more or less similar values with each other. The shortest spike (4.37 cm) was obtained from the interaction of control (without) nitrogen level and 120 kg seed ha^{-1}. This result was similar with the findings of Mozumder (2001).

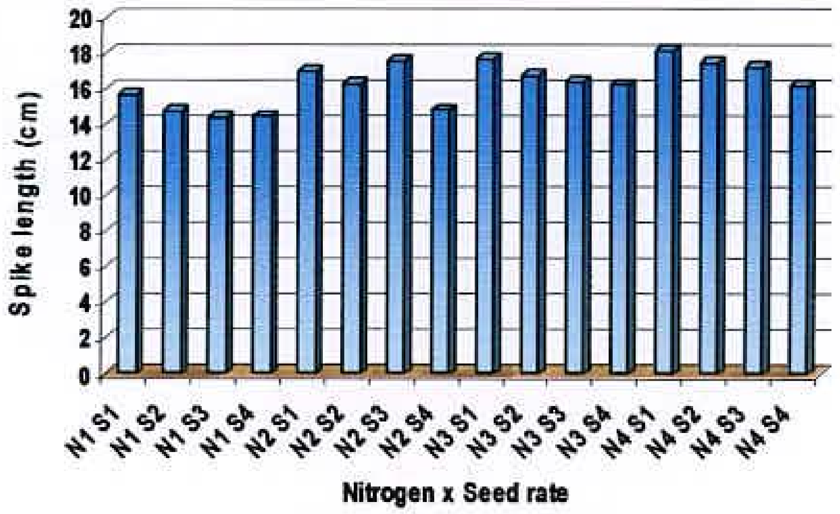

Figure 5. Spike length (cm) of wheat as influenced by interaction between nitrogen and seed rate ($LSD_{0.05}$ = 1.37)

4.8 Number of fertile spikelets spike^{-1}

4.8.1 Effect of nitrogen

Number of fertile spikelets spike^{-1} was significantly influenced by the different rate of nitrogen. Number of fertile spikelets spike^{-1} increased with the gradual increase of nitrogen from 0 to 140 kg N ha$^{-1.}$ The highest number of fertile spikelets spike^{-1} (44.84) was found from nitrogen applied at 140 kg ha^{-1}, the second highest number of fertile spikelets spike^{-1} (44.36) was recorded at 100 kg N ha^{-1} (Table 11). Statistically identical number of fertile spikelets spike^{-1} was produced with treatment of 100 kg and 140 kg N ha$^{-1.}$ The lowest number of fertile spikelets spike^{-1} (33.79) was observed by control treatment. Similar effect of nitrogen in wheat was also reported by Bellido *et al.* (2000) and Hossain (2005), who observed that number of seeds spike^{-1} increased significantly with the increase of nitrogen application.

4.8.2 Effect of seed rate

Number of fertile spikelets spike^{-1} responded significantly due to increasing seed rate. It was observed from Table 12 that the highest number of fertile spikelets spike^{-1} (42.77) was obtained from the seed rate of 120 kg ha^{-1} and it was followed by 40.82 and 40.81 attributed by the seed rates of 140 and 100 kg ha^{-1}, respectively (Table 12). The lowest number of fertile spikelets spike^{-1} (39.03) was obtained from 80 kg seed rate ha^{-1} (Table 12). However, seed rates 140 and 100 kg ha^{-1} produced statistically similar number of fertile spikelets spike^{-1}. Similar results were also found by Latif and Tuhay (1986), Aram-Koomkang (1990), Wali nad Wahab (1987) and Mozumder (2001). Torofder (1993) used three seed rate (80, 100 and 120 kg ha^{-1}) and obtained more number of spikelets spike^{-1} in higher seed rate.

4.8.3 Interaction effect of nitrogen and seed rate

Number of fertile spikelets spike^{-1} showed significant variation due to the interaction between nitrogen and seed rate. The highest number of fertile spikelets spike^{-1} (47.33) was obtained from the interaction of 140 kg N with 120 kg seed ha^{-1} (Table 13), it was significantly differed from 45.83, 45.80, 45.40, and 45.10 obtained from the interaction of 120 kg nitrogen with both 100 kg and 120 kg seed ha^{-1}, and 140 kg N with both 100 kg and 140 kg seed ha^{-1} respectively but those were statistically similar. The lowest number of fertile spikelets spike^{-1} (33.00) was obtained from the interaction of control N with 100 kg seed ha^{-1}.

4.9 Number of unfertile spikelets spike^{-1}

4.9.1 Effect of nitrogen

Nitrogen showed significant response in respect of number of unfertile spikelets spike^{-1}. The highest number of unfertile spikelets spike^{-1} was obtained from the control treatment of nitrogen. There were no statistical relationships among the treatment of 60, 100 and 140 kg nitrogen $^{-1}$ (Table 11). The lowest number of unfertile spikelets spike^{-1} (3.97) was obtained from 100 kg N ha^{-1}. This finding was also supported by Mozumder (2001) and Rahman (2005).

4.9.2 Effect of seed rate

From Table 12 it was found that number of unfertile spikelets spike^{-1} was increased with the increasing rate of seed. The highest number of unfertile spikelets spike^{-1} (6.80) was found in the highest seed rate (140 kg ha^{-1}). It was followed by 4.01 and 3.89 obtained from 120 and 100 kg seed ha^{-1}, respectively. The lowest number of unfertile spikelets spike^{-1} (3.77) was recorded from 80 kg ha^{-1} seed rate, but 80, 100, 120 kg seed ha^{-1} was found statistically similar. From the above discussion it can be conceived that highest seed rate produced highest number of unfertile spikelets because of strong plant competition since plant population was the highest while less plant population produced the lowest number of unfertile spikelets spike^{-1}, as there was less competition for limited food.

4.9.3 Interaction effect of nitrogen and seed rate

Number of unfertile spikelets spike^{-1} also responded significantly due to interaction of nitrogen and seed rate. No nitrogen fertilization (control) combination with 140 kg seed $^{-1}$ produced maximum number of unfertile spikelet spike^{-1} (10.6) followed by 6.25, 5.33 and 5.00 obtained from the combination of 140 kg N with 140 kg seed ha^{-1}, 60 kg N ha^{-1} with 140 kg seed ha^{-1} and 100 kg N ha^{-1} with 140 kg seed ha^{-1} respectably (Table 13), which were also statistically similar. The lowest no of unfertile spikelets was obtained from the interaction of 100 kg N with 80 kg seed ha^{-1}.

4.10 1000 grain weight (g)

4.10.1 Effect of nitrogen

Thousand grain weight responded significantly following different levels of nitrogen. The highest 1000 grains weight of 36.39 g was observed from 140 kg N ha^{-1} that was followed by 35.90 and 34.26 g obtained from 100 and 60 kg N ha^{-1}, respectively (Table 14.). But N @ 100 kg ha^{-1} showed statistically similar performance with @140 kg N ha^{-1}. (The lowest 1000 grains weight 33.66 g was recorded from control) These findings were obtained probably due to plumpness of seeds as well as increment of protein content in seed, which finally increased 1000 grains weight. These findings were in conformity with the findings of Singh and Singh (1991). (Akter (2005) reported that 1000 grains weight increased with the increasing levels of nitrogen up to 100 kg ha^{-1}) Mazurkiewicz and Bojarczyk (2004) found that differentiation of levels of N fertilization did not significantly influence the differential of 1000 grains weight.

Table 14 Effect of nitrogen on 1000 grains weight, straw yield and harvest index of wheat

Treatment	*1000 grains wt. (g)*	*Straw yield (t ha^{-1})*	*Harvest index (%)*
N_1	33.66	3.14	39.06
N_2	34.26	3.58	42.78
N_3	35.90	4.36	43.10
N_4	36.39	4.32	39.99
LSD (0.05)	0.70	0.17	1.50
CV (%)	3.59	5.55	4.40

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

4.10.2 Effect of seed rate

The 1000 grain weight did not differ significantly due to different seed rates of wheat (Table 15). However from Table 15 it was found that the lowest seed rate ha^{-1} produced the maximum 1000 grain weight (35.37 g) and the minimum 1000 grain weight (34.78 g) was produced by the highest seed rate ha^{-1}. From the study, it was clear that lower the seed rate ha^{-1} higher the 1000 grains weight. This result was supported by Pandey *et al.* (2004). Singh *et al.* (2002) who noticed that 1000 grains weight decreased with the increasing of seed rate.

Table 15. Effect of seed rate on 1000 grains weight, straw yield and harvest index of wheat

Treatment	*1000 grains wt (g)*	*Straw yield (t ha^{-1})*	*Harvest index (%)*
S_1	35.37	3.51	40.01
S_2	35.06	3.82	41.40
S_3	34.99	4.07	42.93
S_4	34.78	4.27	40.59
LSD (0.05)	**ns**	0.18	1.53
CV (%)	3.59	5.55	4.40

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

4.10.3 Interaction effect of nitrogen and seed rate

The interaction of seed rate and nitrogen fertilizer demonstrated significant effect in respect of 1000 grains weight. The highest 1000 grains weight (36.71 g) was observed from 140 kg N ha^{-1} with 60 kg seed ha^{-1} (Table 16). The lowest 1000 grains weight (33.43 g) was obtained from the interaction of control N treatment with 140 kg seed ha^{-1}.

Table 16. Interaction effect of nitrogen and seed rate on 1000 grain weight, straw yield and harvest index of wheat

Treatment	*1000 grain wt (g)*	*Straw yield ($t\ ha^{-1}$)*	*Harvest index (%)*
N_1 S_1	33.84	3.10	38.61
N_1 S_2	33.76	3.20	39.62
N_1 S_3	33.60	3.60	40.00
N_1 S_4	33.43	3.75	38.02
N_2 S_1	34.82	3.26	38.49
N_2 S_2	34.00	3.47	42.38
N_2 S_3	34.20	3.66	46.33
N_2 S_4	34.00	3.91	43.90
N_3 S_1	36.10	3.60	42.86
N_3 S_2	36.00	4.40	43.59
N_3 S_3	35.90	4.62	44.14
N_3 S_4	35.60	4.80	41.82
N_4 S_1	36.71	4.07	40.06
N_4 S_2	36.50	4.20	40.00
N_4 S_3	36.25	4.40	41.26
N_4 S_4	36.11	4.61	38.62
LSD (0.05)	2.12	0.37	1.50
CV (%)	3.59	5.55	4.40

N_1 = 0 (Kg ha^{-1}), N_2 = 60 (Kg ha^{-1}), N_3 = 100 (Kg ha^{-1}), N_4 = 140 (Kg ha^{-1})

S_1 = 80 (Kg ha^{-1}), S_2 = 100(Kg ha^{-1}), S_3 = 120(Kg ha^{-1}), S_4 = 140(Kg ha^{-1})

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

4.11.1 Effect of nitrogen

Different nitrogen levels showed significant variation in respect of grain yield of wheat. The grain yield increased with the increased level of nitrogen up to a certain limit and thereafter decreased (Figure 6). The highest grain yield (3.30 t ha^{-1}) was produced from 100 kg N ha^{-1}) It was followed by 2.88, 2.70 and 2.19 t ha^{-1} obtained from the treatment of 140, 60 and 0 (control) kg N ha^{-1}, respectively . The findings showed that the lowest grain yield was produced from control. It may be assumed that nitrogen fertilizer influenced most of the yield parameters, namely, production of effective tillers $plant^{-1}$, spikelets $spike^{-1}$ and 1000 grains weight that directly or indirectly contributed to higher grain yield. Besides, the highest production of grain @ 100 kg N ha^{-1} might be due to improvement in growth and higher photosynthetic activities. This finding confirms the results of Rahman (2005) and Knapowski and Ralcewicz (2004) who obtained higher grain yield with nitrogen at 120 kg ha^{-1} over the lowest rate of nitrogen.

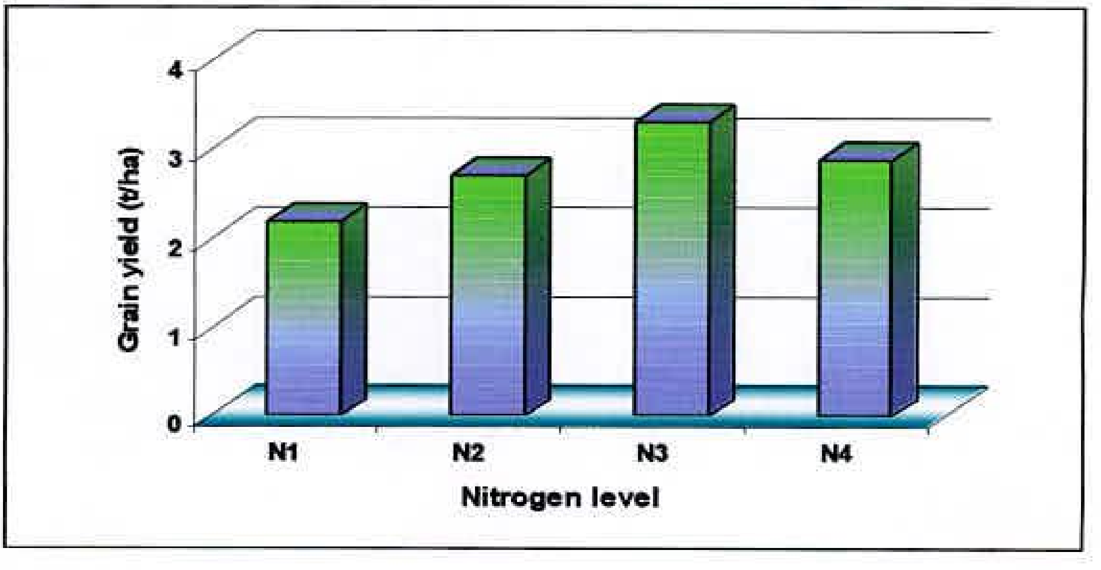

Figure 6. Grain yield (t ha^{-1}) of wheat as influenced by different nitrogen levels ($LSD_{0.05}$ = 0.15)

4.11.2 Effect of seed rate

Grain yield varied significantly due to different seed rates. Figure 7 showed that 120 kg seeds ha^{-1} produced the highest grain yield (3.08 t ha^{-1}) and 80 kg seeds ha^{-1} produced the lowest grain yield (2.35 t ha^{-1}) and they differed significantly with each other. The study revealed that 120 kg seed ha^{-1} gave the higher grain yield above that the grain yield decreased to a substantial level. It was also noticed that due to lower number of effective tillers $plant^{-1}$ and reduced number of grains having small sized seed contributed progressively the lower yield at higher seeding rates. Higher grain yield (3.56 t ha^{-1}) from the highest seed rate was obtained by Arif *et al.* (2002) when they shown at 50 - 150 kg seed ha^{-1}. Uttam and Singh (1996) recorded the maximum grain yield with sowing at 100 kg seed ha^{-1} which was the minimum with higher seed rate of 125 kg ha^{-1}.

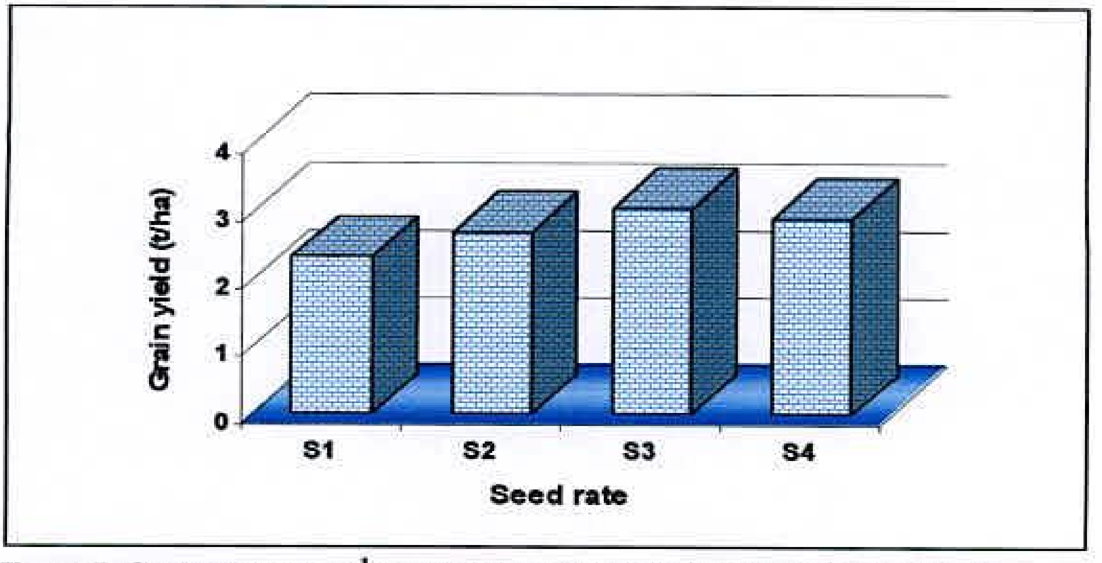

Figure 7. Grain yield (t ha^{-1}) of wheat as influenced by different seed rates ($LSD_{0.05}$ = 0.14)

4.11.3 Interaction effect of nitrogen and seed rate

The interaction of nitrogen and seed rate significantly influenced grain yield of wheat. The highest grain yield (3.65 t ha^{-1}) was found in 100 kg N ha^{-1} with 120 kg seed ha^{-1}(Figure 8). This might be due to the fact that higher seed rate produced higher plant population and their total grain yield was higher than that of other seed rates. The second and third highest grain yield (3.45 and 3.4 t ha^{-1}) was obtained from 100 kg N ha^{-1} with 140 and 100 kg seed ha^{-1}, respectively. But there was no significant difference observed between the interaction of 100 kg N $^{-1}$ with 140 and 100 kg seed ha^{-1}. The lowest grain yield (1.95 t ha^{-1}) was obtained with the interaction of control N treatment with 80 kg seed ha^{-1}.

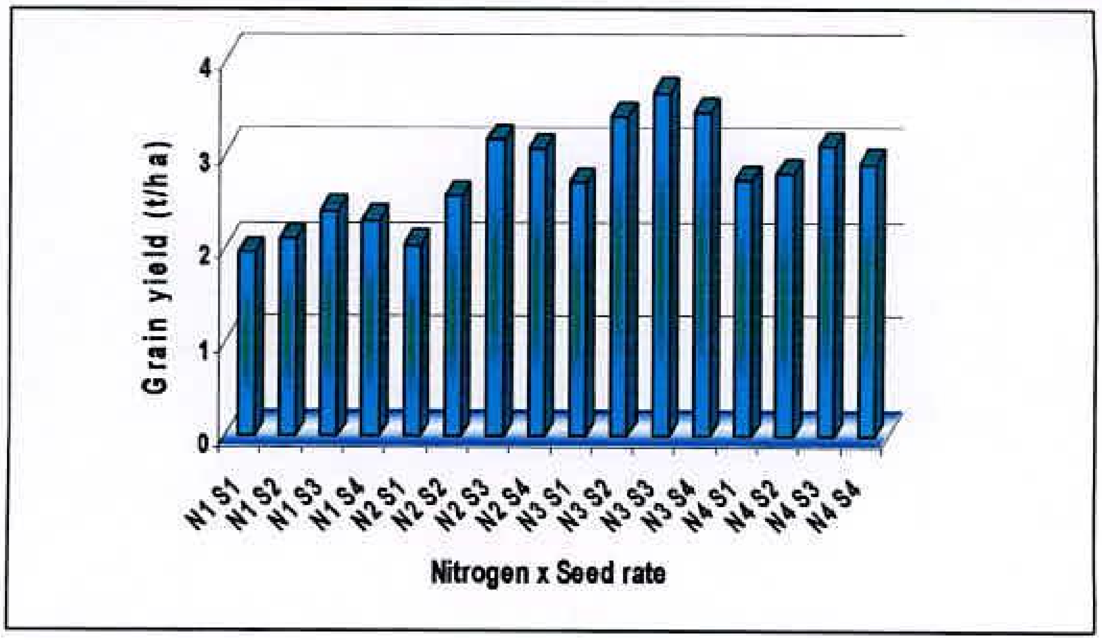

Figure 8. Grain yield (t ha^{-1}) of wheat as influenced by interaction between nitrogen and seed rate ($LSD_{0.05}$ = 0.28)

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

4.12.1 Effect of nitrogen

Straw yield varied significantly due to different rates of nitrogen application. The highest straw yield (4.36 t ha^{-1}) was produced by the application of 100 kg N ha^{-1} (Table 14). The second highest straw yield (4.32 t ha^{-1}) was obtained with 140 kg N ha^{-1}, but it was statistically similar with 100 kg N ha^{-1}. The lowest straw yield (3.14 t ha^{-1}) was produced in 0 (control) kg N ha^{-1} which was also statistically identical with 3.58 t ha^{-1} obtained from 60 kg N ha^{-1}. Straw yield increased with the increasing rate of nitrogen application. The findings of the present study was in agreement with Akter (2005) who reported that straw yield increased progressively with the increasing rate of nitrogen up to 100 kg ha^{-1}. Chandurkar *et al.* (2004), Pandey et *al.* (2004) and Das (2005) reported that straw yield increased gradually with the increase of N levels. It was noted that higher levels of nitrogen produced taller plant having more tillers and leaf canopy which in turn gave the increased straw yield.

4.12.2 Effect of seed rate

Straw yield of wheat was significantly influenced by different seed rate (Table 15). It was revealed that straw yield increased with the increasing level of seed rates. The highest straw yield (4.27 t ha^{-1}) was produced from seeds @ 140 kg ha^{-1}. The second and third highest straw yield 4.07 and 3.82 t ha^{-1} was produced from seeds @120 and 100 kg ha^{-1}, respectively. The lowest straw yield (3.51 t ha^{-1}) was obtained from 80 kg ha^{-1} of seed rate. This finding was impartial agreement with Pandey *et al.* (1999), they reported that straw yield increased up to 150 kg ha^{-1}. But Mozumder (2001) stated that straw yield increase up to 125 kg seed ha^{-1} and there after it declined.

4.12.3 Interaction effect of nitrogen and seed rate

The interaction effect of seed rate and nitrogen was found significant in respect of straw yield of wheat. It was observed from Table 16 that the highest straw yield (4.8 t ha^{-1}) was found in the interaction of 100 kg N with 140 kg seed ha^{-1}. Straw yield of 4.62, 4.61, 4.40 t ha^{-1} was obtained from the interaction of 100 kg N ha^{-1} with 120 kg seed ha^{-1}, 140 kg N with 140 kg seed ha^{-1} and 100 kg N ha^{-1} with 100 kg seed ha^{-1} respectively. But these three figures were statistically similar with each other. The lowest straw weight was obtained from the interaction of control N with 80 kg seed ha^{-1}. Similar result was also reported by Mozumder (2001) who found the highest straw yield from the interaction of highest seed rate and nitrogen level.

4.13 Harvest index (%)

4.13.1 Effect of nitrogen

Harvest index was significantly influenced by the rate of different nitrogen. The highest harvest index (43.10%) was observed with the application of 100 kg N ha^{-1}) (Table 14) which was also statistically similar with 60 kg N ha^{-1} (42.78%).(The lowest harvest index (39.06) produced in 0 kg (control) N ha^{-1} that was statistically similar with 39.99 % that obtained from 140 kg N ha^{-1}. Harvest index increased with the increasing rate of nitrogen at a certain level and thereafter decreased. More harvest index value indicated more mobilization of assimilates to sink in panicles and grains. These findings were similar with the result of Akter (2005), Rahman (2005) and Mozumder (2001). Pandey *et al.* (2004) said that harvest index increased significantly up to 120 kg N ha^{-1} and there after decreased.

4.13.2 Effect of seed rate

Harvest index was significantly influenced by the different seed rates. It was found that the highest harvest index (42.93%) was obtained from the optimum seed rate at 120 kg ha^{-1}. Harvest index 41.40%, 40.59%, and 40.01% were obtained from 100, 140 and 80 kg seed ha^{-1} but all of these were statistically similar (Table 15). Gulzer *et al.* (1995) reported that harvest index was decreased from 42.96% to 35.12 % with corresponding sowing rate.

4.13.3 Interaction of nitrogen and seed rate

There was significant variation in harvest index due to interaction of different nitrogen levels and seed rates (Table 16). The highest harvest index (46.33%) was obtained from the interaction of 60 kg N with 120 kg seed ha^{-1}. It was followed by 44.14%, 43.90% and 43.59% which were obtained from the interaction of 100 kg N with 120 kg seed ha^{-1}, 60 kg N with 140 kg seed ha^{-1} and 100 kg N with 100 kg seed ha^{-1}. But they were statistically similar with the highest harvest index. The lowest harvest index (38.02) was obtained from the interaction of control N treatment with 140 kg seed ha^{-1}.

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2005 to March 2006 to study the growth and yield of wheat as influenced by nitrogen and seed rate.the experiment included four nitrogen levels viz. 0, 60, 100 and 140 kg ha^{-1} and four rates of seed viz. 80, 100, 120 and 140 kg ha^{-1}.

The experiment was laid out in a split-plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into 4 main plots in which nitrogen levels were applied at random. Each main plot was further divided into 4 unit plots or sub-plots and different rates of seeds were sown at random.

The data collected were plant height from 30 DAS to harvest (cm), total dry matter accumulation from 30 DAS to harvest (g per m^2), crop growth rate (CGR), relative growth rate (RGR), number of total tillers per m^2, number of effective tillers per m^2, spike length (cm), number of fertile spikelets $spike^{-1}$, number of unfertile spikelets $spike^{-1}$, 1000 grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), and harvest index (%)

The collected data were complied and analyzed by split plot design to find out the statistical significance of experimental results. The means for all recorded data were calculated and the analyses of variance for all characters were performed. The mean differences were evaluated also by least significant difference (LSD) test.

Nitrogen had significant effect on all the plant characters. Seed rates also significantly influenced on all agronomic characters except 1000 grains weight. Result showed significant difference in interaction of nitrogen application and seed rate.

The plant height was influenced by both nitrogen and seed rates. Nitrogen at the rate of 100 kg and 140 kg ha^{-1} produced statistically the similar plant height at all growth stage except harvest. Seed rate 120 and 140 kg ha^{-1}, produced more or less similar plant height at all growth stage. All the interaction treatments showed more or less similar response with each other considering all growth stage. Combine effect of 100 kg N ha^{-1} and 100 kg seed ha^{-1} performed better than others.

Dry matter accumulation increased significantly at all growth stages. Nitrogen at the rate of 100 kg ha^{-1} produced highest amount of dry matter at different growth stage. Seed rates at 120 and 140 kg ha^{-1} produced the highest dry matter from 30-50 DAS but later stages 120 kg seed ha^{-1} performed the better increase of dry matter production. Nitrogen rate of 100 kg ha^{-1} in combination with 120 kg seed ha^{-1} produced maximum dry matter at 30 and 50 DAS but incase of other growth stages, 100 kg N ha^{-1} in combination with 140 kg seed ha^{-1} produced maximum dry matter.

Crop growth rate (CGR) progressively increase up to 50-70 DAS with different levels of nitrogen and thereafter, CGR gradually declined. Different rates of nitrogen did not show any significant response from 70 DAS to harvest stage. Similar result also found from different seed rate. There was not found any significant results at 70-90 DAS from different seed rate. Interaction effect of nitrogen and seed rates on CGR found significant at all growth stage except 70-90 DAS.

Relative growth rate (RGR) values declined gradually with the age of plant. Different seed rates showed significant response at 30-50 and 50-70 DAS, but there were not found significant response at 70-90 DAS and 90 DAS – harvest. Different seed rates show significant result at all growth stages except 70-90 DAS. Interaction effect of nitrogen and seed rates on RGR found significant over the growth stage except 70-90 DAS.

The highest number of total tillers per m^2 (572.6) was produced from 100 kg N ha^{-1}. The lowest level of seed rate produced highest number of total tillers per m^2 (537.4). Interaction effect of 100 kg N along with 80 Kg seed ha^{-1} was found most conducive to produce total number of tillers per m^2.

The maximum number of effective tillers per m^2 (487.7) was produced from 100 kg N ha^{-1}. The highest number of effective tillers (465.0) per m^2 was produced by120 kg seed ha^{-1}. Interaction effect of 100 kg N ha^{-1} with 120 kg seed ha^{-1} was found most responsible to form the highest number of effective tillers m^{-2}.

Spike length increased with increasing nitrogen level, but 100 kg and 140 kg nitrogen ha^{-1} was found statistically similar to make elongation of spike. Like total tillers per m^2, 80 kg seed ha^{-1} also found to became most conducive to increase the length of spike. Combine effect of nitrogen and seed rates were found similar to each other.

The effect of nitrogen on the number of fertile spikelets $spike^{-1}$ was significant. Statistically similar number of fertile spikelets $spike^{-1}$ was produced with the treatments of 100 kg and 140 kg N ha^{-1}. Seed rate 120 kg ha^{-1} produced the highest number (42.77) of fertile spikelets $spike^{-1}$. The interaction effect of nitrogen and seed rate was also found significant in respect of number of fertile spikelets $spike^{-1}$.

The highest number (5.77) of unfertile spikelets $spike^{-1}$ was obtained from control nitrogen treatment while seed rate @ 140 kg ha^{-1} produced the highest number (6.08) of unfertile spikelets spike.Control treatment of nitrogen and 140 kg seed ha^{-1} produced the maximum number (10.60) of unfertile spikelets $spike^{-1}$. Control treatment of nitrogen with 140 kg seed ha^{-1} was found to be vulnerable to form maximum number of unfertile spikelets $spike^{-1}$.

The 1000 grains weight was influenced significantly with nitrogen application. Statistically similar 1000 grains weight 35.90 and 36.39 g were produced with the treatments of 100 kg and 140 kg N ha^{-1}. Again it was found from the study that 1000 grains weight was not influenced by different seed rates. There were no significance difference among the interaction effect of nitrogen and seed rate.

In respect of grain yield, nitrogen had significant variation at different levels. The highest grain yield (3.30 t ha^{-1}) was obtained from 100 kg N ha^{-1}. Regarding rate of seed, grain yield variation was also significant. Interaction effect showed that 100 kg N in combination with 120 kg seed ha^{-1} produced the highest yield (3.65 t ha^{-1}).

Statistically similar higher straw yield (4.36 and 4.32 t ha^{-1}) was performed with the treatment of 100 kg and 140 kg N ha^{-1} than other N treatments. Incase of seed rate 140 kg seed ha^{-1} produced the highest (4.27 t ha^{-1}) straw yield which was significantly followed by 120, 100 and 80 kg seed ha^{-1}. Interaction showed that no significance difference among the treatments.

Harvest index significantly influenced by both nitrogen levels and seed rates where 60 and 100 kg N ha^{-1} produced statistically similar harvest index value which was 42.78 % and 43.10 %, respectively. The highest harvest index value of 42.93% was produced at 120 kg seed ha^{-1}. In combination of 60 kg N ha^{-1} and 120 kg seed ha^{-1} produced the highest harvest index.

From the above discussion, it may be concluded that the higher yield of wheat could be obtained by applying 100 kg N ha^{-1} and also with 120 kg seed ha^{-1}. However, further trials are necessary to arrive at a definite conclusion.

References

REFERENCE

Abou-Salama, A.M. (1995). Maximizing yield of wheat using nitrogen fertilizer dose splitting. *Assiut J. Agric. Sci.* **26**(2): 115-125.

Ahmad, G., Shah, P., Bari, A. Ahmad, G., Shah, P. and Bari, A. (1995). Effects of different seed rates on the yield and yield components of wheat cv. Pirsabak 85. *Sarhad J. Agric.* **11** (5). 569-573.

Ahmed, M. and Hossain, S.M.A. (1992). Effect of seed rate, nitrogen fertilization and time of harvest on the seed yield of wheat. *Bangladesh Agron. J.* 4(1&2): 35-43.

Akter, H. (2005).Yield and seed quality of wheat cultivars as influenced by fertilizer nitrogen level under rainfed and irrigated conditions. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Andersson, B. and Larsson, S. (1989). Seed rates and nitrogen fertilization, of winter wheat with and without fungicide treatment. Rostlima vyroba, Research Inst. of plant Production, Slovakia. 12: 33.

Aram-Koomklang. (1990). Effects of seed rates and planting methods on yield and yield components of wheat line no. 144. *Sarhad J. Agric.* **10** (3): 60-61.

Arif, M., Taj, F.H., Kakar, K.M.and Khalid N. (2002). Seed rates effect on wheat varieties. *Sarhad J. Agric.* **18**(3): 259-261.

Awasthi, U.D. and Bhan, S. (1993). Performance of wheat (*Triticum aestivum*) varieties with different levels of nitrogen in moisture-scarce condition. *Indian J. Agron.* **38**(2): 200-203.

Ayoub, M., Guertin, S., Lussire, S., Smith, D.L. (1994). Timing and level of nitrogen fertility effects on spring wheat yield in Eastern Canada. *Crop Sci.* **34**(3): 784-786.

Azimzadeh, M. and Koocheki, A. (1999). Effect of different seeding rates and amount of phosphorus fertilizer on yield and yield components of dry land wheat in northern Khorasan. *Agril. Sci. Tech.* **13**(2): 131-139.

Bagga, A.K. and Tomar, O.P.S. (1981). Growth and yield of short strewed wheat under commercial planting densities. *Indian J. Plant Physiol.* **24**(3): 255-268.

Bardsley, C.E. and Lancster, J.D. (1965). Sulphur. In: Black, C.A. (ed) . Methods of Soil Analysis. Part 2. Chemical and Microbiological properties. 2nd ed. Agronomy No. 9. ASA. Madison, Wisconsin, USA. p.1103.

Baten, M.A. and Islam, M.A. (1983). Growth and yield of semidwarf variety of wheat as affected by different levels of nitrogen and phosphorus. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agricultural University, Mymensingh.

BBS (Bangladesh Bureau of Statistics). (2004). Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of Bangladesh.

Bellido, L.L., Bellido, R.J.L., Castillo, J.F. and Bellido, F.J.L. (2000). Effect of tillage, crop ratation and nitrogen fertilization on wheat under rainfed Mediterranean conditions. *Agron. J.* **92**(2): 1056-1066.

Bhagawati, P.C., Faroda, A.S. and Malik, R.K. (1992). Response of wheat (*Triticum aestivum*) and associated weeds to application of nitrogen and isoproturon. *Indian J. Agron.* **37**(4): 721-728.

Bhatnagar, G. S., Porwal, M.K. and Dhakar, L.L. (1990). Response of wheat to different crop geometries and seed rates in southern Rajasthan. *Int. J. Trop. Agric.* **8**(3): 214-216.

Black, A.L. and Aase, J.K. (1982). Yield component comparisons between USA and USSR winter wheat cultivars. *Agron. J.* **74**(3): 436-441.

Borojevic, S. and Kraljevic, B.M. (1983). Determination of optimum density and row spacing for different wheat genotypes. *Agric. Forest Met. Canada.* **43**(5): 390-396.

Bremner, J.M. (1965). In; Black, C.A (ed). Inorganic forms of nitrogen. Chemical and Microbiological Properties. Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. Madison, Wisconsin, USA. p.1185.

Bremner, J.M. and Mulvaney, C.S. (1982). In: Page. A.L. (ed). Nitrogen-Toral. Methods of Soil Analysis. Chemical and Microbiological Properties. Part 2. ASA. SSSA. Madison, Wisconsin, USA. pp. 595-624.

Brown, R.H. (1984). In: Teasar, M.B (ed). Growth of the green plant. Physiological Basis of Crop Growth and Development. ASA. CSSA. Madison, Wisconsin, USA. pp.153-173.

Chanda, K. and Gunri, S. K. (2004). Response of hybrid and high yielding wheat genotypes (*Triticum aestivum* L.) to nitrogen levels under terai zone of West Bengal. *Crop Res. Hisar.* **28**(1/3): 34-38.

Chandurkar, V.P., Kubde, K.J., Dahiphale, A.V., Thakare, G.V. and Deshmukh, A.H. (2004). Effect of different levels of nitrogen on yield protein content and nitrogen uptake by wheat cultivars. *Ann. Plant Physiol.***18**(1): 99-100.

Chapman, H.D. (1965). Cation exchange capacity. In: Black, C.A. (ed). Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. SSSA. Madison, Wisconsin, USA. pp.891-900.

Chatha, M.T., Ahmed, M. and Gill, M.A. (1986). Yield of wheat cultivar as affected by different seed rates under irrigated conditions. *Pakistan J. Agric.* **7**(4): 241-243.

Convertini, G., Maiorana, M., Bari-V-di., Rizzo, V., Vonella, A.V., Di, B.V. (1998). Effects of nitrogen fertilization and watering on grain yield, dry matter accumulation and nitrogen uptake in durum wheat. *Agrochimica*. **42**(5). 190-199.

Curic, R. (1982). Importance of fertilizing wheat with nitrogen, phosphorus and loss of nutrients. Arbiv za Poljoprivredve Nauke. **43**(152): 505-521. [Field Crop Abst., 1975. 38(4): 156].

Das, K.C. (2002). Effect of planting density and rate of nitrogen application on the yield of wheat cv. Kanchan. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Das, P.K. (2003). Effect of row spacing and nitrogen on the growth and yield of wheat. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Day, P. R. (1965). In: Black, C. A. (ed). Particle fractionation and particle size analysis. Methods of Soil Analysis. Part 2. Madison, Wisconsin, USA. pp.545-567.

Dhuka, A.K., Sadaria, S.G., Patel, J.C. and Pate, B.S. (1991). Effect of rate and time of nitrogen application on late sown wheat (*Triticum aestivum*). *Indian J. Agron.* **37**(2): 254- 355.

Dixit, A.K.and Gupta, A.K. (2004). Influence of methods of sowing and seed rates on growth and yield of wheat (*Triticum aestivum*) under different dates of sowing. *Environ. Ecol.* **22**(3): 407-410.

Donald, C. M. (1963). Competition among crop and pasture plants. *Ann. Agron.* **15**:1-18.

Dotlacil, L. and Holubova, K. (1988). The effect of sowing rate on yield levels and yield structure in durum wheat (*Triticum durum* Desf.). *Agri. Trop. Subtrop.* **21**: 11-21.

Endres, V.C. and Joba, I. (1989). Populations and spacing in single and double row and lodging in wheat crops. Documents UEPAE Dourados, M. S. Brazil. No. 39: 195-208.

Gaffer, M.A. and Shahidullah, M. (1985). Study on the effect of seed rates and phosphorus on the performance of wheat. *Bangladesh J. Sci. Ind. Res.* (1-4): 159-162.

Gehl, D. T., Bailey, L. D., Grant, C. V. and Sadler, J. M. (1990). Effects of incremental Nitrogen fertilization on seed yield and dry matter accumulation of six wheat (*Triticum aestivum* L.) cultivars in Southern Manitoba. *Canadian. J. Plant Sci.* **70**: 51-60.

Govil, S.R. and Pandey, H.N. (1995). Growth analysis of wheat and maize as affected by plant population: a comparison of classical and regression methods. *Crop Res. Hisar.* **9** (1). 114-120.

Gulzer, A., Paigham, S., Abdul, B., Ahmed, G., Shah, P. and Bari, A. (1995). Effect of different seed rates on the yield and yield components of wheat cv. Prisabak 85. *Sarhad J. Agric.* **11**(5): 569-573.

Gupta, S.K. (1989). Effect of seed rates and nitrogen doses on the growth and yield of wheat in Tripura. *Indian J. Hill Fmg.* **2** (1). 39-44.

Gurdip, K., Kler, D.S., Singh, S., Kaur, G., and Singh, S. (2001). Relationship of haeight., lodging score an silica content with grain yield of theat (*Triticum aestivum l.).* under different planting techniques at higher nitrogen nutritin . Dept . Agron., Punjab Agril. Univ. India. *Environ. Ecol.* **19** (2): 412-417.

Halvorson, A.D., Black, A.L., Krupinsky, J.M., Merrill, S.D., Wienhold, B.J and Tanaka, D.L. (2000). Spring wheat response of tillage system and nitrogen fertilization with a crop – fallow system. *Agron . J.* **92**(2): 288-294.

Hossain, M. Z. (2002). Effect of seed rate and time of harvest on yield and quality of wheat seed. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Hossain , M.B. (2005). Effect of nitrogen level, seed rate and planting method on the yield performance of wheat. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Huel, P., Baker, R.J. (1990). Seedling rate effects on low tillering spring wheats in a semi arid environment. *Canadian J. Pl. Sci.* **70** (1): 9-17.

Hunter, A.H. (1984). Soil Fertility Analytical Services in Bangladesh. Bangladesh Agricultural Research Council (BARC). pp.1-7.

Ionescu, N. (1994). Influence of the distance between rows and sowing rate on some yield characteristics in winter wheat. Probleme de Agrofitolehnie Teoretica is aplicata. Albota, Romania. **16** (2): 181-187.

Jackson, M.L. (1958). Soil Chemical Analysis. Prentice-Hall Inc, EngleWood Cliffs, N. J. p. 498.

Kataria, N. and Bassi, K. (1999). Effect of organic mulch on early-sown wheat (*Triticum aestivum*) under rainfed conditions . *Indian J. Agron.* **42**(1): 94-97.

Khan, M.S.K., Rahman, M.M., Islam, M.A., Ahmed, A. and Ali, M.A. (2002). Effect of different levels of nitrogen on growth and physiological attributes of wheat. *Progress. Agric.* **13** (1&2): 47-52.

Knapowski, T. and Ralcewicz, M. (2004). Estimation of the quality features of winter wheat corn and flour in the relation to diversificated nitrogen fertilization.Annales Univ. Mariae Curie Skodowska Sectio E, Agricultura. **59**(2): 959-968.

Kreft, I. and Spiss, L. (1988). Relationships between stand density and yield components in wheat. Voroshilorgradskoe NPO Elita Vkrainlan, USSR. **51**: 27-33.

Kumar, A. (1985). Response of wheat cultivars to nitrogen fertilization under late sown condition. *Indian J. Agron.* **40**(1): 38-42.

Kumar, A., Sharma, D.K. and Kumar, A. (1997). Dry matter and nutrient accumulation in wheat as influenced by irrigation and nitrogen in sodic (aquic natrustalf) soil. *Indian J. Agril.Res.* **31**(4): 217-221.

Kumar, A., Sinha, A.K., Sinha, B.P., Singh, K.M.P.and Thakur, S.S. (1991). Response of wheat genotypes to seed rates and row spacing. *Indian J. Agron.* **36** (1): 78-82.

Kumar, A., Sarma, D.K. and Sharma, H.C. (1995). Nitrogen uptake, recovery and N-use efficiency in wheat (*Triticum aestivum*) as influenced by nitrogen and irrigation levels in semi- reclaimed sodic soils. *Indian J. Agron.* **40** (2): 198-203.

Kumar, S. B., Arora, R. P. and Singh, R. (2003). Effect of nitrogen on crop biometrics of wheat. *Ann. Agric. Res.* **24**(4): 743-745.

Kumar, S., Badiyala, D., Singh, C. M. and Saroch, K. (1999) Nitrogen and cutting management in winter wheat (*T. aestivum*) under dry temperature high hills. *Indian J. Agron.* **44**(1): 113-114.

Kumar; R. Agarwal, S.K. and Nanwal, R.K. (2002). Biomass study in bread wheat (*Triticum aestivum* L.) under different planting systems, seed rates and nitrogen levels in sandy loam soils. *Haryana Agric. Univ. J. Res.* **32**(2): 73-76.

Latif, L.I.A. and Tuhamy, M.K.E.L. (1986). Effect of nitrogen fertilization levels and seeding rates on growth and yield of wheat. *Annals Agril. Sci. Ain Shams Univ.* **31**(1): 265-272.

Li, F.S., Kang, S.Z., Li, F.S., and Kang, S.Z. (2002). Effects of atmospheric CO2 enrichment, applied nitrogen and soil moisture on dry matter accumulation and nitrogen uptake in spring wheat. *Pedosphere*. **12**(3): 207-218.

Mahajan, A.K., Dubey, D.P., Namadeo, K.N. and Shukla, N.P. (1991). Response of late sown wheat to seed rates and seed soaking sprouting. *Indian J. Agron.* **36**(2): 288-291.

Markovic, B. (1983). The influence of sowing density and N supply on morphological features of the plant and on grain quality and yield in some wheat cultivars. Arhiv za Poljoprivre dne, Nauke. **44**(154): 185-236.

Mazurek, J. (1984). Effect of sowing density on yield, yield components, and grain quality in new spring wheat lines and varieties. Biuletyn Instutui Hodowli I Aklimalyzacji Roslin, Pulawy, Poland. **155**: 73-81.

Mazurkiewicz, J. and Bojarczyk, M. (2004). The effect of nitrogen fertilization on technological quality of winter wheat cultivars in monoculture. *Annales Univ. Mariae Curie Skodowska Sectio E, Agricultura*. **59**(4): 1621-1629.

Meneses, A. and Ivan M. (1992). Effect of nitrogen and irrigation on yellow berry of five cultivars of hards wheat (*Triticum aestivum L.*) VAR durum. Univer sidder catolica de chile, Santiago (Chile) Agronmia. p. 118.

Mishra, C.M. (1993). Response of wheat (*Triticum aestivum*) genotypes to seed rates on dryland. *Indian J. Agron*. **38**: (2). 288-289.

Mozumder, A.S.M.M.H. (2001). Effect of different seed rates and levels of nitrogen on the performance of Shourav variety of wheat. M. Sc.Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Nag, B.L., Rahman, A.K.M.M., Hassan, M.S. and Uddin, M.S. (1998). Growth analysis and yield of wheat as influenced by seed rate. *Ann. Bangladesh Agric.* **8** (1): 25-34.

Nierobca, P. (2002). Dynamics of dry matter accumulation and distribution in spring triticale and spring wheat plants as affected by plant population. *Folia Univ. Agriculturae Stetinensis, Agricultura*. **91**: 93-99.

Nourafza, M.M. and Langer, R.H.M. 1979. Yield components wheat in response to seeding rate, rates and times of application of nitrogen fertilizer. *Proc. Agron. soc. Newzealand*. **9**: 23-24.

Olsen, S.R. and Dean, L.A. (1965). Phosphorus. In: Black, C. A (ed). Methods of Soil Analysis. Monograph No. 9. ASA. Madisin, Wisconsin, USA. pp.1035-1088.

Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In: Page, A. I (ed). Methods of Soil Analysis. Part II. Chemical and Microbiological properties. 2nd ed. Monograph No. 9.ASA. Madison, Wisconsin, USA. pp. 404-407.

Ottman, M.J., Dverge, T.A. and Martin, E.C. (2000). During grain quality as affected by nitrogen fertilizer near anthesis and irrigation during grain fill. *Agron. J.* **92** (5): 1035-1041.

Pandey, D.S., Mishra, R.D. and Sharma, K.C. (1986). Effect of irrigation based on pan-evaporation and nitrogen on wheat. *Indian J. Agron.* **31**(4): 370-373.

Pandey, I.B. , Bharati, V., Bharati, R.C. and Mishra, S.S. (2004). Effect of fertilizer levels and seed rates on growth and yield of surface-seeded wheat (*Triticum aestivum*) under lowland rice ecosystem of north Bihar. *Indian J. Agron.* **49** (1): 43-45.

Pandey, I.B., Thakur, S.S. and Singh, S.K. (1999). Response of timely sown wheat (*Triticum aestivum*) varieties to seed rate and fertility level. *Indian J. Agron.*, **44**(4): 745-749.

Pasricha, N. S. and Brar, M. S. (1999). Role of mineral fertilizer to increase wheat production. Fertilizer News. **14**(2): 39-43.

Patel, N.M., Sadaria, S.G., Kaneria, B.B. and Khanpara, V.D. (1995). Effect of nitrogen, potassium and zinc on growth and yield of wheat (*Triticum aestivum*). *Indian J. Agron.* **40**(2): 290-292.

Patel, R.M. and Upadhyay, P.N. (1993). Response of wheat (*Triticum aestivum*) to irrigation under varying levels of nitrogen and phosphorus. *Indian J. Agron.* **38**(1): 113-115.

Patra, S.S. (1990). Response of wheat varieties to fertilizer and irrigation. *Indian J. Agron.* **35**(3): 302-303.

Paul, S.R. (1992). Effect of pre-sowing seed treatment, seed rates, fertility levels and surface soil compaction on growth and yield of late sown rainfed wheat in *Assam. Ann. Agric. Res.* **13**(4). 410- 411.

Peterson, R. F. (1965). Wheat Inter Science Publishers. Inc., N. Y. p. 38.

Prasad, K. and Singh, R.S. (1995). Influence of weed and nitrogen management on weed growth nutrient uptake and yield of wheat. *Indian J. Agril. Sci.* **65**(2): 117-122.

Pratt, P.J. (1965). Lithium, Sodium and Potassium. In: Black, C. A (ed). Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. Madison, Wiscon, USA. pp.225-246.

Radford, P.J. (1967). Growth analysis formulae. Their use and absue. *Crop Sci.* **7**: 171-175.

Rahman, M.L. (2005). Yield and quality of wheat as influenced by nitrogen, sulpher and boron under irrigated and rainfed conditions. M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh.

Rajput, A.L., Singh, D.P. and Singh, S.P. (1995). Effect of soil and foliar application of nitrogen and zinc with farmyard manure on late-sown wheat. (*Triticum aestivum*) *Indian J. Agron.* **40**(4): 598-600.

Rajput, F.K.M., Alam, S.M., Baloch, A.W., Arain, A.S. and Rajput, M.J. (1989). Effect of different NP treatment combinations on the growth and yield of wheat. *Sarhad J. Agric.* **5**(4): 347-349 [Field Crop Abst. 1990. 43 (11): 981].

Ram, P., Dwivedi, D. P., Pandey, S. N., Singh, S. K., Singh, T. K., and Verma, S. N. (2004). Effect of varieties and nitrogen doses on growth and yield of wheat in saline-alkali soil under late sown conditions. *Plant Archives*. **4**(2): 351-354.

Razzaque, D.M.A., Sattar, M. A., Amin, D.M.S., Kaiyum, D.M.A. and Alam, M.S. (2000) Krishi Projukti Hatboi (Hand book of Agro- tecnology), 2nd edition. Bangladesh Agricultural Research Institute, Gazipur. p. 10.

Rathore, A.L and Patel, S.L. (1991). Studies on nitrogen and irrigation requirement of late sown wheat. *Indian J. Agron*. **36**(2):184-187.

Reddi, S. G. and Patil, B. N. (2003). Influence of N-levels and seed rates on growth, yield, protein content and N-uptake in wheat genotypes. *Karnataka J. Agric. Sci.***16**(1). 31-34.

Roy, S.K. and Biswas, P.K. (1991).Effect of population on tillering , growth, yield components and yield of wheat. *Ann. Bangladesh Agric.***1** (2): 81-85.

Roy, S.K., Maniruzzaman, A.F.M. and Saifuzzaman, M. (1991). Effect of planting geometry and nitrogen application on growth and yield of wheat. *Indian J. Agron.* **36**: 33-37.

Russell, O.F. (1986). MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA.

Saari, E. E. (1998). Leaf blight diseases and associated soil borne fungal pathogens of wheat in South and Southeast Asia. D. F.: CIMMYT. pp 37-51.

Samad, M.A., Sarker, A.U. and Sarkar, A.R. (1984). Effect of N application on the growth and yield of wheat. *Bangladesh J. Agril. Sci.* **11**(1): 97-100.

Saradon, S.J., Chidichimo, H.O. and Arriaga, H.O. (1988). Effect of sowing density on accumulation and translocation of dry matter in three cultivars of *T. aestivum* L. **38** (3): 185-194.

Sarker, M.A.Z., Miah, M.G., Hamid, A., Haider, J. and Hashem, A. (1997). Effect of nitrogen level and duration of weed competition on weed biomass, yield and yield attributes of wheat. *Ann. Bangladesh Agric.***7** (1): 1-7.

Sharar,M.S.; Ahmad, M.S. and Ayub, M. (1987). The effects of varying seedling densities on the growth and yield of three wheat varieties. *Pakistan J. Sci. and Ind. Res.* **30**(1): 40-42.

Sharma, J.S. and Dillon, S.S. (1993). Effect of seed rate and nitrogen level on new genotypes ('PBW 154' and 'PBW 222') of wheat (*Triticum aestivum*). *Indian J. Agron.* **38**(1): 111-112.

Shukla, A.K., Ladha, J.K., Singh, V.K., Dwivedi, B.S., Vethaiya, B., Gupta, R.K., Sharma, S.K., Yogendra, S., Pathak, H., Pandey, P.S., Padre, A.T., Yadav, R.L. (2004). Calibrating the leaf color chart for nitrogen management in different genotypes of rice and wheat in a systems. *Perspective. Agron. J.* **96**(6): 1606-1621.

Singh, D., Singh , S.P. and Singh, D. (2002). Response of late sown wheat ot seed rate and nitrogen . *Progressive Agric.* **2** (1): 72.

Singh, D., Singh, T., Singh, H., Faroda, A .S., Singh, D., Singh, T. and Singh, H. (1987). Effect of seed rates and nitrogen levels on concentration and uptake of nitrogen in wheat. *Indian J. Agron.* **32**(4): 458-459.

Singh, G., Singh, R. and Kumer, P. (1996). Response of wheat (*Triticum aestivum*) to nitrogen, phosphorus and potassium fertilizer. *Indian J. Agron.* **41**(1): 157.

Singh, H. and Singh, O. (1987). Response of late sown wheat to seed rate and nitrogen. *Indian J. Agron.* **32**(3): 290-291.

Singh, H. and Singh, R. (1991). Effect of nitrogen and seed rate on wheat. *Indian J. Agron.* **29**(1): 129-130.

Singh, R.V., Dubey, V.K. and Vyas, M.D. (1992). Effect of seed rate, nitrogen levels and method of fertilizer placement on wheat (*Triticum aestivum)* under late sown condition. *Indian J. Agron.* **37**(1): 43-46.

Singh, T., Singh, K.N. and Bali, A.S. (1992). Response of wheat (*Triticum aestivum*) varieties to nitrogen under rainfed conditions of Kasmir Valley. *Indian J. Agron.* **37**(1): 49-51.

Singh, V. P. and Singh, J. P. (1995). Response of rainfed wheat (*Triticum aestivum*) to level and methods of nitrogen application. *Indian J. Agron.* **40**(3): 507-509.

Singh, V.K., Bijpai, R.P., Dubey, O.P., Purohit, K.K. and Sisodia, R.I. (1991). Response of tall wheat (*Triticum aestivum*) to irrigation and nitrogen. *Indian J. Agron.* **36**(4): 474-478.

Singh, V.P.N and Uttam, S.K. (1993). Performance of wheat (*Triticum aestivum* L.) cultivars under different sowing methods and fertility levels in central Uttar Pradesh. *Indian J. Agron.* **38**(2): 285-287.

Smocek, J., Mencl, J. and Hlavac, M. (1982). The influence of wheat commercial traits on yield in stands of different density. *Vliv produkcnich znaku psenice na vynos v rozdilne hustych porostech. Rostlinna Vyroba* **28** (4): 347-352.

Srinivas, A., Satyanarayana. V., Ramaiah, N.V. (1997). Dry matter accumulation and yield of wheat (*Triticum aestivum* L.) varieties as influenced by nitrogen and zinc application. *J. Res. ANGRAU.* **25**(4). 5-8.

Sun yuanmin; Ji jiqing; Ji guoqing; Gao, yude and Gu Xiangwn. (1996). Study on population adjusting technique for super high yielding wheat production. *Jiangsu J. Agric. Sci.* **12**(4): 7-11. [Wheat , Barley and Triticale Abst. 14 (3) : 261].

Sushila, R. and Giri, G. (2000). Influence of farmyard manure, nitrogen and biofertilizers on growth, yield attributes and yield of wheat under limited was supply. *Indian J. Agron.* **45** (3): 590-595.

Tomar, R.K.S., Raghu, J.S., Yadav, M. and Ghurayya, R.S. (1993). Response of wheat (*Triticum aestivum* L.) varieties to irrigation under different fertility levels. *Indian J. Agron.* **38** (2): 291-293.

Torofder, M.G.S. (1993). Effect of varieties and seed rates on the yhield of wheat. *Bangladesh J. Agril. Res.* **18** (2):187-190.

Turley, D.B. (1999). Effect of seed rate on tillering and yield of wheat cultivars. Test of Agrochemicals and cultivars. **20**(1): 64-65.

Upadhyay, V. B. and Tiwari, J. P. (1996). Influence of nitrogen, seed rate and mulch on wheat (Triticum aestivum) varieties under late sown condition. *Indian J. Agron.* **41**(4): 562-565.

Uttam, S.K. and Singh, V.P.N. (1996). Effect of seed rate and sowing method on soil moisture, consumptive use,moistures extraction pattern and yield of rainfed wheat. *Advan. Agril. Res. India.* **5** (7): 9-17.

Volynkina, O. V. and Volynkin, V.I. (2003). The effect of planting density and chemicalization on the yield and grain quality of spring wheat. *Agrokhimiya.* **5**: 48-54.

Vostal, J., Vanek, V., Balik, J. and Husa, J. (1989). Effect of date of urea application on winter wheat yields. *Rostlinna Vyroba.* **35** (6): 656-664. [Solis and Fert. 1990. 53(1): 95].

Walli, S.B. and Wahab, A.L. (1987). Effect of sowing rate and nitrogen fertilization on yield and yield components of two wheat cultivars under rain fed conditions in Northern Iraq. *Field Crop Abst.*, **40**(11): 778.

Walkley, A. and Black, C.A. (1947). Chromic acid titration method for determination of soil organic matter. *Soil Sci. Soc. Am. Proc.* 63:257.

Zhang, H.C., Dai, Q.G., and Zhong, M.X. (1991). A study of low- density planting of wheat and the relationship between source and sink. *Jinagsu Agric. Sci.* **2**: 7-10.

Zhenhua, J., Hua, L. and Yuyog, Z. (1995). A study on the physiological and ecological effects of late autumn sowing on the populations of large grain varieties of winter wheat. *Beijing Agril. Sci.* **13**(1): 35-39.

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	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-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)	1790.00	Bremmer & Mulvaney, 1982
3.	Total S (ppm)	225.00	Bardsley & Lanester,1965
4.	Total P (ppm)	840.00	Olsen and Sommers, 1982
5.	Available N (kg/ha)	54.00	Bremmer, 1965
6.	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7.	Exchangeable K (kg/ha)	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, Total Rainfall and Sunshine hour of the experiment site during the period from November 2005 to February 2006

Year	Month	Air temperature (^0c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2005	Nov.	29.1	19.8	24.45	70	03	197.63
	Dec.	27.1	15.7	21.40	64	Trace	217.03
2006	Jan.	25.3	18.2	21.75	68	0	165.10
	Feb.	31.3	19.4	25.35	61	0	171.01
	Mar.	32.5	22.3	27.4	66.6	56.5	152

Source: Bangladesh Meterological Department (Climate division), Agargon, Dhaka – 1212

Appendix iii. Source of variation, degrees of freedom and mean square for plant height and dry matter

Source of variation	d.f.	Mean square									
		Plant height					Dry matter				
		30 DAS	50 DAS	70 DAS	90 DAS	At harvest	30 DAS	50 DAS	70 DAS	90 DAS	At harvest
R	2	10.028	14.698	27.546	14.138	107.023	83.453	564.063	1618.750	1806.250	3423.937
N	3	76.33**	536.23**	1085.20**	339.29**	369.99**	2473.88**	18288.70**	78603.71**	158663.72**	229966.52**
Error I	6	0.936	2.600	6.516	3.705	3.135	6.953	23.396	41.917	72.917	392.604
S	3	4.02**	55.37**	9.280*	85.69**	66.07**	1572.54**	12412.42**	39943.50**	46742.89**	53207.92**
N X S	9	2.20*	25.60**	17.580*	7.052*	26.83**	112.781**	464.944**	658.856**	817.752**	1081.186**
Error II	24	0.862	2.360	7.004	2.893	9.974	9.745	88.896	101.958	152.083	257.937
Total	47										

Note : Single and double asterisks indicate significant at 5% and 1% levels respectively. R= Replication , N=Nitrogen and S = seed rate as planting density

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

Source of variation	d.f.	Mean square							
		CGR				RGR			
		30-50 DAS	50-70 DAS	70 -90DAS	90 DAS-At harvest	30-50 DAS	50-70 DAS	70 -90DAS	90 DAS-At harvest
R	2	1.756	3.802	3.156	2.326	0.000	0.000	0.000	0.000
N	3	18.850**	53.016**	37.030**	15.794**	0.000**	0.000**	0.000^{NS}	0.000^{NS}
Error I	6	0.044	0.054	0.088	0.057	0.00001	0.000001	0.000015	0.000001
S	3	16.673**	22.251**	3.431**	1.950**	0.000**	0.000**	0.000^{NS}	0.000**
N X S	9	0.724**	2.358**	0.373*	1.3852**	0.000**	0.000**	0.000^{NS}	0.000*
Error II	24	0.080	0.225	0.165	0.138	0.000012	0.0000011	0.000016	0.0000011
Total	47								

Note : Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means no significant, R= Replication N=Nitrogen and S = seed rate as planting density

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

Source of variation	d. f.	Mean square				
		Total tiller per m^2	Effective tiller per m^2	Spike length	Fertile spikelets $spike^{-1}$	Unfertile spikelets $spike^{-1}$
R	2	2162.250	1722.250	15.850	25.451	1.630
N	3	60094.195**	45617.745**	13.197**	312.787**	7.744**
Error I	6	486.417	575.417	0.296	0.634	0.417
S	3	40455.308**	17186.642**	6.047**	27.929**	25.486**
N X S	9	1584.158*	2140.882**	0.909*	4.012**	4.288**
Error II	24	663.708	647.792	0.663	0.698	0.133
Total	47					

Note : Single and double asterisks indicate significant at 5% and 1% levels respectively. R= Replication N=Nitrogen and S = seed rate as planting density

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

Source of variation	d. f.	Mean square			
		1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
R	2	23.328	0.212	1.870	21.453
N	3	20.384**	2.545**	2.903**	48.565**
Error I	6	0.487	0.034	0.029	2.259
S	3	0.701 ^{NS}	1.182**	1.295**	19.347**
N X S	9	0.068 *	0.110**	0.078 *	7.356*
Error II	24	1.584	0.028	0.047	3.291
Total	47				

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means no significant, R= Replication N=Nitrogen and S = seed rate as planting density