PERFORMANCE OF WHEAT AS AFFECTED BY TIME OF IRRIGATION AND NITROGEN LEVEL

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CERTIFICATE

This is to certify that the thesis entitled, "*PERFORMANCE OF WHEAT AS AFFECTED BY TIME OF IRRIGATION AND NITROGEN LEVEL*" 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**, embodies the result of a piece of bona fide research work carried out by **MOUSHUMI BAIN HIRA**, Registration No. **04-01451** 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 of during the course of this investigation has duly been acknowledged.

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Dedicated To

My Respected Parents

&

Lovely Younger Sister

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others
Kg	=	Kilogram
Kg/ha	=	Kilogram per hectare
g	=	gram (s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion concentration
TSP	=	Triple Super Phosphate
t/ha	=	ton per hectare
%	=	Percent

PERFORMANCE OF WHEAT AS AFFECTED BY TIME OF IRRIGATION AND NITROGEN LEVEL

ABSTRACT

An experiment was carried out in experimental field of the Sher-e-Bangla Agricultural University, Dhaka to investigate the performance of wheat as affected by time of irrigation and nitrogen level during the winter season of 2009-2010. Five times of irrigation viz. one irrigation at crown root initiation (CRI) stage, one irrigation at maximum tillering stage, one irrigation at grain filling stage, two irrigations at CRI + maximum tillering stage and three irrigations at CRI + maximum tillering + grain filling stage; and four levels of nitrogen viz. 92kg ha^{-1}, 115kg ha^{-1}, 138kg ha^{-1} and 161kg ha^{-1} were used as variables. The experiment was laid out in a split plot design with three replications. Results showed that time of irrigation and nitrogen level had significant effect on different plant characters, yield and yield components of wheat. When irrigation was applied 3 times at CRI + maximum tillering + grain filling stage, various plant characters including yield and yield attributes-plant height, spike length, number of productive tillers $plant^{-1}$, number of effective spikes m^{-2}, dry weight $plant^{-1}$, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index had maximum values. On the other hand, when the plant characters-plant height and spike length were highest with 161kg N ha^{-1}, the yield and yield contributing characters-number of productive tillers $plant^{-1}$, number of effective spikes m^{-2}, dry weight $plant^{-1}$, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index were highest with 115kg N ha^{-1}. Significantly, highest yield of wheat was obtained when irrigation was applied 3 times at CRI + maximum tillering + grain filling stage along with the recommended nitrogen dose of 115kg ha^{-1}.

Chapter 1

Introduction

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INTRODUCTION

Wheat (*Triticum aestivum* L.), the king of the cereals, has been playing a vital role in the country's economy and plays more important role during the prevailing conditions of shortage of food items. Wheat crop has the large acreage among all the field crops in the world (FAO, 2010).

It is preferable to rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008). About one-third, of the world population lives on wheat grains for their subsistence (FAO, 2007). Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006). Rice is the staple food of Bangladesh but its total production is not sufficient to feed her ever increasing population.

Wheat is the second major cereal crop of Bangladesh. Its grain is used as food for men and feed for animals. Bangladesh has been facing an acute food shortage for a long time due to high population pressure. It is necessary to produce more and more food to achieve the goal of self sufficiency in food. Increasing production per unit area is the only way to minimize the food deficit by applying modem cultivation knowledge and technology in Bangladesh.

In Bangladesh the position of wheat is second in respect of total area (0.80 million hectares) and production (2.80 million ton) after rice and the average yield of wheat is only 3.44 t/ha (BBS, 2010) and it can be increased up to 6.8 t/ha (RARS, 2010). So, there is an ample opportunity to increase production of wheat per unit area through adoption of modem and improved agronomic practices such as optimum seed rate, timely sowing, and judicious application of irrigation, fertilizer and other inputs.

Among the factors responsible for low grain yield of wheat, lack of irrigation water and plant nutrient, greater weed competition, insect attack and disease infection are the most important ones. About 40% of wheat yield loss is recorded due to lack of irrigation water supply in the country (Karim, 2007). However, optimum irrigation water and nutrient supply can increase yield up to 70% in our country (Ahmed, 2006).

The effect of water and nitrogen on physiological responses in wheat indicates that supplemental water is needed and proper rate of N is essential to increase the rate and duration of leaf photosynthesis in winter wheat during grain filling period .

Water stress and nitrogen deficiencies during the vegetative phase can cause early senescence and maturity. During grain development stage N stress shortens the duration of grain filling (Singh, 1999). In the cultivation of high yielding wheat varieties, irrigation assumes greater importance because during growing season of crop (October to April) weather remains relatively dry. The judicial application of water calls for immediate attention and this is possible only by following some scientific basis for water application to the crop.

Water is essential for every developmental phase starting from seed germination to plant maturation for harvesting the maximum potential of wheat. There is a positive correlation between grain yield and irrigation frequencies (Chandurkar *et al*., 2007). Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cell but also increase the effectiveness of the mineral nutrients applied to the crop (Chandurkar *et al*., 2007). Water deficit imposed after planting significantly reduces the plant growth and yield .

Wheat yield and production in Bangladesh are less than other countries due to improper water and nitrogen fertilizer management. Specially the farmers have no attention to the irrigation schedule and nitrogen application rates. Wheat yield is reduced by 50% due to soil moisture stress. Number of irrigation also influences on the yield of wheat. It has been observed that water requirement of a crop varies with the stage of its growth. Under limited water supply the critical growth stages are taken into account for irrigation schedule. The critical growth stages are the most sensitive to shortage of water because of wheat yield is reduced drastically. The application of irrigation at all the critical stages significantly increased the grain yield of wheat over control.

Irrigation and its management are very important for successful cultivation of wheat. Supplemental irrigation given to wheat improves the development of grain as well as yield (Singh and Singh, 2005). Irrigation frequency has a significant influence on the growth and yield of wheat. With the increase of irrigation frequencies the grain yield of wheat can be increased (Khajanij and Swivedi, 2007). Proper time of irrigation especially in crown root initiation stage is very important for successful growth of wheat and it has a great impact on grain yield (Randhawa *et al.*, 2004).

In Bangladesh, the rainfall during Rabi season in characteristically scanty and uncertain. As such, wheat gives poor yield when growth under non-irrigated (rainfed) condition. Moreover, Irrigation facilities are not so extensive to ensure abundant irrigation water throughout the country. So, irrigation water with judicious application at the peak period of growth stages is one of the approaches of irrigation scheduling in wheat cultivation and it may provide optimum yield of this crop.

The critical growth stages are different for different crops. The importance of available soil nitrogen to wheat crop has been recognized. Rate of N application has a influence on growth, development and yield of wheat. Not only the acre yield be greatly influenced but also the protein content of the grain. The grain yield due to irrigation was confounded by increased nitrogen usages. High availability of nitrogen during the reproductive stages of growth is necessary for a high protein grain.

Nitrogen, the major essential plant nutrient, plays an important role in producing higher grain yield of wheat (Ahmed and Hossain, 2002). For increasing nitrogen use efficiency top dressing and split application of nitrogenous fertilizers at critical growth stages of wheat are now being emphasized (Singh, 2003). Randhawa *et al.* (2004) also mentioned that the split application of nitrogenous fertilizer for wheat was more beneficial than its single dose application at sowing. So, both timely irrigation and split application of nitrogen are equally essential as because they similarly and vitally influence the grain yield of wheat. Sufficient nutrient supply ensures higher yield performance due to soil condition by increasing productivity. Among the different plant nutrients; nitrogen has the more effectiveness on growth which has the great role on higher grain yield and quality seed production .

Time of irrigation along with split application of nitrogenous fertilizer plays a vital role increasing maximum yield of wheat per unit area. Irrigation schedule based on physiological stage should be used properly and the split application of nitrogen with optimum dose is very important in increasing wheat production (Cheema *et al.*, 1995).

Therefore, the present experiment was conducted to study the influence of irrigation and different levels of nitrogen on the performance of wheat. With this regard the following objectives can be considered for the present experiment:

Objectives:

1. To determine the appropriate time of irrigation on the growth and yield of wheat,
2. To find out the optimum dose of nitrogenous fertilizer for better growth and yield of wheat, and
3. To determine the interaction effect of irrigation and nitrogen for maximum yield of wheat.

Chapter 2
Review of literature

Chapter 2

REVIEW OF LITERATURE

An effort has been given in this chapter to present a brief review of research in relation to growth and yield of wheat as influenced by irrigation and application of nitrogen. Wheat (*Triticum aestivum* L.) is the second most cereal crop in Bangladesh. It plays a vital role in the national economy to minimize the gap between food production and requirement. It is an established fact that balanced fertilization coupled with proper water management increases growth and gives higher yield (Mengping, 2005). Some of the pertinent findings of the research with irrigation and split application of nitrogen on the growth and yield of wheat are reviewed in this chapter.

2.1 Effect of time of irrigation on growth, yield and yield contributing characters of wheat

Numbers of experiments have been conducted on the effect of irrigation on the growth, yield and yield contributing characters of wheat in different wheat growing countries of the world. Some of the results of those experiments were reviewed below:

Venkatachari (2009) in India reported that wheat responded well to low moisture stress. Considering the optimum sowing time to be the first fortnight of November, consumptive use pattern of water in wheat had been established. The daily rate of water use ranged from 2 or 3 mm/day during the first month, 3 to 4 mm/day during the second month with a peak of, 4.1 mm/day at about 75 days and then it declined under 40% depletion of soil moisture.

Kong *et al.* (2008) carried out an experiment in India to study the effect of irrigation on the yield of wheat and water use efficiency under limited irrigation. The irrigation treatments designed were: no irrigation (control); 30 mm at stem elongation and 30 mm at grain filling stage; and 45 mm at stem elongation and booting stages and 45 mm at grain filling stage. Irrigation increased the average yield of wheat by 13.0 -3 9.6% and the water use efficiency by 7.0 -18.0%. The physiological properties and yield compositions of winter wheat was also improved. In a year with enough precipitation, the volume of supplementary irrigation satisfying the maximum water use efficiency of the crop was 45 mm, and the highest volume of water needed for irrigation ranged from 30 to 45 mm. The number of ears of winter wheat could be increased by irrigation during the stem elongation and booting stages and the water use efficiency could also be improved. Irrigation at grain filling stage improved the 1000 grain weight and water use efficiency of wheat. It is concluded that the best time for limited irrigation is the stem elongation and booting stages.

Mushtaq and Muhammad (2005) conducted a field studies in Pakistan to determine the effect of different irrigation frequencies on the growth and yield of wheat on a clay loam soil. Results revealed that wheat receiving 5 irrigations at crown root + tiller + boot + milk + grain development stages produced significantly tiller plants and maximum number of fertile tillers per unit area. It was, however, not significantly superior to 4 irrigations applied at crown root + boot + milk + grain development stages for greater number of grains per spike, 1000-grain weight and grain yield. Plant height, 1000 grain weight and wheat grain yield were significantly higher under 4 irrigations applied at crown root + boot + grain development and crown root + boot stages of plant growth, respectively. A grain yield reduction of 6.63 and 12.20% and increase of only 1.45% was obtained by applying 3, 2 and 5 irrigations, respectively, compared to 4 irrigations.

Sun and Liu (2006) conducted an irrigation experiment during different growing stages of winter wheat to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEen) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield, 300 mm is an optimal amount of irrigation corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirement of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

Ali and Amin (2007) conducted a study in Bangladesh during rabi season to determine the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar Shatabdi. Irrigation treatments were given as: no irrigation, control (T_0); one irrigation at 21 DAS (T_1), two irrigations at 21 and 45 DAS (T_2); three irrigations at 21, 45 and 60 DAS (T_3) and four irrigation at 21, 45, 60 and 75 DAS (T_4). Significant effects were observed oil plant height, number of effective tillers per hill, spike length, number of spikelet per spike, filled grains per spike due to different levels of irrigation. Two irrigations at 21 and 45 DAS significantly enhanced the growth, yield attributes and yield of wheat over the other treatments. Results also showed that grain yield, straw yield and harvest index were significantly higher at T_2 compared to the other treatments of the study.

Onyibe (2008) conducted a field trial to study the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Siete cerros and Pavon 76). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete cerros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m^2 and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the highest water use efficiency of 4.0-4.8 kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Ghodpage and Gawande (2008) conducted a field experiment in Maharashtra, India, during rabi season to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations) at various physiological growth stages of late-sown wheat. The maximum grain yield of 2488 kg/ha was obtained in 6 irrigations treatment and it was significantly superior over all other treatments. In general, there was consistent reduction in grain yield due to lack of irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, lack of irrigation at tillering and milking stages resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, milking and dough stages, recording 29.30% yield reduction. Approximately 50% loss in grain was observed when irrigation was missed at tlllering, flowering, milking and dough stages. The ratio between consumptive use of water (Cu)/ irrigation number was higher in 2-irrigation treatment compared to 6-irrigation treatment although the total value of Cu was higher for 6-irrigation treatment.

Chaudhary and Dahatonde (2007) carried out an experiment in Maharashtra, India to study the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I_4; I_4 + irrigation at the tillering stage or I_5; and I_5 + 4 irrigation at the dough stage) and quantity (irrigation at 100, 75 or 50% of the net irrigation requirement), and kaolin (0 or 6% kaolin sprayed at 50 days after sowing) on the performance of wheat. Grain yield did not significantly vary with irrigation frequency. Irrigation at 100% of the net irrigation requirement resulted in the highest grain yield (27.32 quintal ha^{-1}). Water consumption increased with the increase in irrigation frequency and quantity. Water use, efficiency was highest under I5 (87.74 kg $ha^{-1}cm^{-1}$) and irrigation at 100% of the net irrigation requirement (85.29 kg $ha^{-1}cm^{-1}$). Kaolin significantly reduced grain and straw yields, water consumption, and water use efficiency.

Pal and Upasani (2007) conducted a field experiment in India to determine the effects of irrigation on the growth and yield of wheat cv. HD 2285. The treatments comprised different irrigation frequency (2, 3 or 4 times) carried out during critical growth stages (Crown root Initiation, highest tillering, booting and milking). Wheat plants which received 4 irrigations at the crown root initiation; highest tillering, booting and milking stages recorded the higest yield. Non-irrigation at the highest tillering stage caused the highest yield reduction (34.7%), followed by water stress at the milking (25.9%), booting (12.8%) and crown root initiation stage (6.8%). Reduction in the values of spike, dry matter accumulation, grain growth rate and duration was also observed with the non-irrigation during the highest tillering, milking and booting stage, indicating that these stages are critical with respect to the water requirements of late sown wheat.

Naser (1999) reported that two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. The highest grain and straw yields, the maximum number of tillering/ plant, the highest spike length, the maximum number of grains/ spike were recorded in I_4 treatment where two irrigations were applied. The I_4 treatment increased grain and straw yields by

58.1% and 54.5% respectively over control. The control treatment showed the lowest result in all parameters.

2.2 Effect of split application of nitrogen on growth, yield and yield contributing characters of wheat

The rate and split application of nitrogen have remarkable influence on the growth, yield and yield contributing characters of wheat. Many researcher studied on its and some of the pertinent of those are reviewed here.

Shen *et al*. (2007) conducted a field experiment in China to identify the effects of N application rates (180 and 240 kg/ha) on grain yield, protein and its components in wheat cv. Ningyan 1. The grain number per spike increased with the increase of N application rate, while the 1000-grain weight decreased. The ear number per unit area, dry matter accumulation amount after flowering, leaf area index at heading stage and grain yield increased with the increase of N application rate. The suitable amount of N rate for high yield and good quality in Ningyan 1 was 180 kg N/ha and 240 kg N/ha respectively.

Chaturvedi (2006) conducted a field experiment in India to evaluate the effects of different rates of nitrogen (0, 25, 50, 75, 100 and 125 kg/ha) applied as urea on the growth, yield, and nutrient uptake of wheat (*Triticum aestivum*) cv. Raj 3077. Various growth and yield parameters of the crop were influenced differently by various nitrogen rates. Nitrogen at 125 kg/ha was optimum for the growth, yield and nutrient uptake of wheat. Application of 125 kg N/ha significantly increased plant height (95.2 cm), spike length (16.22 cm), total number of tillers (1402/m^2), number of green leaves (1067/m^2), dry matter accumulation (14.65 t/ha), number of grains per spike (40.5), 1000 grain-weight (48.1 g), grain and straw yields (4667 k/ha based on pooled data), and uptake of N (102.3 kg/ha) respectively.

Cerny *et al.* (2005) conducted a field experiments to study the effects of different levels of nitrogen (N) fertilizer application and different forms of N fertilizers on the qualitative and quantitative parameters of the durum wheat cultivars Istrodur and Martondur. Grain yield technological quality parameters were significantly influenced by fertilizer application. Istrodur produced the highest grain yield (3.85 t/ha; increased by 4.37%) with the application of 80 kg N/ha. Martondur yielded the highest (3.96 t/ha, increased by 16%) at the rate of 120 kg N/ha . Istrodur achieved the highest protein content (13.66% and glassiness (83.63%) at a rate of 1.20 kg N/ha and the protein content and glassiness was 16.65 and 85.89%, respectively for Martondur applied with 80 kg N/ha.

Feng *et al.* (2005) carried out a field experiment in China with wheat cultivars Yumai 66 (large-spike type) and Yumai 49 (mufti-spike type) were supplied nitrogen fertilizer at 0, 150, 225 and 300 kg N/ha, of which half was applied as basal fertilizer and the other half added at the stem-elongation stage of the plant. Noodle-related, quality of Yumai 66 improved with N rate while that of Yumai 49 improved with N rate up to 225 kg N/ha and deteriorated with 300 kg N/ha. Both cultivars gave the highest yield in the 300 kg N/ha treatment. Greatest economic efficiency was obtained in the 150 kg N/ha treatment for Yumai 66. Yumai 66 had better quality for all the traits studied except peak viscosity then Yumai 49, but its yield was lower. Nitrogen apply showed substantial effect on peak viscosity, softening, 1000-seed-weight and yield of Yumai 49 and on sedimentation, stability and extension area of Yumai 66. It is therefore concluded that quality parameters, yield and different types of the cultivars should be taken into consideration in nitrogen management.

Chrzanowska *et al.* (2008) conducted a field experiment in Poland to evaluate the effects of N fertilizer rates and application methods on grain yield and quality of the winter wheat cultivars Kobra. Nitrogen granules influenced the yield and quality of the cultivar. Foliar urea was ineffective. The cultivar exhibited a significant yield increase with nitrogen rate of 40 kg/ha, in comparison with the control. A nitrogen rate of 80 kg/ha (applied in split doses of 40 kg/ha each at the beginning of the growing season and at the shooting stage), compared to the rate of 40 kg/ha, proved to be more efficient for Kobra cultivar. Nitrogen rate of 120 kg/ha did not show any significant effect on the yield parameters under investigation. Foliar nitrogen application improved the protein content, glassiness and sedimentation index of the wheat grain.

Oad *et al*. (2007) conducted a field experiment in Pakistan to assess the suitable nitrogen (N) levels and placements for the yield and yield traits of wheat cv. Kiran-95. Three N levels (80, 120 and 150 kg/ha) were incorporated through broadcast, split, pop-up and foliar methods. Split application of 120 kg N/ha significantly produced lengthy spikes, more grain number per spike, better seed index and maximum grain yield / hectare followed by broadcast, foliar and pop-up N placements.

Chandurkar *et al*. (2007) carried out a field experiment in India, during rabi season to determine the response of improved wheat cultivars (GW-322, MACS-2496 and MACS-2846), and their N content and uptake in grain and straw with increasing N fertilizer rates (90, 120 and 150 kg N/ha). The highest grain yield, harvest index, N content, N uptake and protein content was obtained with 150 kg N/ha treatments. GW-322 gave the highest gain yield, N content, total N uptake and protein content.

Liaqat *et al*. (2008) conducted an experiment in the rabi season in Pakistan to evaluate the response of wheat cv. Uqab-2000 to N at 84, 128, 150, 175 and 200 kg/ha. The number of productive tillers per m^2 (408), number of spikelet/spike (30.18), 1000-grain weight (41.2 g) and crop yield (5160 kg/ha) were highest at a rate of 150 kg N/ha.. N at 175 kg/ha resulted in the highest number of grains per spike. Maximum plant height was obtained at N at 200 kg/ha.

2.3 Interaction effect of irrigation and nitrogen application on growth, yield and yield contributing characters

A good number of research works have been conducted on the interaction effect of irrigation and nitrogen application on the growth, yield and yield contributing characters. Some of the pertinent findings of those research works are received and discussed here.

Gecit and Cakr (2006) conducted the study in Turkey to determine the effects of 3 different irrigation times and four fertilizer application levels of nitrogen on yield of two durum wheat cultivars, Kunduru 1149 and Berkmen 469. The results showed significant effects on number of plants per unit area, number of fertile spikes per unit area, number of grains per spike, grain yield per spike, and grain yield per unit area on some durum wheat varieties Kunduru 1149 and Berkmen-469. The highest grain yield per unit area in cv. Kunduru-1149 was 605 kg/da. The highest yield for cv. Berkmen 469 was 482 kg/da. These values were obtained from the treatment of 3 different nitrogen fertilizer application levels (2 kg/da at sowing + 9 kg/da at booting + 9 kg/da at heading stages) along with similar irrigation treatments. Under this treatment, the number of plants per Unit area was in the range 475-496, number of fertile spikes was in the range 546-600, the number of grains was in the range 35.85-41.50, and grain yield per spike was in the range 2.13-2.54 for Kunduru-1149. The number of plants per unit area was in the range 415-477, number of fertile spikes was in the range 521-554, the number of grains was in the range 25.73-31.10 and grain yield per spike was in the range 1.40-1.55 g for cv. Berkmen-469.

Kibe *et al.* (2006) conducted a field experiment on a sandy loam soil to study the water-nitrogen yield relationships of late sown wheat under adequate and limited water supply conditions. The treatments comprised of four levels of irrigation (I_0, no post-sown irrigation; I_1 one irrigation at CRI stage; I_2, two irrigations, each at crown root initiation (CRI) and flowering stages; I_3, four irrigations each given at CRI, jointing, flowering and dough stages) in main plots and a combination of three N levels (0, 50 and 100 kg N/ha) in sub-plots off a split plot design and were replicated three times. Progressive increase in irrigations from 0 to 4 and nitrogen levels from 0 to 100 kg/ha increased the average leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR), yield attributes, wheat biomass and grain yield significantly ($p<=0.05$) over the control (I_0) and N_0). Analyses by multiple regression techniques reveled that LAI estimates with N uptake were much higher at 84% predictability than the estimate based on water use that could account for 75% of the variations only. Lower levels of water consumption by crop were seen to result in less leaf area therefore, resulting in lower biomass and grain yields at lower levels of irrigation. The highest rate of biomass gains of 53.1 kg/ha-mm was obtained during the 60-90 day period, a period that fell within the maximum growth phase of wheat, followed by 28.3 and 6.7 kg/ha-mm during 90-120 and 0-60 days after sowing (DAS) periods. The response of the above ground biomass to nitrogen uptake was higher (76.6 kg/ha-kg N uptake) during 90 DAS period than during the 0-60 DAS period (22.1 kg/ha-kg N uptake). The maximum growth rates in wheat were commensurate with highest levels of water use as well as nitrogen use observed during the 60-90 DAS period of growth. For this reasons, scheduling of water and nitrogen application ought to consider providing relatively less quantities of water during the 0-60 DAS period as compared to the 90-120 and 60-90 DAS periods respectively, in order to provide just sufficient amounts of water so as to enhance the uptake of avaiable nitrogen required for optimum growth and development of wheat.

Li-Yong and Zheng (2008) conducted a field trial with winter wheat cultivar Jingdong 8 in Beijing; where the normal precipitation during the wheat growing season averaged about 118 mm and effective accumulated temperature above 0 ^{0}C averaged 19.70 ^{0}C. Two factors, irrigation and nitrogen application, each with multiple levels, were combined to form 27 treatments. The data were averaged and subjected to statistical analysis. The irrigation pattern had no significant effect on wheat grain yield, while, irrigation × nitrogen interaction and the effect of N on yield were significant. Adequate application of N improved water and N use efficiencies. No significant difference in wheat yield was recorded between the optimized water and N supply and the traditional water and N management. The optimized N application gave the highest N use efficiency (56.3-70.3%), and the pattern of sub-optimal irrigation gave the highest water use efficiency (2.81-3.71 kg/m^3). The optimized N application pattern had a marked advantage over the traditional pattern in economic benefits, while the traditional irrigation pattern, with its lower cost in man power and materials, was markedly superior to the optimized irrigation water supply pattern in economic benefits.

Hossain *et al.* (2005) conducted an experiment in Dinajpur, Bangladesh to determine the optimum irrigation and nitrogen level for wheat. The highest grain yield (3.71 t/ha) was obtained with three irrigations at crown-root initiation (CRI) + maximum tillering (MT) + grain filling (GF) stages which was identical with two irrigations at CRI + MT stages or at CRI + GF stages. The highest grain yield (3,61 t/ha) was obtained from 120 kg N /ha which was followed by 100 kg N /ha, and the lowest grain yield (2.81 t/ha) was recorded under 40 kg N /ha treatment. No significant effect was observed on yield due to interaction of irrigation and nitrogen level.

Tavakoli (2008) conducted an experiment in Iran to investigate the effects of supplemental irrigation and nitrogen rates on the yield and yield components of wheat. Treatments included four levels of irrigation (rain fed, 1/3, 2/3 and 3/3 of the full supplemental irrigation) as the main plots and five N rates (0, 30, 60, 90 and 120 kg ha^{-1}) the subplots. Grain, straw and biological yield, harvest index, height, kernel number per spike and 1000-kernel weight were determined from the middle of each plot. Yields of rain fed wheat varied with seasonal rainfall and its distribution. With irrigation, crop responses were generally significant up to 60 kg Nha^{-1}. The optimum level of supplemental irrigation was at l/3 of the full supplemental irrigation, with 60 kg N/ha recording maximum water use efficiency (30 kg/mm) arid good yield (minimum water use with one-time irrigation at planting time).

Guler and Akbay (2007) conducted a field studies in Turkey to identify the effects of different irrigation and nitrogen fertilizer applications on the grain protein yield of common wheat cv. Bezostaja 1, Gerek 79 and Gun 91 were determined. 0 mm (S_0), 20 mm (S_1) and 40 mm (S_2) irrigation applications and also 4 kg/da (N_1), 6 kg/da (N_2) and 8 kg/da (N_3) nitrogen doses were applied. Significant increases in grain protein yield were observed from increased N and irrigation rates. Protein yield was affected more by grain yield than by protein content, and the highest grain protein yield was obtained from cv. Gerek 79 because of the high grain yield and with N_3 (8 kg/da N) and S_2 (40 mm) irrigation applications.

Zhai and Li (2006) carried out an experiment with winter wheat, plants were supplied with N (0.07 g/kg soil) with or without irrigation, and soil moisture was maintained at 15 and 23%, respectively. Water stress significantly inhibited the yield improving effect of N fertilizer. The rational combination of water and N fertilizer is favorable for the improvement of yield, as well as its quality. The key and sensitive period of winter wheat to water and N is the stem elongation stage. N applied at this stage helped to increase the contents of free amino acids and protein in the grain, and thus improve quality.

Saren and Jana (2008) conducted a Field experiment in West Bengal, India, in winter to study the effects of irrigation depth (4.5, 6.0, 9.0, and 12.0 cm), N rate (50 and 100 kg/ha) and N application date (50% N before or after irrigation) on the yield, yield components, and nutrient uptake of wheat cv. UP 262. The half rate of N (urea) and full rates of P (50 kg single super phosphate/ha) and K (50 kg muriate of potash/ha) were applied as basal. The irrigation depth of 6.0 cm and the application of 100 kg N/ha as top dressing after irrigation gave the greatest plant height, length of spike, number of effective tillers and grains; grain and straw yields; and N, P, and K uptake by grain and straw. Other irrigation depths reduced wheat yield.

Maqsood *et al.* (2007) carried out an experiment in Pakistan to study the effects of irrigation stress (at crown root, booting, or anthesis stage, or at all the aforementioned growth stage and N rate (100 and 150 kg ha^{-1}) on the yield and yield components of wheat cv. Pb-96. Irrigation at the crown root, booting, and anthesis stage gave the highest dry weight (6.18 g/plant), number of productive tillers (330.33/m^2), number of grains per spike (45.58), 1000-grain weight (39.69 g), grain yield (5.69 t/ha), and harvest index (36.53%). The application of N also increased the yield and yield components of wheat, with 150 kg N/ha giving the highest number of productive tillers (321.73/m2), number of grains per spike (44.28), 100 grain weight (36.57 g), grain yield (4.19 t/ha), harvest index (34.54%).

From the review of literature it was observed that both irrigation and nitrogen has significant effect on growth and yield performance of wheat and it differs from different times of irrigation and different levels of nitrogen. Thus the present work was undertaken with five different times of irrigation and four different levels of nitrogen treatments to assess their effect on growth and yield of wheat.

Chapter 3

Materials and Methods

Chapter 3

Materials and Methods

In this chapter, the details of different materials used and methodology followed during the experimental period are described.

3.1 Experimental site

The research work was carried out at the experimental field of Agronomy Department of Sher-e- Bangla Agricultural University, Dhaka during the period from November 2009 to March 2010 to evaluate the influence of irrigation and nitrogen level on the performance of wheat. The soil of the experimental site was well drained and medium high. Physical and chemical properties of soil, climatic condition (monthly) during the experimental period has been plotted in Appendix I and Appendix II. The average temperature during the experimentation was 20^0 C – 25^0 C. The soil of the experimental plots belonged to the agro ecological zone Madhupur Tract (AEZ-28).

3.2 Planting material

The variety of wheat for the present study was BARI wheat 24 (Prodip). The seeds of this variety were collected from the Bangladesh Agricultural Research Institute (BARI), Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristics of these varieties are mentioned below:

3.2.1 BARI wheat 24 (Prodip)

Plants are of average 95 – 100 cm height. Leaves are darker green and wide. Spikes are long and grains/spike is 45 – 50. Duration of panicle initiation is 64 – 66 days. The seeds are bright, whitish in color and larger in size. Weight of 1000 seed is 48 – 55 g. Duration of crop (from sowing to harvest) is 102 – 110 days. Maximum yield is 4300 – 5100 kg ha^{-1}. This variety is adopted to leaf spot diseases and resistant to leaf rust diseases. Seeds contain strong gluten which is very useful for bread making.

3.3 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 9 November and 14 November 2009, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly before planting.

3.4 Fertilizer application

TSP	:	140 Kg ha^{-1}
MP	:	40 Kg ha^{-1}
Gypsum	:	110 Kg ha^{-1}

The rate of Nitrogen was as per treatment.Nitrogen was applied in the form of urea. Whole amount of TSP, MP and Gypsum were applied as basal dose during final land preparation. For I_2 and I_3 treatments the whole amount of nitrogen (urea) was applied as basal dose during final land preparation. But in case of I_1, I_4 and I_5 treatments two third (2/3) amount of nitrogen (urea) was applied during final land preparation and the rest amount of nitrogen (urea) ($^1/_3$) was applied as top dressing at the time of 1st irrigation.

3.5 Treatments of the experiment

The experiment was of two factors with three times of irrigation and four levels of nitrogen

3.5.1 Factor A: Irrigation

The following time of irrigations were imposed in the experiment:

I_1	=	One irrigation at Crown Root Initiation (CRI) stage
I_2	=	One irrigation at maximum tillering stage
I_3	=	One irrigation at grain filling stage
I_4	=	Two irrigations at CRI + grain filling stage
I_5	=	Three irrigations at CRI + maximum tillering + grain filling stage

3.5.2 Factor B: Different doses of nitrogenous fertilizer (Urea)

The following doses of Nitrogen were applied in the experiment

N_1 = 92 kg ha^{-1} (200 kg ha^{-1} of Urea)
N_2 = 115 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_3 = 138 kg ha^{-1}(300 kg ha^{-1} of Urea)
N_4 = 161 kg ha^{-1} (350 kg ha^{-1} of Urea)

3.5.3 Interaction of Factor A and Factor B

Combining two factors, 20 treatment were obtained---

I_1N_1	I_2N_1	I_3N_1	I_4N_1	I_5N_1
I_1N_2	I_2N_2	I_3N_2	I_4N_2	I_5N_2
I_1N_3	I_2N_3	I_3N_3	I_4N_3	I_5N_3
I_1N_4	I_2N_4	I_3N_4	I_4N_4	I_5N_4

3.6 Experimental design and layout

The experiment was laid out in a split plot design and each treatment was replicated three times where irrigation and nitrogen treatments were assigned in the main plot and subplot, respectively. The size of a unit plot was 4 m × 2.5 m. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.75 m. plot to plot distance was 0.75 m and the inter block and inter row spaces were used as footpath and irrigation/drainage channels.

3.7 Germination test

Germination test was performed before sowing the seeds in the field. For laboratory test, petridishes were used. Filter papers were placed on petridishes and the papers were soaked with water. Seeds were placed at random in petridish. Data on emergence were collected on percentage basis by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds set for germination}} \times 100$$

3.8 Sowing of seeds

Seeds were sown in 14 November, 2009. Line to line distance was maintained as 20 cm. Seeds were sown in rows continuously at 2-3 cm depth and then rows were covered with the loose soil properly.

3.9 Intercultural operations

3.9.1 Weeding

Weeding was done twice at 15 and 40 DAS (Days after sowing). Demarcation boundaries and drainage channels were also kept weed free.

3.9.2 Thinning

Thinning was done once in all the unit plots with care so as to maintain a uniform plant population in each plot. Thinning was done at 15 DAS (Days after sowing).

3.9.3 Irrigation

Five types of irrigations were done according to the treatments and ultimately three times of irrigations were done. First was done at CRI stage, second was done at maximum tillering stage and third was done at grain filling stage.

3.10 Sampling

Ten sample plants were collected at random from each plot. The plant and yield characters data were taken from the ten sample plants.

3.11 Harvesting and threshing

The crop was harvested on 8 March 2010, when leaves and stem became yellowish in color. Two leaner meters were harvested from the center of each plot at ground level with the help of sickle. The harvested plants were bundled separately, tagged and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the plants by beating with paddle thresher and later were cleaned, dried and weighed. The weights of the dry straw were also taken.

3.12 Data collection

3.12.1 Plant characters data

1. Plant height (cm)
2. Productive tillers plan^{t-1}(no.)
3. Spike length (cm)
4. Dry matter weight plant^{-1} (g)
5. Effective spikes m^{-2}(no.)

3.12.2 Yield and yield contributing data

1. Spikelets spikes^{-1}(no.)
2. Grains spike^{-1}(no.)
3. Weight of 1000 seeds (g)
4. Grain yield (t ha^{-1})
5. Straw yield (t ha^{-1})
6. Harvest index (%)

3.13 Procedure of data collection

3.13.1 Plant height (cm)

The heights of selected ten plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.13.2 Productive tillers plant^{-1}(no.)

The number of productive tillers plant^{-1} was counted from sampled ten plants and mean values were taken.

3.13.3 Spike length (cm)

Spike length was taken from sampled ten plants with a meter scale from the base level to the top of the spike and the mean length was expressed in cm.

3.13.4 Dry weight plant^{-1} (g)

For measuring the dry matter weight plant^{-1} 3 plants from each plot were collected in each sampling date (30, 60, 90 DAS and at harvest) and then dried in oven at 60 – 70 ^{0}C for 72 hours and weight was taken carefully. The average weights of three plants were dry matter of a single plant.

3.13.5 Effective spikes m^{-2}(no.)

Number of effective spikes m^{-2} of pre selected ten plants from each unit plot was noted and the mean number was recorded. The mean number was expressed on per plant basis.

3.13.6 Spikelets spike^{-1} (no.)

Number of spikelet spikes^{-1} was counted randomly taking ten spikes from each sample of each plot as per treatment.

3.13.7 Grains spike^{-1} (no.)

Number of grain spike^{-1} was counted randomly taking ten spikes from each sample of each plot as per treatment.

3.13.8 Weight of 1000 seeds (g)

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

3.13.9 Seed yield (t ha^{-1})

Weight of seed of the demarcated area (2 m^2) at the centre of each plot was taken and then converted to the yield in t ha^{-1}.

3.13.10 Straw yield (t ha $^{-1}$)

The straw weight was calculated after threshing and separation of grain from the sample area (2 m^2) and then expressed in t ha^{-1} in dry weight basis.

3.13.11 Harvest index (%)

The harvest index was calculated on the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula .

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

3.14 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT computer package program .Mean difference among the treatments were tested with least significant differences (LSD) at 5% level of significance.

Chapter 4

Results and Discussion

Chapter 4

Results and Discussion

The results obtained from the present study for different crop characters, yields and other analyses have been presented and discussed in this chapter.

4.1 Plant parameters

4.1.1 Effect of irrigation

4.1.1.1 Plant height (cm)

Significant variation was observed in case of plant height as influenced by irrigation (Table 1). It was observed that the tallest plant (95.71 cm) was obtained with I_5 (3 irrigations at CRI + maximum tillering + grain filling stage). On the other hand the shortest plant (58.78 cm) was observed with I_3 (1 irrigation at grain filling stage). The result obtained from all other treatments showed intermediate result under the present study. These results were in conformity with the findings of Ali and Amin (2007), and Mushtaq and Muhammad (2005).

4.1.1.2 Spike length (cm)

Spike length was significantly influenced by different irrigation treatment(Table 1). It was observed that I_5 (3 irrigation at CRI + maximum tillering + grain filling stage) showed the highest spike length (15.82 cm) and that of second highest (14.73 cm) was recorded with I_4 (2 irrigations at CRI + grain filling stage). Single irrigation I_3 (grain filling stage) showed the lowest spike length (9.01 cm). Other 2 single irrigation I_1 and I_2 (at CRI and maximum tillering stage) showed the statistically similar and second lowest spike length (13.35 cm and 12.63 cm, respectively). This result was in agreement with the findings of Ali and Amin (2007) and Naser (1999).

4.1.1.3 Productive tillers plant^{-1}(no.)

Number of productive tillers plant^{-1} was significantly influenced by different irrigation (Table 1). The result showed that I_5 (3 irrigation at CRI + maximum tillering + grain filling stage) showed its superiority by producing number of productive tillers plant $^{-1}$(3.92). Single irrigation at grain filling stage showed the lowest number of productive tillers plant^{-1} (1.25). Statistically similar and second highest productive tillers plant^{-1} was observed in other 3 irrigation treatments comprised with 2 irrigations at CRI + maximum tillering stage, single irrigation at CRI stage and single irrigation at maximum tillering stage (3.17, 3.17 and 2.83, respectively). Similar result was observed with the findings of Onyibe (2008), Pal and Upasani (2007), Ali and Amin (2007) and Mushtaq and Muhammad (2005).

4.1.1.4 Effective spikes m^{-2}(no.)

Number of effective spikes m^{-2} influenced significantly by different irrigation treatments of wheat (Table 1). In general, 2 and 3 times irrigation treatment showed higher level of effective spikes m^{-2}(ranged 240.5-251.3) than single irrigation at different times (ranged 80.33-202.5). The highest number of effective spikes m^{-2} (251.30) was obtained with I_5 (3 irrigations at CRI + maximum tillering + grain filling stage). Significantly the lowest number of effective spikes m^{-2} (80.33) was observed with I_3 (one irrigation at grain filling stage). This result was in conformity with the findings of Onyibe (2008) and Pal and Upasani (2007).

Table 1. Influence of irrigation on different plant characters of wheat

Treatment	Plant height (cm)	Spike length (cm)	Productive tillers $plant^{-1}$ (no.)	Effective spike m^{-2} (no.)
I_1	79.14	13.35	3.17	202.50
I_2	74.72	12.63	2.83	184.10
I_3	58.78	9.01	1.25	80.33
I_4	86.80	14.73	3.17	240.50
I_5	95.71	15.82	3.92	251.30
$LSD_{0.05}$	**1.281**	**1.061**	**0.543**	**7.634**
CV (%)	**4.88**	**6.14**	**9.98**	**7.78**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

4.1.1.5 Dry weight plant^{-1} (g)

Dry weight plant^{-1} differ significantly due to irrigation at different growth stages of wheat (Figure 1). It can be inferred by the figure that the dry weight plant $^{-1}$ increased gradually with advances of growth stages and the highest weight was found at the harvested stage irrespective of irrigation treatments. For all sampling dates, 3 irrigations applied at CRI + maximum tillering + grain filling stage showed the highest dry weight plant^{-1} (5.76, 9.98, 15.93 and 21.14 g at 30, 60, 90 DAS and at harvest, respectively) and that of second highest was obtained from 2 irrigation treatments at CRI + grain filling stage (4.79, 8.33, 14.23 and 18.94 g at 30, 60, 90 DAS and at harvest, respectively). Single irrigation applied at grain filling stage showed the lowest grain weight plant^{-1} for all sampling dates (3.14, 5.55, 8.33 and 12.43 g at 30, 60, 90 DAS and at harvest, respectively). This result was in agreement with the findings of Pal and Upasani (2007).

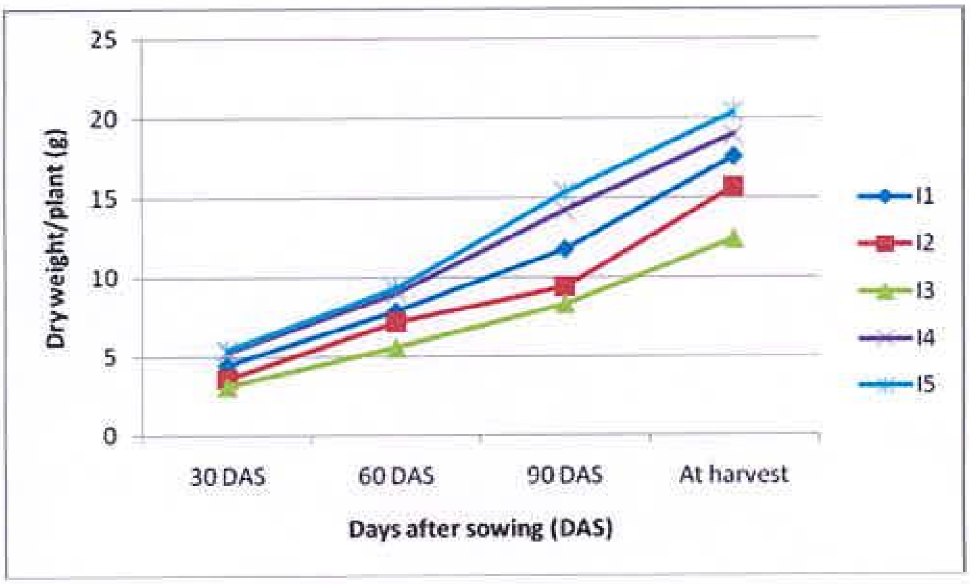

Fig. 1. Influence of irrigation on dry weight plant^{-1} at different stages of wheat

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

4.1.2 Effect of nitrogen

4.1.2.1 Plant height (cm)

Doses of nitrogen showed significant variation in plant height of wheat (Table 2). It was observed that the highest plant height (80.62 cm) was obtained with N_4 (161 kg N ha^{-1}) which was closely followed by N_3 (138 kg N ha^{-1}). On the other hand the lowest plant height (76.84 cm) was observed with N_1 (92 kg N ha^{-1}). The result obtained from all other treatments showed intermediate results compared to highest and lowest plant height under the present study. This result was consistent with the findings of Liaqat *et al.* (2008) and Chaturvedi (2006) that higher amount of nitrogen application enhances the height of plant.

4.1.2.2 Spike length (cm)

Spike length varied significantly by different levels of nitrogen application of wheat (Table 2). The result showed an increasing trend with the increases of nitrogen doses (ranged 12.38-13.94 cm). The lowest dose showed the lowest spike length (12.38cm) and that of highest (13.94 cm) was recorded from the highest dose of nitrogen (161 kg ha^{-1}). The lowest two doses (92 and 115 kg ha^{-1}) showed the statistically similar spike length that was 11.19% and 8.03% lower than the highest dose (161 kgha^{-1}). Similar result was observed with the findings of Chaturvedi (2006).

4.1.2.3 Productive *tillers* plant^{-1}(no.)

Number of productive tillers per plant^{-1} affected significantly by the different levels of nitrogen application of wheat (Table 2). The optimum dose of nitrogenous fertilizer (115kgha^{-1}) produced the highest number of productive tillers plant $^{-1}$ (3.33) which was statistically similar (2.87) with the preceding nitrogen dose (92 kgha^{-1}). Higher doses than optimum (138 and 161 kgha^{-1}) produced the lower and statistically similar number of productive tillers plant^{-1}. This result was in agreement with the findings of Liaqat *et al.* (2008).

4.1.2.4 Effective spikes m^{-2}(no.)

Number of effective spikes m^{-2} was significantly influenced by different levels of nitrogen application (Table: 2). Number of effective spikes m^{-2} showed similar trend as found in productive tillers per plant mentioned in section 4.1.2.3 optimum and lower than doses of nitrogen (115 and 92 $kgha^{-1}$) application showed the higher and statistically similar number of effective spike m^{-2} and the spike number reduces with increases of nitrogen doses. However, the highest two doses (138 and 161 $kgha^{-1}$) nitrogen ha^{-1} showed the statistically similar and lower number of effective spike m^{-2}.

Table 2. Influence of nitrogen on plant characters of wheat

Treatment	Plant height (cm)	Spike length (cm)	Productive tillers $plant^{-1}$ (no.)	Effective spike m^{-2} (no.)
N_1	76.84	12.38	2.87	194.30
N_2	78.86	12.82	3.33	199.40
N_3	79.80	13.29	2.80	189.20
N_4	80.62	13.94	2.47	184.00
$LSD_{0.05}$	1.146	0.5946	0.4859	6.828
CV (%)	**4.88**	**6.14**	**9.98**	**7.78**

N_1 = 92 kg ha^{-1} (200 kg ha^{-1} of Urea)
N_2 = 115 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_3 = 138 kg ha^{-1} (300 kg ha^{-1} of Urea)
N_4 = 161 kg ha^{-1} (350 kg ha^{-1} of Urea)

4.1.2.5 Dry weight plant^{-1} (g)

Dry weight plant^{-1} was significantly influenced by different levels of nitrogen application at different growth stages of wheat. Dry weight plant^{-1} at different sampling dates due to nitrogen doses have been presented in Figure: 2. The figure shows that the highest dose of nitrogen gave the highest dry weight plant^{-1} and the weight reduces gradually with the reduction of nitrogen doses. The lowest dose showed the lowest dry weight plant^{-1}. Similar result was observed with the findings of Chaturvedi (2006) and Shen *et al.* (2007).

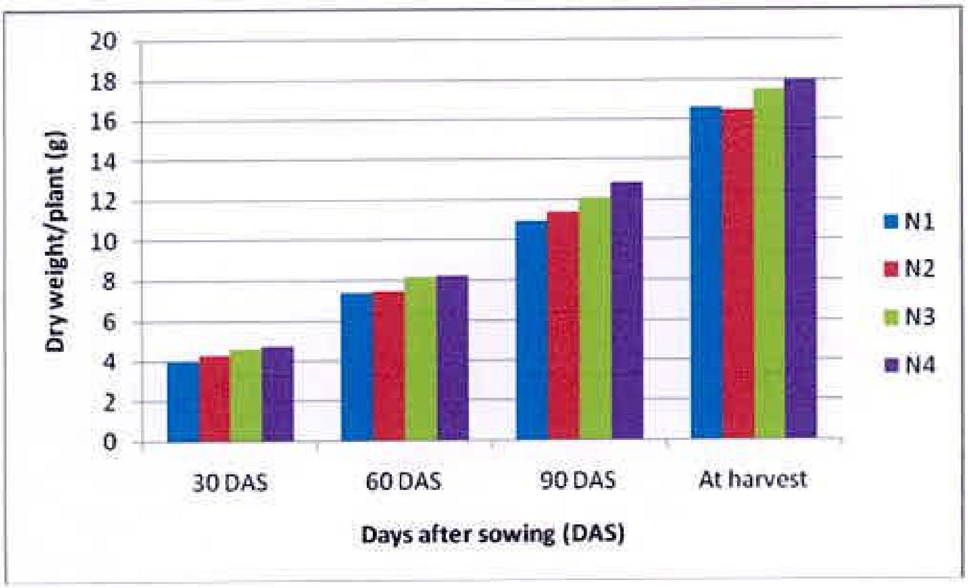

Fig. 2. Influence of nitrogen on dry weight plant^{-1} at different stagesof wheat

N_1 = 92 kg ha^{-1} (200 kg ha^{-1} of Urea)
N_2 = 115 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_3 = 138 kg ha^{-1} (300 kg ha^{-1} of Urea)
N_4 = 161 kg ha^{-1} (350 kg ha^{-1} of Urea)

4.1.3 Interaction effect of irrigation and nitrogen

4.1.3.1 Plant height (cm)

Plant height was significantly influenced by interaction effect of irrigation and nitrogen (Table:3). The tallest plant (98.07 cm) was obtained with I_5N_4 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 161 kg ha^{-1}) which was closely followed by I_5N_3 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 138 kg ha^{-1}). The treatments I_5N_1 and I_5N_2 also showed comparatively higher plant height but significantly different from I_5N_4. On the other hand the lowest plant height (55.48 cm) was observed with I_3N_1. The treatments I_3N_2, I_3N_3 and I_3N_4 also showed comparatively lower plant height but significantly different from I_3N_1. The results obtained from all other combined treatments showed significantly different results in respect of highest and lowest plant height under the present study. Similar result was observed with the findings of Saren and Jana (2008).

4.1.3.2 Spike length (cm)

Spike length was significantly influenced by interaction effect of irrigation and nitrogen (Table 3). The result showed that the highest spike length (16.60 cm) was obtained with I_5N_4 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 161 kg ha^{-1}) which was statistically similar with I_5N_3 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 138 kg ha^{-1}) and I_5N_2 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 115 kg ha^{-1}). On the other hand the lowest spike length (8.29 cm) was observed with I_3N_1 which was statistically similar with I_3N_2 and I_3N_3. However, second highest and statistically similar spike length was measured in I_5N_3, I_5N_1, I_4N_4, I_4N_3 and I_4N_2 combinations. The results obtained from all other combined treatments showed significantly different results in respect of highest and lowest spike length under the present study. This result was in agreement with the findings of Saren and Jana (2008).

4.1.3.3 Productive tillers plant^{-1}(no.)

Significant influence was observed in number of productive tillers plant^{-1} by combined effect of irrigation and nitrogen (Table 3). The result showed that irrespective of irrigation treatments, N_2 (115 kg ha^{-1}) produced higher level of productive tillers plant^{-1} than the other nitrogen doses. On the other hand, 3 irrigation applications showed its superiority by producing productive tillers plant^{-1} in all the nitrogen dose combinations. However, the highest number of productive tillers plant^{-1} at harvest (4.67) was obtained with I_5N_2 which was closely followed by I_5N_1, I_5N_3 and I_1N_2. The lowest number of productive tillers plant^{-1} (1.00) was observed with I_3N_1 and I_3N_4 which was closely followed by I_3N_3. Similar result was observed with the findings of Saren and Jana (2008) and Maqsood *et al.* (2007).

4.1.3.4 Effective spikes m^{-2}(no.)

Number of effective spikes m^{-2} differs significantly by the interaction effect of irrigation and nitrogen (Table 3). The highest number of effective spike m^{-2} at harvest (262.00) was obtained with I_5N_2. Effective spike m^{-2} obtained from the interaction of I_5N_1 and I_5N_3 showed second highest and similar number of effective spike m^{-2}. On the other hand the lowest number of effective spike m^{-2} (72.67) was observed with I_3N_4 which was closely followed by I_3N_3. All other combined treatments showed significantly different results in respect of highest and lowest number of effective spike m^{-2} under the present study. This result was in conformity with the findings of Gecit and Cakr (2006).

Table 3. Combined effect of irrigation and nitrogen on plant characters of wheat

Interaction	Plant height (cm)	Spike length (cm)	Productive tillers plant^{-1} (no.)	Effective spike m^{-2} (no.)
I_1N_1	78.17	12.33	3.33	207.00
I_1N_2	79.37	13.27	3.67	210.00
I_1N_3	79.17	13.80	3.00	199.00
I_1N_4	79.87	14.00	2.67	194.00
I_2N_1	72.63	11.80	3.00	186.00
I_2N_2	74.48	12.13	3.33	192.00
I_2N_3	75.83	12.61	2.67	182.00
I_2N_4	75.93	13.97	2.33	176.30
I_3N_1	55.48	8.29	1.00	82.67
I_3N_2	59.20	8.30	1.67	87.00
I_3N_3	59.70	9.31	1.33	79.00
I_3N_4	60.73	10.13	1.00	72.67
I_4N_1	84.38	14.40	3.00	242.00
I_4N_2	86.86	14.73	3.33	246.00
I_4N_3	87.48	14.80	3.33	239.00
I_4N_4	88.49	14.98	3.00	235.00
I_5N_1	93.54	15.05	4.00	254.00
I_5N_2	94.41	15.67	4.67	262.00
I_5N_3	96.80	15.94	3.67	247.00
I_5N_4	98.07	16.60	3.33	242.00
$LSD_{0.05}$	**2.563**	**1.330**	**1.086**	**7.452**
CV(%)	**4.88**	**6.14**	**9.98**	**7.78**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

N_1 = 92 kg ha^{-1}
N_2 = 115 kg ha^{-1}
N_3 = 138 kg ha^{-1}
N_4 = 161 kg ha^{-1}

4.1.3.5 Dry weight plant^{-1} (g)

Significant variation of dry weight plant^{-1} was observed in all the sampling dates of wheat. Due to interaction effect of irrigation and nitrogen (Table: 4). It can be inferred from the table that irrespective of nitrogen doses and 3 times irrigation (CRI + maximum tillering + grain filling stage) maintained its superiority in producing dry weight plant^{-1} of wheat for all sampling dates. Among the interactions of I_5N_4 combination gave the highest dry weight plant^{-1} at 30, 60, 90 and at harvest (5.98, 10.20, 16.84 and 22.16 g, respectively). Single irrigation at grain filling stage showed the lowest and similar dry weight with all the nitrogen dose combinations. This result was in conformity with the findings of Maqsood *et al*. (2007).

Table 4. Combined effect of irrigation and nitrogen on dry weight plant^{-1} at different stages of wheat

Interaction	Dry weight plant^{-1}			
	30 DAS	60 DAS	90 DAS	At harvest
I_1N_1	4.123	7.693	10.91	17.06
I_1N_2	4.477	7.807	11.04	17.18
I_1N_3	4.637	7.943	11.18	17.40
I_1N_4	4.607	8.117	14.03	18.73
I_2N_1	3.400	7.213	9.363	15.81
I_2N_2	3.550	7.143	9.423	15.55
I_2N_3	3.683	7.330	9.623	15.98
I_2N_4	3.743	6.943	9.103	15.38
I_3N_1	3.010	5.393	8.043	12.17
I_3N_2	3.107	5.607	8.400	12.54
I_3N_3	3.157	5.543	8.280	12.38
I_3N_4	3.283	5.667	8.583	12.63
I_4N_1	4.733	8.223	14.16	18.88
I_4N_2	4.983	8.000	11.39	17.66
I_4N_3	5.483	9.743	15.51	20.40
I_4N_4	5.717	9.920	15.62	20.85
I_5N_1	4.807	8.400	14.30	18.97
I_5N_2	5.020	8.583	14.42	19.19
I_5N_3	5.843	10.10	15.75	21.13
I_5N_4	5.980	10.20	16.84	22.16
$LSD_{0.05}$	**0.5844**	**0.5174**	**0.6316**	**0.4931**
CV(%)	**7.11**	**8.86**	**9.48**	**8.89**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

N_1 = 92 kg ha^{-1}
N_2 = 115 kg ha^{-1}
N_3 = 138 kg ha^{-1}
N_4 = 161 kg ha^{-1}

4.2 Yield and yield contributing parameters

4.2.1 Effect of irrigation

4.2.1.1 Spikelet spikes^{-1}(no.)

Number of spikelet spikes^{-1} was significantly influenced by different time of irrigations at different growth stages of wheat (Table 5). Application of 2 or 3 irrigations at different stages of wheat showed higher number of spikelets spike $^{-1}$ than single irrigation at different stage. 3 irrigations at CRI + maximum tillering + grain filling stage produced the highest spikelets spike^{-1} (38.83). Among the 'One irrigations', irrigation at crown root initiation stage showed the highest spikelets spike^{-1} (25.83). However, the lowest spikelets spike^{-1} (9.17) was found in one irrigation treatment at grain filling stage. This result was in agreement with the findings of Ali and Amin (2007).

4.2.1.2 Grains spike^{-1}(no.)

Statistically significant variation was observed in number of grains spike^{-1} due to application of irrigation (Table: 5). The trend of grains spike^{-1} was similar as observed in number of spikelets spike^{-1} due to irrigation application. It was observed that three irrigation at different stages of growth gave 417.15, 129.31 and 62.99 % higher number of grains spike^{-1} than one irrigation at grain filling, one irrigation at maximum tillering and one irrigation at crown root initiation stage treatment, respectively and that of 352.16, 100.49 and 42.51 % respectively, higher than two irrigations. Similar result was observed by the findings of Mushtaq and Muhammad (2005) and Naser (1999).

4.2.1.3 Weight of 1000 seeds

Weight of 1000 seeds was significantly influenced by different time of irrigations on wheat field (Table 5). It can be inferred from the table that two and three irrigations at different growth stages of wheat gave heavier seed (ranged 48.79-49.44 g) than single irrigation treatments (ranged 43.66-46.61 g). The highest 1000 seed weight (49.44 g) as influenced by irrigation was obtained with I_5 (3 irrigations at CRI + maximum tillering + grain filling stage) which was statistically similar with I_4 (2 irrigations at CRI + grain filling stage). On the other hand, the lowest 1000 seed weight (43.66 g) was observed with I_3 (one irrigation at grain filling stage). Other treatments showed intermediate results. Similar result was observed by Kong *et al.* (2008) and Mushtaq and Muhammad (2005).

Table 5. Influence of irrigation yield components of wheat

Treatment	Spikelets Spike^{-1} (no.)	Grain spike^{-1} (no.)	Weight of 1000 seeds (g)
I_1	25.83	22.75	46.61
I_2	18.00	16.17	46.28
I_3	9.17	7.17	43.66
I_4	35.33	32.42	48.79
I_5	38.83	37.08	49.44
LSD $_{0.05}$	**2.398**	**2.347**	**0.7620**
CV(%)	**7.14**	**9.58**	**8.77**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

4.2.1.4 Grain yield

Different time of irrigation exerted significant variation in grain yield of wheat (Table 6). The trend of grain yield showed that 3 irrigations (at CRI + maximum tillering + grain filling stage) gave the highest grain yield (4.32 t ha^{-1}) and the grain yield trend showed positive trend with the increase of irrigation number. However, among the single irrigation treatments, irrigation applied at grain filling stage showed the lowest grain yield (.46 t ha^{-1}). This was 89.35% and 87.36% lower than 3 and 2 irrigation treatments respectively. Similar result was observed with the findings of Kong *et al.* (2008), Ghodpage and Gawande (2008), Onyibe (2008), Pal and Upasani (2007), Chaudhary and Dahatonde (2007), Sun and Liu (2006) and Naser (1999).

4.2.1.5 Straw yield

Straw yield was significantly influenced by different time of irrigations in wheat (Table 6). The highest straw yield (4.92 t ha^{-1}) as influenced by irrigation of I_5 (3 irrigations at CRI stage, maximum tillering stage and grain filling stage) which was closely followed by I_4 (2 irrigations at CRI stage and grain filling stage). On the other hand the lowest straw yield (2.07 t ha^{-1}) was observed with I_3 (1 irrigation at grain filling stage). This result was in agreement with the findings of Chaudhary and Dahatonde (2007) and Naser (1999).

4.2.1.6 Harvest Index (%)

Harvest Index influenced significantly by different time of irrigations in wheat (Table: 6). Harvest index showed similar trend as observed in grain and straw yield mentioned in section 4.2.1.3 and 4.2.1.4. However, the highest Harvest Index (46.69%) was calculated with I_5 (3 irrigations at CRI stage, maximum tillering stage and grain filling stage). On the other hand the lowest Harvest Index (17.88%) was observed with I_3 (one irrigation at grain filling stage). The result obtained from all other treatments showed intermediate values.

Table 6. Influence of irrigation on yield and harvest index of wheat

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index (%)
I_1	2.34	3.84	37.78
I_2	1.643	3.35	32.07
I_3	0.46	2.07	17.88
I_4	3.64	4.54	44.49
I_5	4.32	4.92	46.69
$LSD_{0.05}$	**0.680**	**0.7027**	**0.6337**
CV(%)	**7.98**	**9.68**	**9.16**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

4.2.2 Effect of nitrogen

4.2.2.1 Spikelets spike^{-1}(no.)

Number of spikelets spike^{-1} varied significantly due to different levels of nitrogen application at different growth stages of wheat (Table 7). Recommended dose (115 kg ha^{-1}) of nitrogen application showed highest number of spikelets spike^{-1} (27.53) after that the number of spikelets spike^{-1} showed a decreasing trend with the increases of nitrogen dose and the lowest number was found in highest nitrogen dose (161kg ha^{-1}) treatment. The highest two doses (138 and 161 kg ha^{-1}) showed the statistically similar number of spikelets spike^{-1}. This result was in conformity with the findings of Liaqat *et al*. (2008).

4.2.2.2 Grains spike^{-1}(no.)

Number of grains spikes^{-1} was significantly varied by different levels of nitrogen application at different growth stages of wheat (Table 7). The result showed that 115 kg N ha^{-1} gave highest number of grains spike^{-1} (25.40) and the preceding 92 kg N ha^{-1} and 138 kg N ha^{-1} doses of nitrogen treatment showed similar number of grains spike^{-1}. On the other hand two highest doses (138 and 161 kg Nha^{-1}) showed lower and statistically similar number of grains spike^{-1}. This result was in agreement with the findings of Shen *et al.* (2007).

4.2.2.3 Weight of 1000 seeds (g)

Weight of 1000 seeds was significantly influenced by different levels of nitrogen application on wheat (Table 7). The highest 1000 seed weight was found in 115 kg N ha^{-1} applied treatment (47.47 g) which was statistically similar with N_1 (92 kg N ha^{-1}) treatment. Nitrogen dose higher than 115 kg ha^{-1} showed the decreasing trend in 1000 seed weight. However, the lowest 1000 seed weight (46.37 g) was observed with 161 kg N ha^{-1} treatment which was closely followed by 138 kg N ha^{-1}.

Table 7. Influence of nitrogen on yield components of wheat

Treatment	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000 seeds (g)
N_1	26.07	23.20	47.29
N_2	27.53	25.40	47.47
N_3	24.53	22.27	46.71
N_4	23.60	21.60	46.37
LSD $_{0.05}$	**1.150**	**1.063**	**0.6815**
CV(%)	**7.14**	**9.58**	**8.77**

N_1 = 92 kg ha^{-1} (200 kg ha^{-1} of Urea)
N_2 = 115 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_3 = 138 kg ha^{-1} (300 kg ha^{-1} of Urea)
N_4 = 161 kg ha^{-1} (350 kg ha^{-1} of Urea)

4.2.2.4 Grain yield

Grain yield was significantly influenced by different levels of nitrogen application on wheat (Table 8). The table showed that grain yield showed a decreasing trend with the increases of nitrogen dose from 115 kg Nha^{-1}. Nitrogen dose lower than 115 kg ha^{-1} showed the second highest grain yield (2.54 t ha^{-1}). It can be inferred from the result that 115 N ha^{-1} showed 8.26%, 17.02% and 20.61% higher grain yield than 92, 138 and 161 kg N ha^{-1}, respectively. This result was in agreement with the findings of Chrzanowska *et al.* (2008), Liaqat *et al.* (2008), Shen *et al.* (2007).

4.2.2.5 Straw yield

Straw yield varied significantly due to different levels of nitrogen application in wheat (Table 8). The highest straw yield (3.98 t ha^{-1}) as influenced by nitrogen was obtained with N_2 (115 kg N ha^{-1}). On the other hand the lowest straw yield (3.59 t ha^{-1}) was observed with N_4 (161kg N ha^{-1}) which was closely followed by N_3 (138 kg N ha^{-1}). Chandurkar *et al.* (2007) and Chaturvedi (2006) found similar result.

4.2.2.6 Harvest Index (%)

Harvest Index showed significant variation by different levels of nitrogen application in wheat (Table 8). The table showed that the highest Harvest Index (36.73%) as influenced by nitrogen was obtained with N_2 (115 kg N ha^{-1}) which was statistically identical with N_1 (92 kg N ha^{-1}). On the other hand the lowest Harvest Index (34.56%) was observed with N_4 (161 kg N ha^{-1}). This result was in conformity with the findings of Chandurkar *et al.* (2007).

Table 8. Influence of nitrogen on yield and harvest index of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
N_1	2.54	3.75	36.48
N_2	2.75	3.98	36.73
N_3	2.35	3.65	35.36
N_4	2.28	3.59	34.56
LSD $_{0.05}$	**0.1343**	**0.1121**	**0.5668**
CV(%)	**7.98**	**9.68**	**9.16**

N_1 = 92 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_2 = 115 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_3 = 138 kg ha^{-1} (250 kg ha^{-1} of Urea)
N_4 = 161 kg ha^{-1} (250 kg ha^{-1} of Urea)

4.2.3 Interaction effect of irrigation and nitrogen

4.2.3.1 Spikelets spike^{-1}(no.)

Significant influence was obtained in number of spikelets spike^{-1} by the interaction effect of irrigation and nitrogen (Table 9). Two or three irrigation treatments produced the higher number of spikelets spike^{-1} (ranged 32.67-42.67) than single irrigation application (ranged 7.67-26.67) irrespective of nitrogen treatments. Among the nitrogen treatments 115 kg N ha $^{-1}$ showed higher number of spikelets spike^{-1} than higher (138 and 161kg N ha^{-1}) and lower (92 kg N ha^{-1}) doses irrespective of irrigation application treatment. However, the highest number of spikelet spike^{-1} (42.67) was obtained with I_5N_2 (irrigation at CRI + maximum tillering + grain filling stage and nitrogen dose of 115 kg ha^{-1}) and that of lowest (7.67) was observed with I_3N_4.

4.2.3.2 Grains spike^{-1}(no.)

Number of grains spike^{-1} was significantly influenced by interaction effect of irrigation and nitrogen (Table 9). Significantly the highest number of grains spike^{-1} (40.60) was obtained with I_5N_2 interaction. But the treatments I_4N_2 and I_5N_1 also showed comparatively higher number of grain spike^{-1} but significantly different from I_5N_2. On the other hand the number of grain spike^{-1} (6.67) was observed with I_3N_4 which was statistically similar with I_3N_1, I_3N_2 and I_3N_3. Other combined treatments showed significantly different results in respect of highest and lowest number of grain spike^{-1} under the present study. Similar result was observed with the findings of Tavakoli (2008), Gecit and Cakr (2006) and Maqsood *et al.* (2007).

4.2.3.3 Weight of 1000 seeds (g)

Weight of 1000 seeds of wheat under the present study was significantly influenced by the interaction effect of irrigation and nitrogen (Table 9). The result showed that application of 2 or 3 irrigations at different growth stages of wheat showed statistically similar level of 1000 seed weight irrespective of nitrogen doses. On the other hand irrespective irrigation treatments 115 kg N ha^{-1} showed the higher level of 1000 seed weight than other nitrogen doses.

The highest 1000 seed weight (49.76 g) was obtained with I_5N_2 and that of lowest (43.18 g) was recorded with I_3N_4 which was statistically similar with I_3N_3, I_3N_1 and I_3N_2. This result was in agreement with the findings of Maqsood *et al.* (2007).

Table 9. Combined effect of irrigation and nitrogen on yield and harvest index of wheat

Interaction	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	1000 seeds weight (g)
I_1N_1	26.67	23.33	47.26
I_1N_2	26.67	23.67	47.66
I_1N_3	25.33	22.33	46.12
I_1N_4	24.67	21.67	45.41
I_2N_1	18.67	16.67	46.43
I_2N_2	19.33	17.33	46.52
I_2N_3	17.33	15.33	46.09
I_2N_4	16.67	15.33	46.09
I_3N_1	10.00	7.33	43.92
I_3N_2	10.33	7.67	44.00
I_3N_3	8.67	7.00	43.54
I_3N_4	7.67	6.67	43.18
I_4N_1	35.67	32.00	49.24
I_4N_2	38.67	35.67	49.38
I_4N_3	34.33	31.33	48.54
I_4N_4	32.67	30.67	48.01
I_5N_1	39.33	36.67	49.61
I_5N_2	42.67	40.60	49.76
I_5N_3	37.00	35.33	49.25
I_5N_4	36.33	33.67	49.15
$LSD_{0.05}$	**3.057**	**3.334**	**1.524**
CV(%)	**7.14**	**9.58**	**8.77**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

N_1 = 92 kg ha^{-1}
N_2 = 115 kg ha^{-1}
N_3 = 138 kg ha^{-1}
N_4 = 161 kg ha^{-1}

4.2.3.4 Grain yield

Grain yield of wheat under the present study was significantly influenced by interaction effect of irrigation and nitrogen (Table 10). Recommended nitrogen dose (115 kg ha^{-1}) gave the highest grain yield with all the irrigation treatments and lowest yield obtained from highest dose of Urea (161 kg ha^{-1}). Among the irrigation treatments 3 irrigation applications showed higher grain yields irrespective of irrigation treatments. On the other, hand all the interactions of single irrigation with all the nitrogen doses gave lower level of grain yield. However, all the irrigation with N_2 (115 kg ha^{-1}) treatment combination performed better than other interactions. However, interaction of I_5N_2 gave the highest grain yield (4.98 t ha^{-1}). The treatments I_2N_1, I_2N_2, I_2N_3 and I_2N_4 showed lower grain yield. Other combined treatments showed significantly different results in respect of highest and lowest grain yield under the present study. This result was in conformity with the findings of Saren and Jana (2008), Gecit and Cakr (2006) and Hossain *et al.* (2005).

4.2.3.5 Straw yield

Straw yield showed significant influence by interaction effect of irrigation and nitrogen (Table 10). It was observed that the highest straw yield (5.38 t ha^{-1}) was obtained with I_5N_2. The treatments I_4N_1, I_4N_2, I_4N_3, I_4N_4, I_5N_1 I_5N_3 and I_5N_4 also showed higher straw yield but significantly different from I_5N_2. On the other hand the lowest straw yield (1.98 t ha^{-1}) was observed with I_3N_4 which was statistically similar with I_3N_1, I_3N_2 and I_3N_3. The treatments I_2N_1, I_2N_2, I_2N_3 and I_2N_4 showed lower straw yield but significantly different from I_3N_4. The results obtained from all other combined treatments showed significantly different results in respect of highest and lowest straw yield under the present study. Similar result was observed with the findings of Saren and Jana (2008) and Tavakoli (2008).

4.2.3.6 Harvest Index

Harvest index exerted significant influence by the interaction effect of irrigation and nitrogen (Table 10). The result showed that the highest harvest index (48.07%) was obtained with I_5N_2 which was closely folloSwed by I_5N_1. The treatments I_4N_1, I_4N_2, I_4N_3, I_4N_4, I_5N_3 and I_5N_4 also showed comparatively higher harvest index but significantly different from I_5N_2. On the other hand the lowest harvest index (17.15%) was observed with I_3N_4 which was statistically similar with I_3N_2 and I_3N_3. The treatments I_2N_1, I_2N_2, I_2N_3 and I_2N_4 also showed comparatively lower harvest index but significantly different from I_3N_4. This result was in agreement with the findings of Tavakoli (2008) and Maqsood *et al.* (2007).

Table 10. Combined effect of irrigation and nitrogen on yield and harvest index of wheat

Interaction	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index (%)
I_1N_1	2.48	3.85	39.18
I_1N_2	2.54	4.07	38.43
I_1N_3	2.23	3.77	37.17
I_1N_4	2.10	3.68	36.33
I_2N_1	1.65	3.36	32.93
I_2N_2	1.74	3.48	33.33
I_2N_3	1.51	3.30	31.39
I_2N_4	1.67	3.26	30.64
I_3N_1	0.48	2.02	18.55
I_3N_2	0.49	2.17	18.42
I_3N_3	0.46	2.09	17.39
I_3N_4	0.41	1.98	17.15
I_4N_1	3.70	4.55	44.85
I_4N_2	4.00	4.81	45.40
I_4N_3	3.50	4.40	44.30
I_4N_4	3.37	4.39	43.43
I_5N_1	4.39	4.97	46.90
I_5N_2	4.98	5.38	48.07
I_5N_3	4.07	4.67	46.57
I_5N_4	3.85	4.66	45.24
$LSD_{0.05}$	**0.3003**	**0.2507**	**1.267**
CV(%)	**7.98**	**9.68**	**9.16**

I_1 = One irrigation at CRI
I_2 = One irrigation at maximum tillering stage
I_3 = One irrigation at grain filling stage
I_4 = Two irrigations at CRI + grain filling stage
I_5 = Three irrigations at CRI + maximum tillering + grain filling stage

N_1 = 92 kg ha^{-1}
N_2 = 115 kg ha^{-1}
N_3 = 138 kg ha^{-1}
N_4 = 161 kg ha^{-1}

Chapter 5

Summary and Conclusion

Chapter 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the influence of irrigation and nitrogen level on the performance of wheat. The experiment comprised of two different factors such as (1) four levels of irrigation viz. I_1 (One irrigation at CRI), I_2 (One irrigation at maximum tillering stage), I_3 (One irrigation at grain filling stage), I_4 (Two irrigations at CRI + grain filling stage) and I_5 (Three irrigations at CRI stage, maximum tillering + grain filling stage) and (2) Four levels of nitrogen viz. N_1 (92 kg N ha^{-1}), N_2 (115 kg N ha^{-1}), N_3 (138 kg N ha^{-1}), and N_4 (161 kg N ha^{-1}).

The experiment was set up in Split Plot Design with three replications. There were 20 treatment combinations. The experimental plot was fertilized at the rate of 140 kg ha^{-1} Triple Super Phosphate (TSP), 40 kg ha^{-1} Muriate of Potash (MP) and 110 kg ha^{-1} gypsum. Urea was applied according to the treatments. BARI wheat 24 (Prodip) were sown on 14 November 2009 and harvested on 8 March 2010. Data on different growth and yield parameters were recorded and analyzed statistically.

Results showed that effect of irrigation was significant in respect of various plant characters including yield and yield attributes. Plant height, spike length, productive tillers $plant^{-1}$, effective spikes m^{-2}, dry weight $plant^{-1}$s, spikelets $spike^{-1}$, grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index were significantly influenced by different times of irrigation.

It was observed that the plant character parameters- plant height, spike length, productive tillers $plant^{-1}$ and effective spikes m^{-2} always were highest (95.71cm, 15.82cm, 3.92 and 251.30, respectively) with three times of irrigations at CRI stage, maximum tillering + grain filling stage where the lowest (74.72cm, 12.63cm, 2.83 and 184.10, respectively) with one irrigation at grain filling stage. Again, the dry weight $plant^{-1}$ at different days after sowing was the highest (5.41, 9.32, 15.33 and 20.36 g, respectively at 30, 60, 90 DAS and at harvest) with three times of irrigations at CRI + maximum tillering + grain filling stage where the lowest (3.14, 5.55, 8.33 and 12.43 g, respectively) was with one irrigation at grain filling stage.

Incase of yield contributing characters- the highest spikelets $spike^{-1}$ (38.83), grains $spike^{-1}$ (37.08) and weight of 1000 seeds (49.44 g) were with three times of irrigations at CRI stage, maximum tillering + grain filling stage where the lowest were 9.17, 7.17 and 43.66 g, respectively with one irrigation at grain filling stage.

In case of yield parameters- the highest grain yield (4.32 t ha^{-1}), straw yield (4.92 t ha^{-1}) and harvest index (46.69%) were obtained with three times of irrigations at CRI stage, maximum tillering + grain filling stage, whereas the lowest were 0.46 t ha^{-1}, 2.07 t ha^{-1} and 17.88%, respectively were obtained with one irrigation at grain filling stage.

Various plant characters including yield and yield attributes-plant height, spike length, productive tillers $plant^{-1}$, effective spikes m^{-2}, dry weight $plant^{-1}$, spikelets $spike^{-1}$, grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index were significantly influenced by different doses of nitrogen application.

It was observed that the growth parameters- plant height and spike length (80.62cm and 13.94cm, respectively) were highest with 161 kg N ha^{-1}, whereas the lowest 76.84cm and 12.38cm, respectively were obtained with 92 kg N ha^{-1}. But the highest productive tillers $plant^{-1}$ (3.33) and effective spikes m^{-2} (199.40) were obtained with 115 kg N ha^{-1}, whereas the lowest (2.47 and 184.40, 23.60 respectively) were obtained with 161 kg N ha^{-1}. Again, the highest dry weight $plant^{-1}$ at 30, 60, 90 DAS and at harvest were 4.67, 8.17, 12.84 and 17.95 g, respectively with 161 kg N ha^{-1} where the lowest (4.02, 7.39, 10.93 and 16.58 g, respectively) was with 92 kg N ha^{-1}.

Incase of yield contributing characters- the highest spikelets $spike^{-1}$ (27.53), grains $spike^{-1}$ (25.40) and weight of 1000 seeds (47.47 g) were with 115 kg N ha^{-1} where the lowest were 23.60, 21.60 and 46.37 g, respectively with 161 kg N ha^{-1}.

In case of yield parameters- the highest grain yield (2.75 t ha^{-1}), straw yield (3.98 t ha^{-1}) and harvest index (36.73%) were also obtained with 115 kg N ha^{-1} where the lowest were 2.28 t ha^{-1}, 3.59 t ha^{-1} and 34.56%, respectively were with 161 kg N ha^{-1}.

Various plant characters including yield and yield attributes- plant height, spike length, productive tillers $plant^{-1}$, effective spikes m^{-2}, dry weight $plant^{-1}$, spikelets $spike^{-1}$, grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index were significantly influenced by combined effect of different irrigation levels and doses of nitrogen application.

It was observed that the highest growth parameters of plant height and spike length (98.07cm and 16.60cm, respectively) were obtained with I_5N_4 (Three irrigations at CRI stage, maximum tillering + grain filling stage with 161 kg N ha^{-1}) where the lowest plant height and spike length were 55.48 cm and 8.29 cm, respectively were obtained with I_3N_1 (Interaction of one irrigation at grain filling stage with 92 kg N ha^{-1}.But the highest productive tillers $plant^{-1}$ (4.67) and effective spikes m^{-2} (262.00) were obtained with I_5N_2 (Interaction of three irrigations at CRI stage, maximum tillering + grain filling stage with 115 kg N ha^{-1}), whereas the lowest (1.00 ,72.67 and 43.18, respectively) were obtained with I_3N_4 (Interaction of one irrigation at grain filling stage with 161 kg N ha^{-1}). Again, the highest dry weight/plant at 30, 60, 90 DAS and at harvest were 5.98, 10.20, 16.84 and 22.16 g, respectively) with I_5N_4 (Interaction of three irrigations at CRI stage, maximum tillering + grain filling stage with 161 kg N ha^{-1}), whereas the lowest (3.01, 5.39, 8.04 and 12.17 g, respectively) were with I_3N_4 (Interaction of one irrigation at grain filling stage with 161 kg N ha^{-1}).

Yield contributing characters- the highest spikelets $spike^{-1}$ (42.67), grain $spike^{-1}$ (40.60) and weight of 1000 seeds (49.76 g) were obtained with I_5N_2 (Interaction of three irrigations at CRI stage + maximum tillering + grain filling stage with 115 kg N ha^{-1}) where the lowest were 7.67, 6.67 and 43.18 g, respectively with I_3N_4 (one irrigation at grain filling stage with 161 kg N ha^{-1}).

Yield parameters like the highest grain yield (4.98 t ha^{-1}), straw yield (5.38 t ha^{-1}) and harvest index (48.07%) were obtained with I_5N_2 (Interaction of three irrigations at CRI stage+ maximum tillering + grain filling stage with 115 kg N ha^{-1}),whereas the lowest were 2.28 t ha, 3.59 t ha^{-1} and 34.56%, respectively were obtained with the combination of I_3N_4 (One irrigation at grain filling stage with 161 kg N ha^{-1} interaction).

It may be concluded from the result that three irrigation applied at CRI + maximum tillering + grain filling stage along with 115 kg N ha^{-1} application performed best in producing higher yield as well as growth and yield characters than other treatments. However, to reach a specific conclusion and recommendation, more research work on time of irrigation and nitrogen level should be done over different agro-ecological zone.

References

REFERENCES

Ahmed, M. and Hossain, S.M.A. (2002). Effect of seed rate, nitrogen fertilization and time of harvest on the seed yield of wheat. *Bangladesh J. Agril. Sci.* **4**(1 & 2): 135-143.

Ahmed, M. (2006). Maximizing yield of wheat under sufficient water using nitrogen fertilizer dose splitting, *Australian J. Sci.* **26**(2): 113-125.

Ali, M.A. and Amin, S. (2007). Effect of irrigation frequency on yield and yield attributes of wheat cultivar 'Shatabdi'. Faisalabad, Pakistan. *Pakistan J .Agril. Sci.* **2**(3): 145-147.

BARI (2006). Wheat production technology (A booklet in Bengali), Wheat Res. Centre. Bangladesh Agril. Res. Ins. Nashipur, Dinajpur. pp. 18-19.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Pocket Book of Bangladesh Bur. Stat. Stat. Divn., Min. Plan. Govt. People's Repub. Bangladesh. pp. 194.

Cerny, I., Karabinova, M. and Upohlav, T. (2005). Grain yield and quality of winter durum wheat depending on a level of nitrogen fertilization and fertilizer form applied. Sci. Pep. Fac. Agric. Slovakia Univ. Slovakia. **8**(2): 129-33.

Chandurkar, V.P., Thakare, G.V. and Deshmukh, A.H. (2007). Effect of different levels of nitrogen on yield protein. content and nitrogen uptake by wheat cultivars. *Indian J. Ecol.* **18**(1): 99-100.

Chaturvedi, I. (2006). Effects of different nitrogen levels on growth, yield and nutrient uptake of wheat. Muzaffaarnagar, India, *Indian. J. Agril. Sci.* **2**(2). 372-374.

Chaudhary, A.A. and Dahatonde, B.N. (2007). Influence of irrigation frequency, irrigation deptlh and antitranspirants on the, growth, yield and water use efficiency of wheat. *Madras Agric. J.* **24**(l): 54-55.

Cheema, S.S. (1995). Effect of missing irrigation at different stages of growth in dwarf wheat. J. Res. *Punjab Agric. J.* **10** (1): 41-46. -

Chrzanowska, D.B. Gil, Z., Liszewski, M. and Malarz, W. (2008). Quality and quantity of yield of winter wheat in relation to doses and methods of nitrogen application. *Poland J. Crop Sci.* **23**(3): 29-38.

FAO (Food and Agricultural Organization), (2010). Production Year Book. FAO. UN. Italy. Rome. p. 95: 98.

FAO (Food and Agricultural Organization), (2008). Production Year Book. FAO. UN. Italy. Rome. p. 65: 66.

FAO (Food and Agricultural Organization), (2007). Production Year Book. FAO. UN. Italy. Rome. p. 118.

Feng, W. and Yao, Z. (2005). Effects of nitrogen (N) on the yield and quality of two wheat cultivars with different spike types. Shaanxi. China: Editorial Department of Journal of Triticeae Crops. *J. Triticeae Crops.* **25**(2): 57-60.

Gecit, H.H. and Cakr, E. (2006). The effect of nitrogen and irrigation on the yield, yield components of durum wheat (*Triticum durum* L.). Ankara, Turkey: Ankara Universitesi Ziraat Fakultesi Adina. *Turkish j. Agron.* **l2**(3): 259-266.

Gomez, K.A. and Gomez. A.A. (1984). Statistical procedures for Agricultural Research. 2nd edn. John Wiley and Sons. New York. Pp. 680.

Guler, M. and Akbay, G. (2007). Effects of irrigation and nitrogen fertilization on protein yield of common wheat. *Turkish J. Agric. Crops.* **24**(3): 317-325.

Hossain, M.F., Kabir, M.A. and Majumder, U.K. (2005). Influence of irrigation and nitrogen level on the yield of wheat. Faisalabad. Pakistan. ANSInet, Asian Network for Scientific Information. *Pakistan J. Biol. Sci.* **8**(1): 152 -158.

Karim, M.M. (2007). Growth and yield of modern wheat cultivars under different practices of irrigation and fertilizer doses. *Bangladesh J. Agril. Res.* **12**(1)-18-22.

Karim, M.M. and Siddique, K.A.M. (2001). Crop growth and relative growth rates of old and modern wheat cultivars. *Australian J. Agril. Res.* **42**(1)-13-20.

Khajanji, S.N. and Swivedi, R.K. (2007). Response of wheat (*Triticum aestivtcm*) to irrigation and fertilizer mixture under late condition. ভারতীয় কৃষি অনুসন্ধান পত্রিকা. **3**(1): 37-42.

Kibe, A.M., Singh. S. and Kalra, N. (2006). Water-nitrogen relationships for wheat growth and production, in late sown conditions. Amsterdam, Netherlands. Elsevier. Agril. Water Manag. **84**(3): 221-228.

Kong, X.X., Yanva, Z.P. and Cheng, W.J. (2008). Effect of limited irrigation on yield of winter wheat and water use efficiency. China. **20**(5):64-66.

Liaqat, A., Qamar, M. and Mushtaq. A. (2008). Effect of different doses of nitrogen fertilizer on the yield of wheat. Faisalabad, Pakistan: Friends Science Publishers. *Int. J. Agric, Biol*. **5**(4): 438-439.

Li-Yong, B. and Zheng, L. (2008). Effects of water and nitrogen (N) management on the yield and water and nutrient utilization efficiency of winter wheat in the suburbs of Beijing. Shaanxi, China. Editorial Journal of Triticeae Crops. *J. Triticeae Crops*. **25**(2): 51-56

Mushtaq, A. and Muhammad, S. (2005). Growth and yield of wheat as influenced by different irrigation frequencies. Faisalabad. Pakistan: Directorate of Agricultural Information, Ayub Agricultural Research Institute. *Pakistan J. Agric. Res.* **43**(4): 331-338.

Naser, H.M. (1999). Response of wheat to irrigation. M.S. Thesis, Dept. of Soil Sci. Bangladesh Agril. Univ. Mymensingh. P. 1-77.

Oad, F.C., Buriro, L.A. and. Siddiqui, M.H. (2007). Yield and yield components of wheat under inorganic nitrogen levels and their application method. Faisalabad, Pakistan. *Intl. J. Agric., Biol.* **6**(6): 1159-1161.

Onyibe, J.E. (2008). Effect of irrigation regime on growth and development of two wheat cultivars in the Nigerian Savanna. Shaanxi, China: Editorial Journal of Triticeae Crops. *J. Tnticeae Crops.* **25**(2): 80-86.

Pal, S.K. and Upasani. R.R. (2007). Grain growth and yield of late sown wheat under different irrigation schedules. Ranchi, India. Birsa Agricultural University. *J. Res. Birsa Agril. Univ.* **14**(2): 187-192

Randhawa, A.S.,Jolly. R.S. and Arora, B.S. (2004). The effect of sowing time and. rates and time of nitrogen application, on dwarf wheat. *J. Res. Punjab* **13**(2): 130- 135.

RARS (Regional Agricultural Research station). (2010). Annual wheat Research Report (2001-02), Bangladesh Agricultural Research Institute, Jessore. **14**(2): 162-170.

Saren, B.K. and Jana, P.K. (2008). Effect of depth of irrigation and level and time of nitrogen application on growth, yield and nutrient uptake by wheat (*Triticum aestivum*), New Delhi, India. *Indian J. Agron.* **46**(2): 227-232.

Shen, Y.X., Guo,W.S. and Zhou, Y.Z. (2007), Effects of nitrogen application, amount and saddlebag number on grain yield, population quality, protein content and its components in wheat variety : Ningyan 1. Shaanxi, China. *J. Triticeae Crops.* **27**(1): 134-137.

Singh, P. (2003). Effect of nitrogen application in different wheat cultivars with nitrogen at different growth stages. *Indian J. Agric. Sci.* **33**(1): 31-33.

Singh, B. and Singh, C.P. (2005). Effect of nitrogen application in wheat in north hill condition. *Indian J. Agron.* **36**(3): 326-328.

Singh, G. and Singh, O.P. (2001). Effect of wheat varieties and levels of N on yield and nutrient uptake under late sown condition. *J. Agric. Sci.* **27**(1): 65-68.

Tavakoli, A (2008). Effects of supplemental fertilization and nitrogen rates on yield and yield components of rainfed wheat cultivar Sabalan. Seed and Plant Improvement Institute. Karaj, Iran. **19**(3): 367-381.

Zhai, B.N. and Li, S.X. (2006). Combined effects of water and nitrogen fertilizer on yield and quality of winter wheat. *Field Crops. Abst.* 9(1): 26-32.

Appendices

APPENDICES

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2009 to March, 2010

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%)	Rain fall (mm)
November	26.98	14.88	71.15	Terrace
December	25.78	14.21	68.30	Terace
January	25.00	13.46	69.53	0
February	29.50	18.49	50.31	0
March	33.80	20.28	44.95	0

Source: Bangladesh Meteorological Department (Climate Division), Agargaon,
Dhaka 1212.

Appendix II. Physical characteristics and chemical composition of soil of the experimental plot.

Soil Characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	5.47 – 5.63
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka