GROWTH AND YIELD OF WHEAT AS INFLUENCED BY TIME OF IRRIGATION AND SPLIT APPLICATION OF NITROGEN

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Dedicated to

My

Beloved Parents

&

Elder Brother

CERTIFICATE

This is to certify that the thesis entitled, **"Growth and Yield of Wheat as Influenced by Time of Irrigation and Split Application of Nitrogen"** 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 **MOSAREF HOSSAIN** Registration No. **07-2595** 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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The Author

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LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
et al.	And others
FAO	Food and Agriculture Organization
g	Gram (s)
HI	Harvest Index
hr	Hour(s)
K_2O	Potassium Oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter squares
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM/ TDW	Total Dry Matter/ Total Dry Weight
TSP	Triple Super Phosphate
var.	Variety
Wt.	Weight
t ha^{-1}	Ton per hectare
^{0} C	Degree Centigrade
%	Percentage

ABSTRACT

The experiment was conducted at the experimental site of Sher-e-Bangla Agricultural University (SAU) during the period from December, 2007 to March, 2008 to study the growth and yield of wheat as influenced by time of irrigation and split application of nitrogen. The treatments comprised (A) three irrigation levels (i) no irrigation, (ii) one irrigation given at crown root initiation stage, (iii) two irrigations, one at crown root initiation stage and another at panicle initiation stage and (B) four split application of nitrogen viz. (i) no nitrogen application, (ii) one basal application of nitrogen at the time of sowing, (iii) two equal split- one at basal and another at 30 DAS, (iv) three equal split- one at basal, one at 30 DAS and the other at 60 DAS and (C) their combination effect. It was observed that the highest plant height, number of tillers/plant, leaf area index (LAI), fresh weight plant^{-1}, dry weight plant^{-1}, spike length, number of spikelets spike^{-1}, number of grains spike^{-1}, 1000 seed weight, total grain yield, straw yield and harvest index were obtained with the application of irrigation and nitrogen. In case of the combined effect on irrigation and split application of nitrogen, the tallest plant (96.37 cm), highest number of tillers/plant (4.50), highest leaf area index (2.71), highest fresh weight (66.97g) and dry weight (36.56g) plant^{-1}, longest spike length (17.35 cm), highest number of spikelets spike^{-1} (60.00) and highest number of grains spike^{-1} (39.33), highest 1000 seed weight (48.50g), total grain yield (4.30 t ha^{-1}), straw yield (5.82 t ha^{-1}) and harvest index (42.49%) were obtained with the combination of two irrigations with three split application of nitrogen. So, it may be concluded that the treatment combination of two irrigations at crown root initiation and panicle initiation with three splits of nitrogen one each at basal, 30 DAS and 60 DAS considered as the best treatment compared to all other treatments and it can be recommended for further trial.

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the leading cereals in the world. It belongs to the family Gramineae and it is the world's most widely cultivated cereal crop which ranks first followed by rice. 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 growing population.

In Bangladesh the position of wheat is second in respect of total area of land (0.80 million hectares) and production(2.80 million ton) after rice and the average yield of wheat is only 3.4 t/ha^{-1} (BBS, 2006) and it can be increased up to 6.8 t ha^{-1} (RARS, 2002). So, there is an ample opportunity to increase production of wheat per unit area through adoption of modern and improved agronomic practices such as optimum seed rate, timely sowing and judicious application of irrigation, fertilizer and other inputs.

Bangladesh is an over populated country. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population. From nutritional point of view, wheat is superior to rice for its higher protein content.

Among the factors responsible for low grain yield of wheat, different factors such as lack of irrigation water and plant nutrient, weed competition, insect attack, disease infection etc. are the most important. About 30% of wheat production is lost due to lack of irrigation water and 40% yield loss due to lack of nutrient supply in the country (Karim, 2007). However, enough irrigation water and nutrient supply can increase yield up to 70% in our country (Ahmed, 2006).

Food production in Bangladesh is not increasing by keeping pace with the increase of population growth. Total land area under food production has been decreasing year after year to accommodate the ever-increasing population. On the other hand, yield of rice, the major food crop of this country has been declining for the last two decades due to decreasing of soil fertility and crop production (Roy, 2004) and as a result the country has been suffering from food shortage. So, in this situation efforts should be taken to increase the food production by cultivating promising crop like wheat other than rice.

In Rabi season, most of the lands, especially in North-western part of the country remain fallow due to lack of irrigation facilities which could easily be brought under wheat cultivation. The climate and soil of Bangladesh are quite favorable for the cultivation of wheat during this period.

Time of irrigation and its management are very important for successful cultivation of wheat. Supplement 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 higher grain yield (Randhawa *et al*., 2004).

In Bangladesh, the rainfall during Rabi season in characteristically scanty and uncertain. As such, wheat gives poor yield 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.

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 fertilizers 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 (Ashok *et al*. 2004).

Time of irrigation along with split application of nitrogenous fertilizer would play a vital role for increasing maximum yield of wheat per unit area. Irrigation schedule based on physiological stage (Cheema *et al.*, 1995) should be used properly and the split application of nitrogen with optimum dose is very important in increasing wheat production (Cheng *et al*., 2006).

Researches on the influence of time of irrigation and split application of nitrogen in wheat, therefore, warrant special attention under conditions of Bangladesh. The present study was undertaken with the following objectives:

i. To determine the effect of time of irrigation on the growth and yield of wheat,
ii. To find out the optimum split of nitrogen application for better growth and yield of wheat, and
iii. To determine the interaction effect of time of irrigation and split application of nitrogen for maximum yield of wheat.

CHAPTER 2

REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief review of research in relation to growth and yield of wheat as influenced by time of irrigation and split application of nitrogen. It is an established fact that balanced fertilization especially nitrogen which is the most important plant nutrient and water management increases crop growth and gives higher yield (Mengping, 2005). Some of the pertinent findings of the research with time of 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

Many experiments have been conducted on the effect of time 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:

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 of irrigation norm at elongation and booting stage; 45 mm at elongation and booting stage; 30 mm at filling stage; 45 mm at filling stage; 30 mm at elongation and 30 mm at filling stage; and 45 mm at elongation and booting stages and 45 mm at the filling stage. Irrigation increased the average yield of wheat by 13.0-39.6% and the water use efficiency by 7.0-18.0%. The physiological properties and yield compositions of winter wheat could be 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 elongation and booting stages and the water use efficiency could also be improved. Irrigation at 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 elongation and booting stages.

Ju-Hui (2006) studied the impacts of single irrigation at different stage on wheat yield components. Results indicate that single irrigation at different stage has different contribution to wheat yield components. Irrigation at floret differentiation stage can increase the number of ears greatly, irrigation at quadrant stage significantly enhanced grains number per ear. Irrigation at heading stage increased 1000 grain weight. 1000 Grain weight was the key factor determining yield under water saving cultivation, the next was the number of grains per unit area. Sink was enlarged and the total grain number of population was increased by irrigation at pistil-stamen differentiation stage. Irrigated after pistil-stamen differentiation stage, the effect of enlarging sink is reduced gradually and the contribution of strengthening source is increased. The irrigation at heading stage has the most grain number of population. Population was with small source and big sink while irrigation is at pistil-stamen differentiation stage and with big source and small sink while irrigation is at heading stage. The relationship of source and sink has relative good balance while irrigation at quadrant stage with highest level of grain yield.

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 cv. Uqaab-2000 on a clay loam soil. Results revealed that wheat receiving 5 irrigations at crown root + tiller + boot + milk + grain development stages produced significantly taller 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 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..

Limited precipitation restricts yield of winter wheat. Sun and Liu (2006) conducted an irrigation experiments during different growing stages of winter wheat (*Triticum aestivum* L.) at North China 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 (WUEet) 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 requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUE. 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 on plant height, number of effective tillers per hill, spike length, number of spikelets 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.

Sher and Parvender (2006) carried out a field experiment during winter on sandy loam soils in Haryana, India, to evaluate the effects of irrigation regimes (IW/CPE 0.5, 0.7 and 0.9) on growth, yield and nutrient uptake of wheat under late-sown conditions. The irrigation level IW/CPE 0.9 (4 irrigations) being statistically at par with IW/CPE 0.7 (3 irrigations) produced significantly higher plant height, number of tillers/m2, 1000-grain weight and straw yield than IW/CPE 0.5 (2 irrigations), which was at par with 3 irrigations. The irrigation regime IW/CPE 0.9 recorded significantly higher dry matter accumulation, grains per spike and grain yield than IW/CPE 0.7 and 0.5. The percentage increase in grain yield due to IW/CPE 0.9 over IW/CPE 0.7 and 0.5 was 14.1 and 21.3%, respectively. N, P and K uptake by both grain and straw also increased progressively with increasing number of irrigations.

Grain yield and water use efficiency (WUE) of spring wheat (*Triticum aestivum* L.) in ari environment can be improved by applying irrigation selectively to allow soil water deficits to develop at non-critical stages of crop development. Zhang *et al*., (2005) conducted a field experiment on a loam soil in China to determine the grain yield, yield components, and water use characteristics of spring wheat in response to regulated deficit irrigation (RDI) schemes. Wheat grown under the RDI schemes produced 29% higher grain yield than wheat grown under water deficit-free control 6.2 t ha^{-1}). Among six RDI schemes studied, wheat having a high water deficit at the jointing stage, but free from water deficit from booting to grain-filling produced highest grain yield (7.26 t ha^{-1}). Compared with the control, wheat plants grown under the RDI schemes received 59 mm (or 15%) less water via irrigation, but they either extracted 41 mm more (or 74%) water from the soil profile. Grain yield increased as ET increased from 415 to 460 mm, and declined beyond 460 mm. The WUE values varied from 0.0116 to 0.0168 t ha^{-1} mm^{-1}, and wheat grown under the RDI had 26% greater WUE compared with the control. Grain yield and WUE of spring wheat can be greatly improved by regulated deficit irrigation with reduced amounts of water. This practice is particularly valuable in arid regions where wheat production relies heavily on irrigation.

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 ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m2 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.

Drought tolerance levels in some wheat lines and cultivars based on uniform regional wheat yield trial (URWYT-M-75) were investigated (by Baghani and Ghodsi, 2006) using a strip plot design based on complete block design with 3 replications in Iran. The main plots (horizontal factor) were composed of 3 levels of irrigation (10, 20 and 30 days interval), while the sub-plots (vertical factor) were of 20 lines or cultivars of spring bread wheat set up for URWYT (M-75-1-20). Sowing date and sowing and fertilizer rates were under normal condition. Soil water content was also determined. The results showed that when irrigation interval was 10 days, the line yields of M-75-8, M-75-6, M-75-2 and M-75-16 were higher than other lines. When the irrigation interval was 20 days, the highest lines were observed for M-75-2, M-75-14, M-75-16 and M-75-12. In 30 days irrigation interval, the lines of M-75-15, M-75-4, M-75-2 and M-75-14 had maximum yields. As a summary, M-75-2 line was better than others showing good flexibility and water use efficiency, under normal and stress conditions.

The growth rate, yield and yield components of 4 wheat cultivars (Sabalan/1-27-56-4, Anza/3/Pi/Nor//Hys/4/sefid, 4493-P.1533-Bez and Sabalan) under rainfed conditions and 2 irrigation regimes (irrigation at planting time and ear emergence, and irrigation at planting time, ear emergence and grain filling) were studied in Maragheh, Iran (Abdorrahmani *et al*., 2005). Crop growth rate, relative growth rate, dry matter accumulation per unit area, number of ears per unit area, number of grains per ear, 1000-grain weight, biological yield, grain yield, harvest index, plant height and productivity were evaluated. Drought stress reduced dry matter production, crop growth rate and relative growth rate. Green cover percentage, crop growth rate, and relative growth rate did not significantly vary among the cultivars. All traits except the number of grains per ear and harvest index were affected by water deficit. No significant variation was observed between irrigation regimes. The green cover percentage, plant height, crop growth rate, biological yield and productivity were significantly correlated with grain yield. The mean green cover had the greatest positive correlation with grain yield. This trait can be recommended as a suitable index for the evaluation of the field performance of various crops (Abdorrahmani *et al*., 2005).

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 missing irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, missing 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 tillering, 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 I4; I4 + irrigation at the tillering stage or I5; and I5 + 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). 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. [1 quintal=100 kg].

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 highest 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.

Alsohaibani (2007) conducted a field experiment in Saudi Arabia to evaluate the effects of irrigation level (65, 100 and 170 mm accumulated vapour) on the growth and yield of different bread wheat lines (L.9, L.11 and L.18) and the local cultivar (Yecorarogo). Irrigation level had highly significant effect only on spike length, but had significant effect on biological and grain yields and their components. Grain yield reduction was 16.4% and biological yield reduction was 13-20% at 100 mm accumulated vapour. No significant differences in these parameters were observed between 65 and 100 mm accumulated vapour rates.

An Experiment was carried out by Jana and Mitra (2004) on wheat cv. Sonalika giving irrigation at crown root initiation, tillering, flowering and dough stages. They found that irrigation increased plant height, number of effective tillers, ear plant^{-1} and grain and straw yields.

Irrigation plays a positive role in increasing the number of tillers, ear plant^{-1} and grain of wheat. Ear length and number of grains reduced significantly if irrigation is stopped at tillering and booting stages of wheat (Hefni *et al*., 2000)

Singh and Singh (2001) reported that growth of wheat was poor when crop was grown under rainfed condition. Under this condition tiller number, panicle length, grain number and 1000-grain weight were lower.

Ashok and Sharma (2004) conducted field trials in the winter seasons of 1990-91 at Karnal, Haryana, India, where wheat cv. HD-2285 was irrigated at IW:CPE ratios or 0.6,0.9 or 1.2. It was observed that the irrigation treatments increased dry matter accumulation.

Mandal *et al.*(2002) conducted a field experiment in India during 1984-86 and 1986-87 on wheat with 2 levels of irrigation: one at crown root initiation (CRI) and at CRI + booting stages and reported that LAI increased significantly with increasing levels of irrigation.

Nahar and Paul (1998) reported that LAI was higher in irrigated plants than in the rainfed plants at all the vegetative phases in wheat (cv.Kanchan). They also found that LAI reached a certain Peak and then declined.

Pal *et al*. (2002) conducted a field experiment during winter season on sandy loam of Ranchi. The treatment consisted of three irrigation schedule (2 irrigation at CRI and maximum tillering, booting and milk stages). They observed that application of 4 irrigations gave higher crop growth rate (CGR) than 2 or3 irrigations.

Relative Growth Rate (RGR) is the rate of dry matter increase per unit total dry matter (TDM) per unit time (Milthorpe and Moorbby, 1997).

El-Zahab *et al*. (2003) stated that RGR increased steadily during early growth stage and then decreases slowly.

Grain and straw yields and yield contributing characters gradually increased with increasing number of irrigation (Islam, 2003). The highest grain and straw yields, the maximum plant height , the highest number of effective tillers, and the maximum number of grains spike^{-1} were obtained by three irrigations (I_4) applied at 25, 50 and 70 days after sowing. The increased grain and straw yields in I_4 treatment over control was 60.7% and 59.4% with irrigation.

Razi-us Shams (2001) observed that the effect 0f irrigation treatments on yield and yield contributing characters were statistically significant. When irrigation frequency was increased the grain and straw yields, number of tillers, panicle length, number of grains panicle^{-1} were gradually increased over control.

Jadhav and Jadhav (2000) reported that significantly higher number of spikelets spike^{-1} was obtained from 4 and 5 irrigations compared to 2irrigations.

Yadav *et al*. (2001) reported that two irrigation scheduled at CRI and milking stages gave the maximum number of grains spike^{-1}(65) of wheat, which was found to be at par with those at one irrigation. Eunus *et al*. (1998) observed higher number of grains in irrigated plots than in non irrigated ones.

Ottman *et al*. (2000) conducted a field experiment on a Casa Grande sandy loam soil in 1995 and 1996 growing seasons at the University of Arizona Maricopa Agricultural Centre, USA. The treatments consisted of 3 levels of N (0, 2.4 and 6.7 gm m^{-2}) until anthesis and irrigation based on 30%, 50% and 70% depletion of plant available soil water . It was observed that irrigation frequency during grain filling increased 1000-grain weight.

Upadhyaya and Dubey (2003) performed a field experiment on wheat where 3 irrigations frequencies viz. (a) one irrigation at CRI stage, (b) two irrigation one each at CRI and booting stages and (c) four irrigations one each at crown root initiation (CRI), booting, flowering and milking stage were included. They observed that grain yield varied significantly with irrigation frequencies. Four irrigations performed the maximum grain yield which was significantly greater than one or two irrigations.

Patil *et al*. (2002) conducted a field experiment with irrigation at Agricultural Research Station, Niphad, Maharashtra during the winter (rabi) season of 1992-93. There were 3 irrigations treatments viz. one irrigation at 42 days after sowing, two irrigations at 21 and 65 DAS and five irrigation at 21,42,65,85 and 105 DAS. They observed that grain yield of wheat was 1.17 t ha^{-1} when irrigated once at 42 DAS, 1.69 t $ha^{-1}$when irrigated twice at 21 and 65 DAS and 2.02 t $ha^{-1}$when irrigated five times at 21,42,65,85 and 105 DAS.

Ghosh *et al.* (2003) in Kalyani, West Bengal carried out experiment on wheat grown as pure and intercropping system and observed that without irrigation , with irrigation at 21 and 65 DAS and with irrigation at four critical growth stages crop gave grain yields of 2.08 tha^{-1}, 2.99 t ha^{-1}, 3.40 t ha^{-1}respectively.

Hosamani *et al*. (2003) conducted experiments at Dharwad, Karnataka, India where the treatment consisted of 3 irrigation frequencies one irrigation (at CRI), two irrigations (one each at CRI and tillering stages) and five irrigations (one each at CRI, tillering, booting, flowering and dough stages). They observed that mean grain yield was 1.04, 1.36 and 1.90 t $ha^{-1}$with one, two and five irrigation respectively.

BARI (2000) recorded maximum straw yields with three irrigations applied at CRI, maximum tillering and grain filling stages of crop. Irrigations given at CRI+ maximum tillering (MT), CRI+ Booting (BT) and CRI+grain filling (GR) were at par in respect of number of spikes m^{-2} and grains $spike^{-1}$, but had highest spikes and grains over CRI+MT stages.

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 $plant^{-1}$, the highest spike length, the maximum number of grains $spike^{-1}$ 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.

Cooper (1998) reported that harvest index increases with increase in irrigation frequencies. Boogaard *et al*. (1999) carried out an experiment in a

Mediterranean environment in North Syria with wheat under rainfed and irrigated conditions and reported that under rainfed conditions harvest index was increased.

The findings presented above indicate that irrigation influences growth and yield through affecting yield components at different phonological stages. Irrigation at different critical stages showed variable responses to growth, yield and yield contributing characters. The literature discussed above suggests that irrigation water should be applied at critical crop growth stages depending on the soil moisture situation to achieve higher yield of wheat crops.

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

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.

The effects of nitrogen (N) applications on winter wheat cultivars were studied in field trials conducted in a central Hungarian region by Szentpetery *et al*., (2005). Nitrogen fertilizer rates of 0, 40, 80, 120, 40+40 and 80+40 kg a.i./ha were applied at tillering and after anthesis (Feekes 3 and Feekes 10.5). The N fertilizer applied was ammonium nitrate in 34% cc. In the experiment, the changes of quantity of the yield were analyzed. N top dressing had a great importance. The 80 and 120 kg/ha fertilizer doses were the most effective.

Shen *et al*., (2007) conducted a field experiment in Jiangsu, 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. When the N rate was 180 kg/ha, the ear number could increase. 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), total number of tillers (1402/m^2), number of green leaves (1067/m2), 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 and technological quality parameters were significantly influenced by fertilizer application. Isodur 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 120 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, wheat cultivars Yumai 66 (large-spike type) and Yumai 49 (multi-spike type) were supplied with 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 than Yumai 49, but its yield was lower. Nitrogen supply 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.

The performance of durum wheat cultivars PBW 34supplied with 120, 150 and 180 kg N/ha was evaluated in a field experiment conducted in India during the rabi season by Virender *et al*., (2006). Plant height, number of ears per head, 1000-grain weight, grain yield, straw yield, grain appearance score and hectolitre weight increased with increasing rates of N and highest with 180 kg N/ha.

Hakoomat *et al*., (2005) conducted an experiment in Multan, Pakistan with N at 0, 70, 140 and 210 kg/ha were applied on wheat cultivars Inqlab-91 and Bakhar-2000. Bakhar-2000 produced more tillers and taller/plants than Inqlab-91. Plant height increased with increasing N rate. N at 210 kg/ha produced the highest number of fertile tillers (569.75/m2), straw yield (9.05 t/ha) and grain yield (4.77 ton/ha). N application increased vegetative growth and biological yield.

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 on the stand after rape 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 per 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, N content, N uptake and protein content was obtained with 150 kg N/ha treatments. GW-322 gave the highest grain yield, N content, total N uptake and protein content.

Raigar and Pareek (2006) carried out a field experiment in India to determine the yield and yield attributes of wheat as influenced by different levels of nitrogen and time of application. Application of nitrogen at 120 kg/ha significantly enhanced yield attributes, grain and straw yield of wheat. Application of nitrogen in three split (1/3 sowing + 1/3 CRI + 1/3 FN) significantly increased grain, straw yield and effective tillers/m row length whereas number of grain per ear, Ear length and test weight did not differ significantly due to time of application.

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 m2 (408), 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.

The effects of mineral N fertilizer (at 30, 60, 90 and 120 kg/ha) on the leaf area, dry matter content of the aboveground part of 100 plants, number of spikelets in the spikes of the main and secondary stems, and the relation of these indices to grain yield of winter wheat cv. Sirvinta 1. A linear relationship was established between grain yield and leaf area, however, in many cases it was significant at a lower than 95% probability level. The tightest correlation between grain yield and leaf area index was established in the middle booting stage. The effect of N on the number of spikelets in the spikes of the main and secondary stems as well as on the dry matter content of the aboveground part of 100 plants was inconsistent (Janusauskaite, 2007).

Longnecker and Robson (2004) reported that low N supply at the vegetative stage decreased the total number of leaves on the main stem, while low N supply after the double ridge stage did not. Frank and Bauer (2003) also reported that terminal spikelet increased with increasing levels of nitrogen.

Plant height of wheat are usually influenced remarkably with different levels of N application. Several workers such as Behera (2003), Awasthi and Bhan (2001) and many others reported that plant height of wheat are influenced significantly due to the application of N fertilizer.

Deshmukh *et al*. (2003) reported that nitrogen application in three splits at sowing, crown root initiation and jointing (1:2:1) produced higher number of effective tillers m^{-2}, spikelets ear^{-1}, 1000 grain weight and yield of grain and straw compared to other splits.

Kumar *et al*. (2003) observed from an experiment at karnal, India with 4 levels of N (0, 60, 120 and 180 Kg N ha^{-1}) that productive tillers increased significantly with increase of N doses from 0 to 120 kg ha^{-1}, but differences in productive tillers was evident between 120 and 180 kg N ha^{-1}.

Total dry matter production is the integration of crop growth rate over the entire growth period. Balyan (2000) reported that dry matter accumulation in wheat increased with an increase of N up to 80 kg N ha^{-1}.

Kumar and Sharma (2004) conducted a field experiment at Indian Agricultural Research Institute, New Delhi, during 1992-93 and 1993-94 with 3 dates of sowing and 4 levels of N (0, 40, 80 and 120 kg N ha^{-1}). It was observed that dry matter accumulation in wheat increased significantly when the rate of N application increased from 0 to 40 kg N ha^{-1} at 40 DAS, 0 to 120 kg N ha^{-1} at

60 DAS, 0 to 80 kg N ha^{-1} at 80 DAS. Nitrogen application also hastened the growth and resulted in higher percentage of total dry matter accumulation in early stage of crop growth.

Bellido *et al.* (2000) carried out a field experiment during 1986 in Cordoba, Southern Spain , on a vertisol (Typic Haploxerert) with 4 levels of N (0, 50, 100 and 150 kg N ha^{-1}). They reported that the amount of total dry matter was significantly greater at N fertilizer rates 100 and 150 kg N ha^{-1}.

Dotlacil and Toman (2002) observed that grain yield was positively correlated with LAI. LAI and TDM were influenced by different levels of nitrogen fertilizer. Awasthi and Bhan (1993) reported that increasing levels of N uptake to 60 kg N ha^{-1} influenced LAI and dry matter production. Frederick and Camberato (1995a) observed that increase in N rate resulted in higher LAI. Maximum LAI values was found at 90 kg N ha^{-1}.

Crop growth rate (CGR) is the rate of dry matter production per unit area of land per unit time and it is a simple and important index of agricultural productivity (Hunt, 1999). Kumar *et al*. (2000) reported that increasing levels of N from 0 to 180 kg ha^{-1} increased CGR. Cell developed with increasing levels of N tended to show higher meristematic activities, formation and functioning of protoplasm, which consequently increase the plant growth.

Karim and Siddique (2001) reported that higher RGR was obtained at vegetative phase. Haloi and Baldev (2000) observed higher RGR at initial stage of crop growth.

The findings presented above indicate that nitrogen influences growth and yield through affecting yield components at different phonological stages. Nitrogen at different critical stages showed variable responses to growth, yield and yield contributing characters. The literature discussed above suggests that irrigation water should be applied at critical crop growth stages depending on the soil moisture situation to achieve higher yield of wheat crops.

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

A good number of research works have been conducted on the interaction effect of time of irrigation and split application of nitrogen on the growth, yield and yield contributing characters. Some of the pertinent findings of those research works are reviewed 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-was 469 482 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 of 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 60-90 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 available 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 degrees C averaged 19.70 degrees 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 x 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/m3). 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.

Jarwar *et al*., (2005) conducted an experiment in Pakistan to study the effect of nitrogen (N) source (urea and ammonium nitrate), N rate (0, 100, 150 and 200 kg N/ha) and irrigation depth (5, 7.5 and 10 cm) on N recovery, yield components (number of productive tillers per plant, plant height, ear head length, oven dry weight of flag leaves and 1000-grain weight) and grain yield of wheat cv. TJ-83. All treatments received basal application of 90 kg P2O5 and 60 kg K2O/ha. The soil was a Miani series with 45% clay in surface soil, alkaline (pH 7.9) and calcareous (lime 7.7%) in nature. Organic matter and mineral N contents of the surface soil were 0.65% and 26 mg/kg, respectively. Wheat growth and yield were maximum at 100 kg N/ha for each source of N. Further increase in N rates did not significantly influence the yield. The growth parameters showed non-significant influence in case of depth of irrigation, except for the number of productive tillers per plant. The interaction between N and irrigation depth was also non-significant. N uptake increased continuously up to the highest N rate, while the grain and straw yields were maximum at 100 kg N/ha. N uptake was not influenced by the N source and irrigation treatments. The maximum N recovery (35.7%) was noted when urea was applied at 100 kg N/ha, under the irrigation depth of 5 cm. The corresponding value for ammonium nitrate was 30%. A decrease in N recovery was noted as N rate increased beyond 100 kg N/ha or when irrigation depth was more than 5 cm per irrigation.

Nutrient status in the root zone regulates the actual evapotranspiration (AET) pattern from the crop field. Sarkar (2005) carried out a field study in Bengal, India to evaluate the effects of irrigation frequency (IW/CPE=1.2, 1.0 and 0.8) and fertilizer levels (100, 50 and 0% of recommended N:P2O5:K2O rates of 80:40:40 kg ha-1) on leaf area index, crop growth, yield, components of water balance and water use efficiency (WUE) of wheat (cv. CV-UP 262). The experiment was laid out in a split-plot design where irrigation frequencies were assigned to main plot and fertilizer levels were under sub-plot treatments. The magnitudes of yield and other crop parameters, moisture content and AET declined temporarily with the decrease in both irrigation frequency and fertilizer level. The AET showed a strong positive correlation with grain and straw yields. Good match between potential and actual evapotranspiration was observed. The WUE values increased with the increase in the frequency of irrigation. Under the wet (IW/CPE=1.2) regime, the highest level of WUE was attained with 50% of the recommended fertilizer rate. However, under moderately wet or dry conditions, WUE decreased with a decrease in the fertilizer rate. A good match between cumulative values of potential and actual evapotranspiration was observed.

Li-Jiu and Rao (2005) conducted a field experiment in China to determine the effects of non-uniformity of sprinkler irrigation and the amount of fertilizers applied through irrigation on nitrogen uptake and crop yield of winter wheat. Fertilizer was applied with the sprinkler irrigation system varying from 71 to 85% uniformity and 0-180 kg N/ha. Results showed that sprinkler fertigation uniformity had insignificant effects on nitrogen uptake and crop yield for the uniformity range tested. Also, the influence of fertilizer applied through sprinkler fertigation on crop yield was minor while total nitrogen content in the stem and nitrogen uptake increased as fertilizer levels were increased.

Hossain *et al*., (2005) conducted an experiment in Dinajpur, Bangladesh to determine the optimum irrigation time and nitrogen level for wheat. The highest grain yield (3.71 t ha-1) 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-1) was obtained from 120 kg N ha-1, which was followed by 100 kg N ha-1, and the lowest grain yield (2.81 t ha-1) was recorded under 40 kg N ha-1 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 (rainfed, 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) as 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 rainfed wheat varied with seasonal rainfall and its distribution. With irrigation, crop responses were generally significant up to 60 kg N/ha. The optimum level of supplemental irrigation was at 1/3 of the full supplemental irrigation, with 60 kg N/ha recording maximum water use efficiency (30 kg/mm) and good yield (minimum water use with one-time irrigation at planting time).

Kocon and Suek (2007) carried out an experiment to study the effect of different nitrogen fertilizer rates on the yield and chosen grain quality parameters of selected spring wheat cultivars Napola, Jasna and Kosma, growing under water deficit condition. The following doses of N were applied: 0.6, 1.2, 2.4 g/pot. Plants were harvested at full ripeness. Water deficiency in soil decreased the grain yield of all cultivars in comparison with the controls (given optimum water condition). In the water deficit conditions in the subsoil the best yielding cultivar was Kosma, independent of nitrogen fertilization. All wheat cultivars reacted favourably to the increase of N rate. The grain yield, protein and gluten content increased together with the increase in N rate applied to the soil. Water deficit favourably affected grain quality parameters of the examined cultivars in comparison to objects with a higher moisture level.

Singh and Subhash (2006) conducted a field experiment in India, to determine the effects of soil water availability and nitrogen use efficiency on wheat crop production. The soil of the study site was sandy loam. The treatments were comprised of: three moisture regimes in main plot (rainfed, presowing irrigation and irrigation at crown root initiation (CRI) stage); and four nitrogen levels (0, 10, 20 and 40 kg N/ha) as top dressing in subplots. A basal dose of 40:20:0 (N:P2O5:K2O) was applied to all treatments. Results showed that wheat yield significantly increased due to irrigation either as pre-sowing (mean 35.30 q/ha) or at CRI stage (mean 36.03 q/ha). The grain yield progressively increased with top dressing up to 40 kg N/ha (38.60 q/ha) but the response to per kg N decreased with the increase in N dose. The rainfall received during winter months ensured adequate soil water for efficient utilization of nitrogen. The irrigation treatments recorded more seasonal water use and expense than that of rainfed control. The water use efficiency was highest with rainfed and lowest with pre-sowing irrigation treatment. No significant difference was observed in water expense efficiency between irrigation treatments, but both were superior to rainfed treatment. Similarly, the apparent water use efficiency did not show significant difference among the moisture regimes.

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 favourable 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 superphosphate/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; 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 in Pakistan to study the effects of irrigation stress (at crown root, booting, or anthesis stage, or at all the aforementioned growth stages) and N rate (100 and 150 kg/ha) on the yield and yield components of wheat cv. Pb-96. Irrigation at the crown root, booting, and anthesis stage gave the highest number of productive tillers (330.33/m2), 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), 1000-grain weight (36.57 g), grain yield (4.19 t/ha), and harvest index (34.54%).

Two *Triticum aestivum* cultivars (PBW 222 and HD 2329) and one T. durum cultivar (PDW 215), sown on 12, 17 were treated with 3 irrigation (40, 50 and 60% depletion of available soil moisture (ASM) at 0-15 cm depth) and 4 N rates (120, 150, 180 and 210 kg/ha) in a field experiment conducted in India (Narang *et al*., 2007). *T. aestivum* cultivars recorded higher yield compared to PDW 215 at all irrigation levels. The yield of all cultivars tested decreased with increasing levels of irrigation. All cultivars recorded a yield increase with 150 and 180 kg N/ha application, with PBW 222 recording the highest yield of 6.4 t/ha at both N rates. A positive interaction between genotypes and moisture regimes was observed. Water use and water use efficiency were highest with 40 and 60% depletion of ASM, respectively.

Sawires (2008) studied in field trials in Egypt, wheat cv. Giza 162, plants were given 40, 65 or 100 kg N/feddan [1 feddan = 0.42 ha], and were subjected to water stress at tillering, heading, the milk-ripe or the dough-ripe stage. Yield and yield component values increased with increasing N rate. Yield was reduced by water stress, with the effect being greatest at the earliest stage of development, and decreasing over the growing season.

Guler and Akbay (2007) conducted a field studies in Turky 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 (S0), 20 mm (S1) and 40 mm (S2) irrigation applications and also 4 kg/da (N1), 6 kg/da (N2) and 8 kg/da (N3) 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 N3 (8 kg/da N) and S2 (40 mm) irrigation applications.

A field experiment was conducted by Karczmarczyk *et al.* (2004) carried out on good rye complex soils during 1984-89 with three N-levels (0, 90 and 150 kg N ha^{-1}) and without sprinkler irrigation. They observed that irrigation and increasing N rate increased the total dry matter of wheat CV. Emika at heading, flowering and milk-ripe stage.

Misra *et al*. (2004) conducted a field experiment during rabi (winter) season of 1986-87 and 1987-88 at Ambikapur, Madhaya Pradesh and reported that LAI increased significantly with increasing levels of nitrogen from 0 to 90 kg ha^{-1} and irrigation at 5 growth stages or at an IW:CPE (irrigatin water : cumulative pan evaporation) ratio of 1.0.

Srivastava (2000) conducted an experiment on wheat irrigated at 30 or 60% available soil moisture and nitrogen was applied at the rate 100 kg N ha^{-1}in equal two split-half at sowing and half at crown root initiation stage (CRI) and joining stage. He found that when the crop was irrigated at 60% available soil moisture with splitting of nitrogen at sowing and crown root initiation stage gave the highest yield of grain.

Agarwal and Yadav (2000) investigated the effect of irrigation and split application of nitrogen on the yield of wheat. They reported that crown root initiation (CRI) was the most critical stage among all six stages with respect to irrigation. A reduction in 27% grain yield was found by missing irrigation at CRI stage was 60% when irrigation was missed at both CRI and late tillering stages. In this experiment, significant effects between irrigation and nitrogen were noticed in that application of 120 kg N ha^{-1} in combination with irrigation produced significantly higher grain and straw yields compared to control treatment.

Shafei and Barwish (2003) conducted a field trial on wheat providing different rates of nitrogen (0, 50, 75, 100 or 125 kg ha^{-1}) applied in split at 30 and 70 days after seeding and irrigated by improved methods. They observed highest grain yield with increasing nitrogen rate in combination with two irrigation.

Koshta and Raghu (2002) carried out an experiment with three irrigation treatment (two, four and six irrigation), two nitrogen rates (90 and 120 kg N ha^{-1}) and two splits (two thirds nitrogen as basal + one third at CRI, and one third nitrogen as basal + two thirds nitrogen equally spread over irrigation). Six irrigation with 120 kg N ha^{-1}in two splits two thirds as basal and one third at CRI stage gave significantly higher yield than any of other treatments.

In another experiment Koshta *et al.* (2003) reported that grain and straw yields were highest when 120 kg N ha-1 was applied in two splits, half at sowing and the rest half at crown root initiation stage with six irrigation levels. On the other hand, Gungor and Balci (2002) stated that maximum irrigation (including irrigation at flowering) coupled with 140 kg N ha^{-1} given at sowing and at the booting stage gave 5.58 t ha^{-1} grain yield against the non-irrigated condition which yield 3.95 t ha^{-1}.

Dawood and Kheiralla (2004) investigated the effect of application of 110, 165, 215 and 260 kg N ha^{-1} and reported that split application of nitrogen at the first and second irrigation with supplying irrigation at 2-6 different growth stages increased grain yield . They also mentioned that increased grain yield was influenced by the irrigation frequency and nitrogen rate.

The combined effect of irrigation and application of nitrogen in splits were also studied by Munyindra *et al.* (2003) on wheat maintaining soil moisture above 70% of field capacity and giving 0, 60, 120, or 180 Kg N ha^{-1}.Nitrogen was applied during the renewal of growth in spring in and one-node stage or by foliar application at one-node stage or during heading stage. The grain yield increased from 3.87 to 4.09 t ha^{-1}in irrigation condition with the nitrogen rate of 120 kg ha^{-1}.

In an experiment Chaudhury and Bhatnagar (2000) found increased grain yield snd nitrogen uptake by applying 150 kg N ha^{-1} in three splits with 5.5 cm of irrigation water.

An observation was made by Patra (2003) with wheat given two irrigations and different doses and methods of fertilizer application. The increased grain yield was reported due to the increased number of productive tillers per plant, ear weight, grains/ear and 1000-grain weight.

Drewitt (2000) conducted an experiment on wheat to study the response to irrigation and nitrogen. They observed that 50 kg N ha^{-1} when applied at tillering or at shoot emergence under irrigated condition increased grain yield.

Adjetey *et al*. (2004) conducted a field experiment at the University of Sydney Farm in Australia, under dry land and supplementary irrigation. They observed that increasing N rate increased shoot dry matter and N uptake consistently but grain yield response was greatly depended on soil moisture or rainfall in the post-heading period. Water availability at this time determined kernel weight and hence grains yield, even when sufficient grain number had been established. Split application of N increased N uptake most, when the second dose was applied at tillering. On the other hand, delayed applications to the time of heading or anthesis resulted in a relatively lower uptake od N even with supplementary irrigation. The effect of a single pre-sowing application was similar to that applied at sowing or early tillering.

Maqsood *et al*. (2002) observed that the effects of irrigation stress (at crown root, booting, or anthesis, or at all the aforementioned growth stages) and N rates (100 and 150 kg ha^{-1}) on the yield and yield components of wheat cv. Pb-

96 in 1996-2000. Irrigation at crown root, booting and anthesis stage gave the highest number of productive tillers (330.33/m^2), number of grains spike^{-1} (45.58), 1000-grain weight (39.69g), grain yields (5.69 t ha^{-1}) and harvest index (36.53%). The application of N also increased yield and yield components of wheat, with 150 kg N ha^{-1} giving the highest number of productive tillers (321.73/m^2), number of grains spike (44.28), 1000-grain weight (36.57g), grain yield (4.19 t ha^{-1}), and harvest index (34.55).

Saren and Jana (2001) conducted a field experiment in Kalyani, West Bengal, India, in 1992-93 and 1993-94 to study the effects of irrigation depth (4.5, 6.0, 9.0 and 12.0 cm), N rate (50 and 100 kg ha^{-1}), and N application date (50% N before or after irrigation) on the yield , yield components, and nutrient uptake of wheat cv. UP262. They observed that irrigation depth of 6.0 cm and the application of 100 kg N ha^{-1} as top dressing after irrigation gave the greatest plant height, number of effective tillers and grains, grain and straw yields, and N, P, and K uptake by grain and straw.

From the brief review of literature as presented above it seems that application of irrigation water at proper time and application of nitrogen in different splits appear to be better for its maximum and efficient utilization towards higher grain yield. Research work on this perspective thus warrant due attention under Bangladesh condition.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2007 to March 2008. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the Rabi season of 2007. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and

Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.4 Treatments

The following treatments were included in this experiment.

a. Irrigation: 3
b. Split application of nitrogen:4

The following treatments were included in this experiment.

a. Irrigation:

- No irrigation application, coded as I_0
- One irrigation given at crown root initiation stage (18 DAS), coded as I_1
- Two irrigations, one at crown root initiation stage (18 DAS) and other at panicle initiation stage (55 DAS), coded as I_2.

b. Split application of nitrogen: 3

Only one rate of nitrogenous fertilizer viz. urea (175 Kg ha^{-1}) was applied in the experiment with the following split arrangements

- No nitrogen application, coded as N_0
- One at basal at the time of sowing (175 Kg of urea ha^{-1}), coded as N_1
- Two equal split- One at basal at the time of sowing (87.5 Kg of urea ha^{-1}) and the other at 30 DAS (87.5 Kg of urea ha^{-1}), coded as N_2
- Three equal split- One at basal at the time of sowing (58.33 Kg of urea ha^{-1}) and the other at 30 DAS (58.33 Kg of urea ha^{-1}) and 60 DAS (58.33 Kg of urea ha^{-1}), coded as N_3.

There were 12 treatment combination of irrigation and split application of nitrogen applied in the experiment (2 irrigations and 3 split of nitrogen) as follows:

1. No irrigation + no nitrogen application, coded as I_0N_0
2. No irrigation + one basal application of nitrogen at the time of sowing, coded as I_0N_1
3. No irrigation + two equal split- One at basal and another at 30 DAS, coded as I_0N_2
4. No irrigation + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as I_0N_3
5. One irrigation given at crown root initiation stage + no nitrogen application, coded as I_1N_0
6. One irrigation given at crown root initiation stage + one basal application of nitrogen at the time of sowing, coded as I_1N_1
7. One irrigation given at crown root initiation stage + two equal split- One at basal and another at 30 DAS, coded as I_1N_2
8. One irrigation given at crown root initiation stage + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as I_1N_3
9. Two irrigations, one at crown root initiation stage and another at panicle initiation stage + no nitrogen application, coded as I_2N_0
10. Two irrigations, one at crown root initiation stage and another at panicle initiation stage + one basal application of nitrogen at the time of sowing, coded as I_2N_1
11. Two irrigations, one at crown root initiation stage and another at panicle initiation stage + two equal split- One at basal and another at 30 DAS, coded as I_2N_2
12. Two irrigations, one at crown root initiation stage and another at panicle initiation stage + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as I_2N_3

3.5 Seed collection

Seeds of BARI Gam 23 (Bijoy) were collected from BARI, Joydebpur, Gazipur, Bangladesh. It is a high yielding Variety and suits better as a late variety. It was released in 2005. Bijoy is a semi-dwarf erect and non-lodging type of cultivar of wheat. Plant height range is 95-105cm producing 4-5 tillers plant^{-1}. Seeds spike^{-1} is 35-40 containing seed colour white. Bijoy matures within 103-112 days and yield varies between 4300-5000 Kg ha^{-1}. The cultivar is claimed to be resistant to leaf rust and leaf spot (BARI 2005).

3.6 Collection and preparation of initial soil sample

The initial soil samples from the main field were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis. The physico-chemical properties of the soil are shown in Appendix III.

3.7 Preparation of experimental land

The land was first ploughed on 15 November, 2007 by disc plough. The land was then harrowed again on 26 and 28 November to bring the soil in a good tilth condition. The final land preparation was done by disc harrow on 30 November, 2007. The land was prepared thoroughly and leveled by a ladder. Weeds and stubbles were removed from the field. The experiment was laid out on 6 December, 2007 according to the design adopted.

3.8 Fertilizer dose and methods of application

At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental area was fertilized with 175, 175, 110, 110 and 7 kg ha^{-1} urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and Boric acid respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and Boric acid were applied at final land preparation as a basal dose. Urea was applied as per treatment no nitrogen, one each at basal at the time of sowing (175 kg urea ha^{-1}), two equal splits, one each at basal at the time of sowing (87.5 kg of urea ha^{-1}) and other at 30 DAS (87.5 kg of urea ha^{-1}), three equal split one each at basal at the time of sowing (58.33 kg of urea ha^{-1}) , other at 30 DAS (58.33 kg of urea ha^{-1}) and 60 DAS (58.33 kg of urea ha^{-1}).

3.9 Experimental design

The experiment was laid in a split-plot design with three replications. Each replication was first divided into three main plots on which the irrigation treatments were assigned. Each of the main plots was then subdivided into four unit plots to accommodate the split application of nitrogen. Thus the total number of unit plots was 3×4×3=36. The size of the unit plot was 3m × 2.3m. The distance maintained between two unit plots was 0.5m and that between blocks was 1m. The treatments were randomly assigned to the plots within each replication.

3.10 Sowing of seeds

Seeds were sown on 6th December, 2007 by hand. Seeds were sown in line and then covered properly with soil. The line to line distance for wheat was 20 cm and plant to plant distance was 4 - 5 cm.

3.11 Intercultural operations

3.11.1 Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after transplantation followed by second weeding at 15 days after first weeding. The weeds identified were kakpaya ghash (*Dactyloctenium aegyptium* L.), Shama (*Echinocloa crussgalli*), Durba (*Cynodon dactylon*), Arail (*Leersia bexandra*), Mutha (*Cyperus rotundus* L.) Bathua (*Chenopodium album*) Shaknatey (*Amaranthus viridis*), Foska begun

(*Physalis beterophylls*), Titabegun (*Solanum torvum*), and Shetlomi (*Gnaphalium luteolabum* L.)

3.11.2 Plant protection measures

The wheat crop was infested by Aphid and rodent. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied in some times because wheat field was highly infested by rodent.

3.11.3 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.11.4 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. Ten plants per plot were preselected randomly from which different growth and yield attributes data were collected and 1 m^2 areas from middle portion of each plot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly.

3.12 Recording of data

Experimental data were recorded from 45 days of sowing and continued up to harvest. The following data were recorded during the experimentation.

3.12.1. Crop growth characters

i. Plant height (cm)

ii. Number of tillers $plant^{-1}$

iii. Leaf area index (LAI)

iv. Total fresh weight $plant^{-1}$

v. Total dry matter

3.12.2. Yield and yield components

i. Length of spike (cm)

ii. Number of spikelets spike^{-1}

iii. Number of grains spike^{-1}

iv. Weight of 1000 grains (g)

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

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

vii. Harvest index (%)

3.13 Detailed procedures of recording data

A brief outline of the data recording procedure is given below:

3.13.1 Crop growth characters

3.13.1.1 Plant height

Plant height was measured at 15 days interval starting from 45 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

3.13.1.2 Number of tillers plant^{-1}

Number of tillers plant^{-1} were counted at 15 days interval starting from 45 DAS and up to harvest and finally averaged as their number plant^{-1}.

3.13.1.3 Leaf area index (LAI)

Leaf area index was estimated measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981).

3.13.1.4 Fresh weight plant^{-1}

Five plants at different days after sowing (45, 60, 75 DAS and at harvest) were collected and cleaned by removing soils and other waste materials and oven drying for 24 hours then weighed and averaged.

3.13.1.5 Dry weight of plant

Five plants at different days after sowing (45, 60, 75 DAS and at harvest) were collected and dried at 70° C for 24 hours. The dried samples were then weighed and averaged.

3.13.2 Yield and yield contributing characters

3.13.2.1 Spike length

Spike length were counted from five plants from basal node of the rachis to apex of each spike and then averaged. This was taken at different days after sowing (DAS) separately.

3.13.2.2 Number of spikelets spike^{-1}

Number of spikelets were counted from 5 spikes and averaged to determine the number spikelets spike^{-1}.

3.13.2.3 Number of grains spike^{-1}

The number of grains spike^{-1} was counted from 10 spike and number of grains spike^{-1} was measured by the following formula

$$\text{Number of grains spike}^{-1} = \frac{\text{Total number of grains}}{\text{Number of spike}}$$

3.13.2.4 Weight of 1000 grains

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

3.13.2.5 Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.13.2.6 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.13.2.7 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula.

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

3.14 Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT computer package program developed. Least Significant Difference (LSD) technique at 5% level of significance was used by DMRT to compare the mean differences among the treatments (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

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

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of irrigation

Plant height was significantly influenced by the number of irrigations (Appendix IV and Fig.1). It was observed that that plant height increased with more irrigation compared with less irrigation or no irrigation. At 45, 60, 75 DAS and at harvest, the tallest plant (54.36, 76.51, 84.79 and 93.02 cm respectively) was obtained with two irrigations. On the other hand the lowest plant height (51.61, 71.75, 79.17 and 86.66 cm at 45, 60, 75 DAS and at harvest respectively) was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This findings was supported by Mushtaq and Muhammad (2005) who obtained increased plant height with increased irrigation treatments.

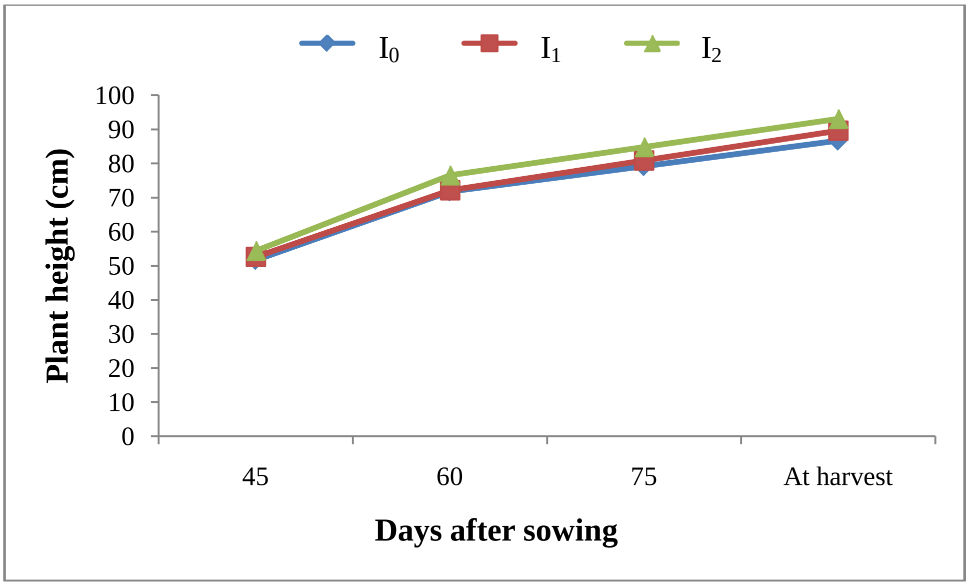

Fig. 1. Plant height at different growth stages with different time of irrigation

Here,

I_0 = No irrigation application I_1 = One irrigation I_2 = Two irrigations

4.1.1.2 Effect of nitrogen

Significant variation was observed in case of plant height with split application of nitrogen (Appendix IV and Fig. 2). It was observed that at 45, 60, 75 DAS and at harvest, the tallest plants were obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which were 55.88, 77.28, 84.89 and 92.55 cm respectively. On the other hand the shortest plant at 45, 60, 75 DAS and at harvest were obtained with no nitrogen application which were 50.01cm, 69.79cm, 78.31cm and 86.83 cm respectively. It was also observed that one and two split application of nitrogen showed intermediate results compared to with all other treatments. This findings was supported by Chaturvedi, (2006) who obtained increased plant height with increased nitrogen application.

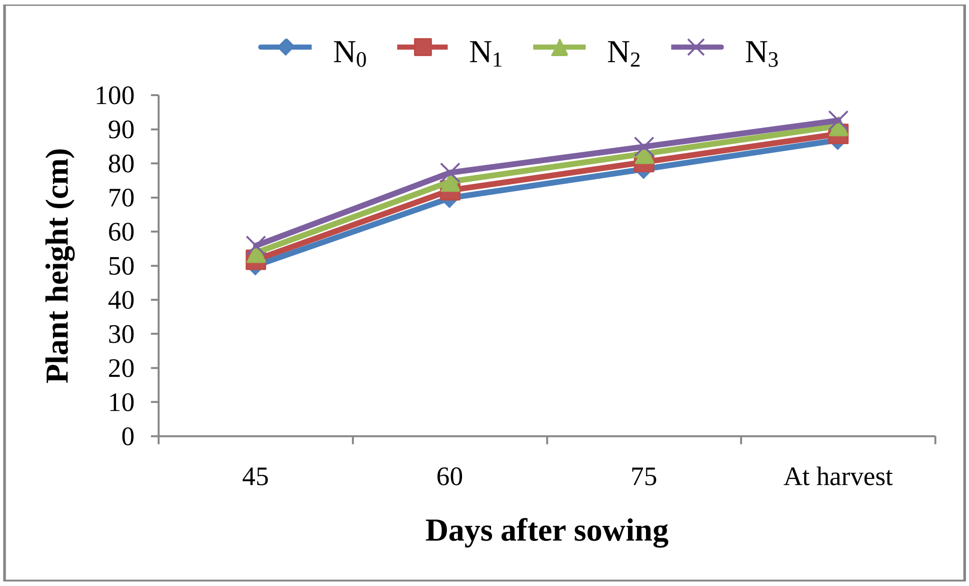

Fig. 2. Plant height at different growth stages with different split application of nitrogen

Here,

N_0	=	No nitrogen application	N_1	=	At basal application (175 Kg of urea ha^{-1})
N_2	=	Two equal split application of N_2	N_3	=	Three equal split application of N_2

4.1.1.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen were significant for the plant height at 45, 60 and 75 DAS and at harvest (Appendix IV and Table 1). It was observed that the tallest plant at 45, 60, 75 DAS and at harvest was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which were 57.26cm, 81.07cm, 88.76cm and 96.37cm respectively. On the other hand significantly the shortest plant (49.57, 69.03, 76.60 and 84.17 cm) were obtained from no irrigation with no nitrogen application (I_0N_0) at 45, 60 and 75 DAS respectively. At 45 DAS the tallest plant (57.26cm) obtained from I_2N_3 was statistically similar with 55.85cm and 55.97cm obtained respectively from I_2N_2 and I_1N_3 and 60DAS the tallest plant 81.07 was statistically similar with 77.91cm obtained from I_2N_2 when at 75DAS and at harvest I_2N_3 was statistically different from all other interactions. The results obtained from all other treatments were significantly different compared to the highest and lowest plant height. This finding was supported by Jarwar *et al*., (2005) and Saren and Jana (2008) who obtained the similar result with the interaction effect of irrigation and nitrogen application in the same plot.

Table 1. Plant height at different growth stages with different time of irrigation and different split application of nitrogen

Treatments	**Plant height (cm)**			
	45 DAS	**60 DAS**	**75 DAS**	**At harvest**
Interaction				
$\mathbf{I_0N_0}$	49.57 g	69.03 f	76.60 j	84.17 k
$\mathbf{I_0N_1}$	50.60 fg	70.79 d-f	78.39 hi	85.99 j
$\mathbf{I_0N_2}$	51.85 ef	72.43 c-f	79.97 fg	87.52 hi
$\mathbf{I_0N_3}$	54.42 b-d	74.75 b-d	81.73 de	88.97 fg
$\mathbf{I_1N_0}$	49.50 g	68.97 f	77.79 ij	86.61 ij
$\mathbf{I_1N_1}$	51.21 fg	69.96 ef	79.19 gh	88.43 gh
$\mathbf{I_1N_2}$	53.73 c-e	73.60 c-e	82.24 d	90.87 de
$\mathbf{I_1N_3}$	55.97 ab	76.03 bc	84.17 c	92.31 c
$\mathbf{I_2N_0}$	50.95 fg	71.36 d-f	80.53 ef	89.70 ef
$\mathbf{I_2N_1}$	53.39 de	75.69 bc	83.63 c	91.57 cd
$\mathbf{I_2N_2}$	55.85 a-c	77.91 ab	86.22 b	94.43 b
$\mathbf{I_2N_3}$	57.26 a	81.07 a	88.76 a	96.37 a
$\mathbf{LSD_{0.05}}$	2.027	3.668	1.229	1.208
CV (%)	7.24	5.91	8.88	7.78

Here,

I_0 = No irrigation application
I_1 = One irrigation
I_2 = Two irrigations

N_0 = No nitrogen application
N_1 = At basal application (175 Kg of urea ha^{-1})
N_2 = Two equal split application of N_2
N_3 = Three equal split application of N_2

4.1.2 Number of tillers plant^{-1}

4.1.2.1 Effect of irrigation

Number of tillers plant^{-1} was significantly influenced by different irrigation treatments at all stages (Appendix V and Fig. 3). It was observed that the highest number of tillers plant^{-1} at 45, 60, 75 DAS and at harvest (2.39, 2.56, 4.47 and 4.05 respectively) was obtained with two irrigations. On the other hand the lowest number of tillers plant^{-1} such as 1.22, 1.38, 2.62 and 2.22 at 45, 60, 75 DAS and at harvest respectively was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. The results of the present study is in agreement with Sher and Parvender (2006) who observed that number of tillers plant^{-1} increased by increased levels of irrigation.

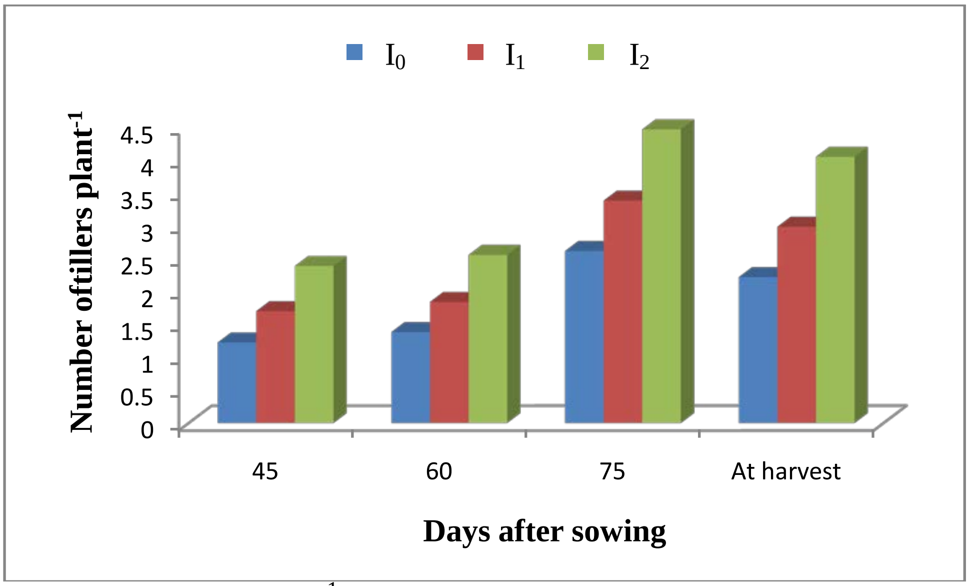

Fig. 3. Number of tillers plant^{-1} at different growth stages with different time of irrigation

Here,

I_0 = No irrigation application I_1 = One irrigation I_2 = Two irrigations

4.1.2.2 Effect of nitrogen

Significant variation was observed in case of number of tillers plant^{-1} with split application of nitrogen (Appendix V Fig. 4). It was observed that at 45, 60, 75 DAS and at harvest, the highest number of tillers plant^{-1} were obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which were 2.30, 2.53, 4.10 and 3.70 cm respectively. On the other hand the lowest number of tillers plant^{-1} at 45, 60, 75 DAS and at harvest were obtained with no nitrogen application which were 1.24, 1.21, 2.86 and 2.43 respectively. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. Results indicate that nitrogen application encouraged tiller production and for this reason number of tillers plant^{-1} increased with the split application of nitrogen fertilization. The results of the present study is in agreement with Hakoomat *et al*., (2005) who observed that higher number of tillers plant^{-1} obtained by increased split application of nitrogen.

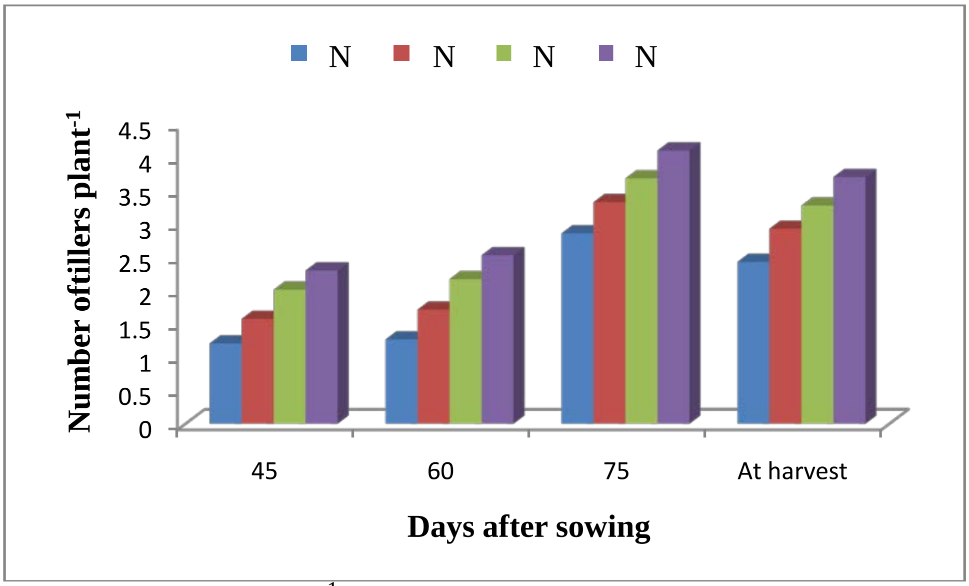

Fig. 4. Number of tillers plant^{-1} at different growth stages with different split application of nitrogen

Here,

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.1.2.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen were significant for the number of tillers plant^{-1} at 45, 60 and 75 DAS and at harvest (Appendix V and Table 2). It was observed that the highest number of tillers plant^{-1} at 45, 60, 75 DAS and at harvest (2.96, 3.13, 4.90 and 4.50cm respectively) were obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was not significantly different from I_2N_2 at 45, 60 and at 75 DAS. On the other hand the lowest number of tillers plant^{-1} (0.83, 0.87, 1.93 and 1.53) were obtained from no irrigation with no nitrogen application (I_0N_0) at 45, 60 and 75 DAS respectively which was not significantly different from I_0N_1 at 75 DAS. The results obtained from all other treatments were significantly different compared to the highest and lowest number of tillers plant^{-1}. The findings of the study are in accord with the findings of Nahar and Paul (1998) and Maqsood *et al*. (2007).

Table 2. Number of tillers $plant^{-1}$ at different growth stages with different time of irrigation and different split application of nitrogen

Treatments	**Number of tillers $plant^{-1}$**			
	45 DAS	**60 DAS**	**75 DAS**	**At harvest**
Interaction				
I_0N_0	0.83 h	0.87 i	1.93 g	1.53 h
I_0N_1	1.13 g	1.17 h	2.23 g	1.83 g
I_0N_2	1.30 fg	1.47 g	2.87 f	2.47 f
I_0N_3	1.60 de	2.00 de	3.43 e	3.03 e
I_1N_0	1.07 g	1.10 hi	2.73 f	2.33 f
I_1N_1	1.43 ef	1.60 fg	3.30 e	2.90 e
I_1N_2	1.97 c	2.13 cd	3.57 de	3.17 de
I_1N_3	2.33 b	2.47 b	3.97 c	3.57 c
I_2N_0	1.70 d	1.81 ef	3.90 cd	3.43 cd
I_2N_1	2.13 bc	2.37 bc	4.47 b	4.07 b
I_2N_2	2.77 a	2.91 a	4.60 ab	4.20 b
I_2N_3	2.96 a	3.13 a	4.90 a	4.50 a
$LSD_{0.05}$	0.237	0.249	0.360	0.297
CV (%)	11.14	8.22	6.93	8.69

Here,

I_0 = No irrigation application

I_1 = One irrigation

I_2 = Two irrigations

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.1.3 Leaf area index

4.1.3.1 Effect of irrigation

Irrigation treatment had significant effect on leaf area index (LAI) at all dates of sampling (Appendix VI and Fig. 5). The highest leaf area index at 45, 60, 75 DAS and at harvest were obtained with two irrigations given at CRI (18 DAS) and panicle initiation (55 DAS) stages which were 1.51, 2.13, 3.12 and 2.52 respectively. It was observed that LAI increased up to 75 DAS and then decreased till maturity at all irrigation treatments. The lowest LAI at the same period were observed with no irrigation which were 1.30, 1.83, 2.50 and 2.03 respectively. This result is in accord with that of Abdorrahmani *et al*. (2005).

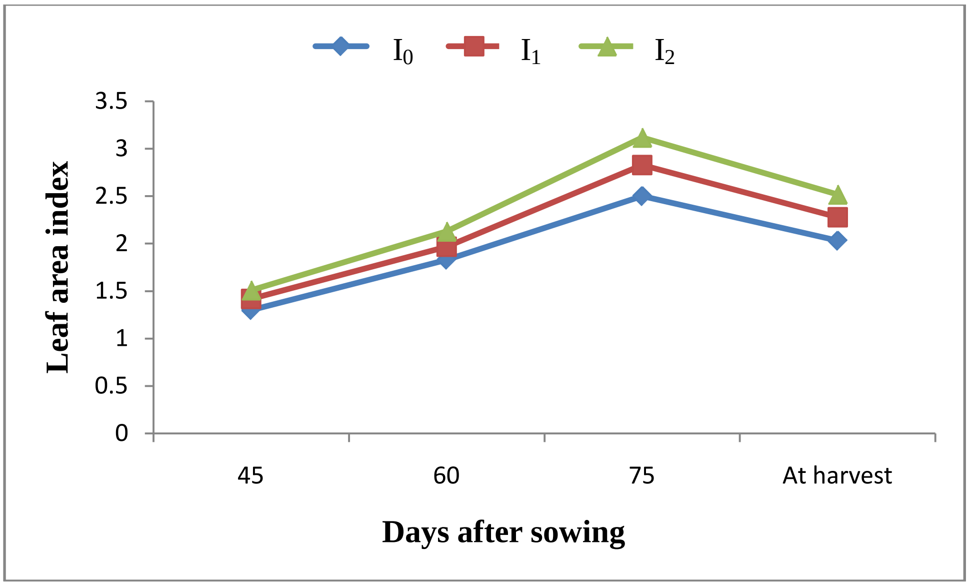

Fig. 5. Leaf area index at different growth stages with different time of irrigation

Here,

I_0 = No irrigation application I_1 = One irrigation I_2 = Two irrigations

4.1.3.2 Effect of nitrogen

Split application of nitrogen had also significant effect on leaf area index at 45, 60, 75 DAS and at harvest (Appendix VI and Fig. 6). The highest leaf area index (1.50, 2.09, 3.04 and 2.43 respectively) were recorded at 45, 50, 75 DAS and at harvest with nitrogen applied in three splits one each at basal, 30 DAS and 60 DAS which was significantly similar at 45, 60 DAS and at harvest with nitrogen applied in two splits one each at 10 DAS and 40 DAS. The lowest value of LAI (1.33, 1.86, 2.55 and 2.07 respectively) at 45, 60, 75 DAS and at harvest were obtained with no nitrogen application. LAI values observed from the present study increased progressively up to 75 DAS and then declined till maturity. This result is in accord with that of Janusauskaite, 2007.

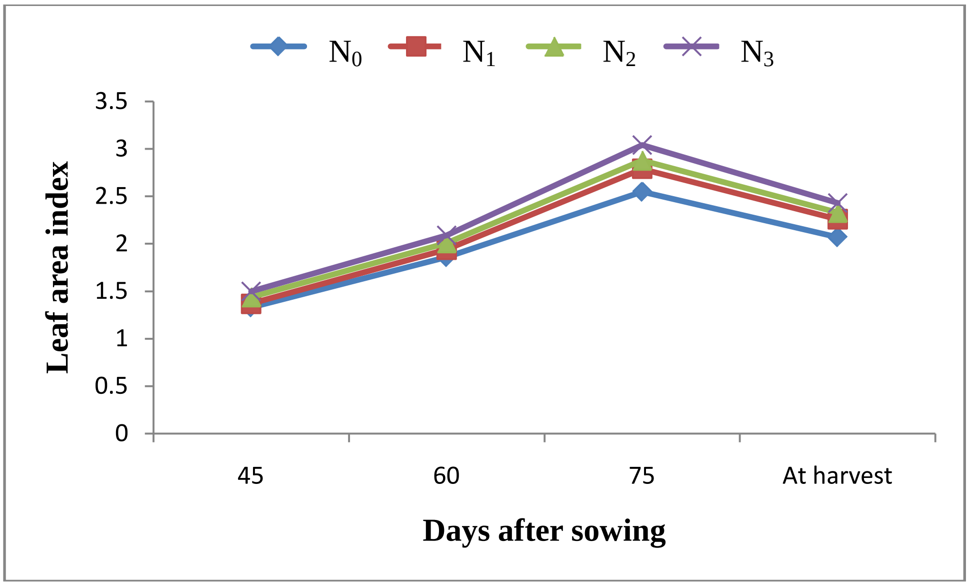

Fig. 6. Leaf area index at different growth stages with different split application of nitrogen

Here,

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.1.3.3 Interaction effect of irrigation and nitrogen

Leaf area index (LAI) differed significantly due to interaction by time of irrigation and split application of nitrogen at 45, 60, 75 DAS and at harvest (Appendix VI and Table 3). Significantly the highest LAI (1.67, 2.32, 3.44 and and 2.71 respectively) were observed at 45, 60, 75 DAS and at harvest in two irrigations coupled with three splits of nitrogen (I_2N_3) which was significantly similar with I_2N_2 at 45, 60, 75 DAS and at harvest. On the other hand, significantly the lowest LAI (1.24, 1.73, 2.37 and 1.92 respectively) were obtained at 45, 60, 75 DAS and at harvest through no irrigation with no nitrogen application (I_0N_0) which was statistically similar with I_0N_1 at 45, 60, 75 DAS and at harvest. The findings of the LAI had similar to that of Misra *et al*. (2004) and Kibe *et al*. (2006).

Table 3. Leaf area index at different growth stages with different time of irrigation and different split application of nitrogen

Treatments	Leaf area index			
	45 DAS	60 DAS	75 DAS	At harvest
Interaction				
I_0N_0	1.24 d	1.73 d	2.37 g	1.92 g
I_0N_1	1.27 cd	1.79 cd	2.45 fg	1.99 fg
I_0N_2	1.33 b-d	1.85 c	2.51 f	2.05 e-g
I_0N_3	1.37 b-d	1.93 b-d	2.65 ef	2.16 d-f
I_1N_0	1.35 b-d	1.89 cd	2.60 e-g	2.11 d-g
I_1N_1	1.41 b-d	1.97 b-d	2.78 de	2.26 c-e
I_1N_2	1.46 bc	2.00 b-d	2.91 cd	2.31 cd
I_1N_3	1.47 bc	2.02 bc	3.03 bc	2.43 bc
I_2N_0	1.39 b-d	1.95 b-d	2.68 d-f	2.19 d-f
I_2N_1	1.44 b-d	2.06 bc	3.14 bc	2.54 b
I_2N_2	1.53 ab	2.18 ab	3.23 ab	2.63 ab
I_2N_3	1.67 a	2.32 a	3.44 a	2.71 a
$LSD_{0.05}$	0.188	0.243	0.231	0.217
CV (%)	7.40	8.73	7.14	5.06

Here,

I_0 = No irrigation application
I_1 = One irrigation
I_2 = Two irrigations

N_0 = No nitrogen application
N_1 = At basal application (175 Kg of urea ha^{-1})
N_2 = Two equal split application of N_2
N_3 = Three equal split application of N_2

4.1.4 Fresh weight plant^{-1}

4.1.4.1 Effect of irrigation

Fresh weight plant^{-1} was significantly influenced by different irrigation treatments at all stages (Appendix VII and Fig. 7). It was observed that the highest fresh weight plant^{-1} at 45, 60, 75 DAS and at harvest (64.45 g, 68.98 g, 136.40 g and 59.60 g respectively) was obtained with two irrigations. On the other hand the lowest fresh weight plant^{-1} (26.54 g, 39.61 g, 93.28 g and 44.69 g) at 45, 60, 75 DAS and at harvest respectively was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. The result is in conformity with that of Sher and Parvender (2006).

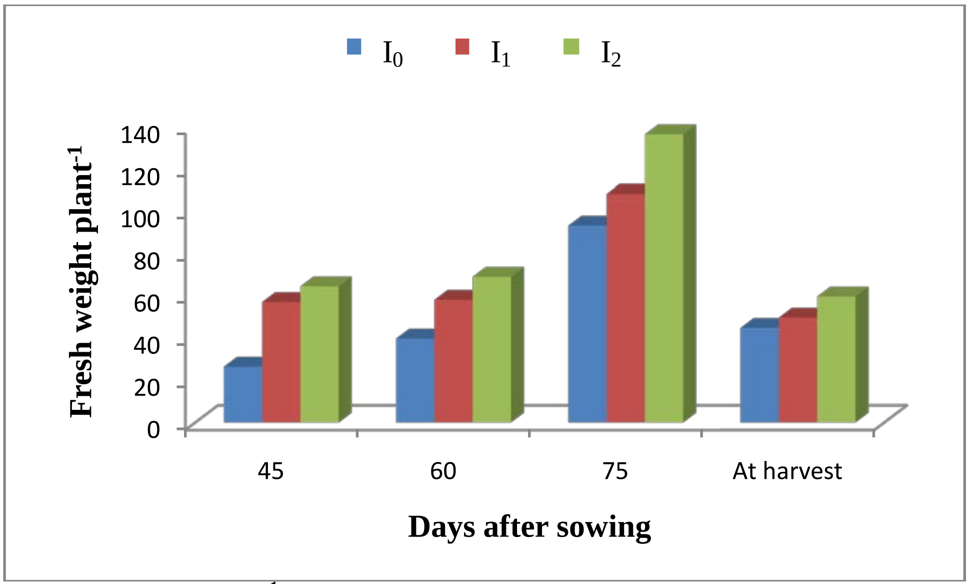

Fig. 7**.** Fresh weight plant^{-1} at different growth stages with different time of irrigation

Here,

I_0 = No irrigation application I_1 = One irrigation I_2 = Two irrigations

4.1.4.2 Effect of nitrogen

Significant variation was observed in case of fresh weight plant^{-1} with split application of nitrogen (Appendix VII Fig. 8). It was observed that at 45, 60, 75 DAS and at harvest, the highest fresh weight plant^{-1} were obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which were 66.25 g, 72.90 g, 140.20 g and 60.93 g respectively. On the other hand the lowest fresh weight plant^{-1} at 45, 60, 75 DAS and at harvest were obtained with no nitrogen application which were 30.20 g, 37.21 g, 87.93 g and 42.42 g respectively. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. The result is in conformity with that of Balyan (2000).

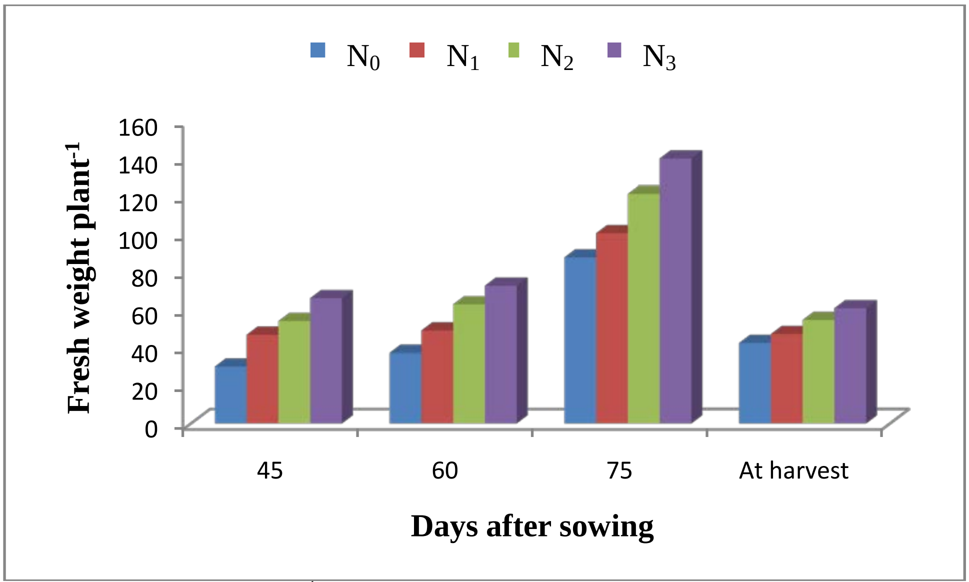

Fig. 8. Fresh weight plant^{-1} at different growth stages with different split application of nitrogen

Here,

N_0	=	No nitrogen application	N_1	=	At basal application (175 Kg of urea ha^{-1})
N_2	=	Two equal split application of N_2	N_3	=	Three equal split application of N_2

4.1.4.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen were significant for the fresh weight plant^{-1} at 45, 60 and 75 DAS and at harvest (Appendix VII and Table 4). It was observed that the highest fresh weight plant^{-1} at 45, 60, and 75 DAS and at harvest (85.73 g, 94.83 g, 157.20 g and 66.97 g respectively) was obtained with two irrigations and three split applications of nitrogen (I_2N_3). On the other hand the lowest fresh weight plant^{-1} (20.36 g, 28.70 g, 69.67 g and 36.06 g) were obtained from no irrigation with no nitrogen application (I_0N_0) at 45, 60, 75 DAS respectively which was not significantly different from I_0N_1 at 45, 60 DAS and at harvest but significantly similar at 75 DAS. The results obtained from all other treatments was significantly different compared to the highest and lowest fresh weight plant^{-1}.

Table 4. Fresh weight plant^{-1} at different growth stages with different time of irrigation and different split application of nitrogen

Treatments	Fresh weight plant^{-1}			
	45 DAS	60 DAS	75 DAS	At harvest
Interaction				
I_0N_0	20.36 g	28.70 g	69.67 h	36.06 h
I_0N_1	22.05 g	33.98 g	75.40 gh	38.73 h
I_0N_2	31.85 f	45.23 f	102.50 f	48.05 fg
I_0N_3	33.91 f	50.53 ef	125.60 d	55.94 cd
I_1N_0	22.74 g	34.35 g	82.23 g	40.23 h
I_1N_1	70.61 c	58.41 de	95.43 f	44.88 g
I_1N_2	55.53 d	65.93 cd	117.80 e	53.28 de
I_1N_3	79.11 b	73.34 bc	137.70 bc	59.88 bc
I_2N_0	47.50 e	48.59 ef	111.90 e	50.98 ef
I_2N_1	49.73 e	54.81 ef	131.60 cd	57.86 c
I_2N_2	74.84 bc	77.68 b	144.70 b	62.56 b
I_2N_3	85.73 a	94.83 a	157.20 a	66.97 a
$LSD_{0.05}$	4.855	10.40	7.280	4.219
CV (%)	6.20	10.92	9.98	6.44

Here,

I_0 = No irrigation application

I_1 = One irrigation

I_2 = Two irrigations

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.1.5 Dry weight plant^{-1}

4.1.5.1 Effect of irrigation

Dry weight plant^{-1} was significantly influenced by different irrigation treatments at all stages (Appendix VIII and Fig. 9). It was observed that the highest dry weight plant^{-1} at 45, 60, 75 DAS and at harvest (16.02 g, 17.10 g, 26.25 g and 32.23 g respectively) was obtained with two irrigations. On the other hand the lowest dry weight plant^{-1} (9.70 g, 11.04 g, 17.74 g and 23.73 g) at 45, 60, 75 DAS and at harvest respectively was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This finding was supported by the findings of Ashok and Sharma (2004) and Abdorrahmani *et al*. (2005).

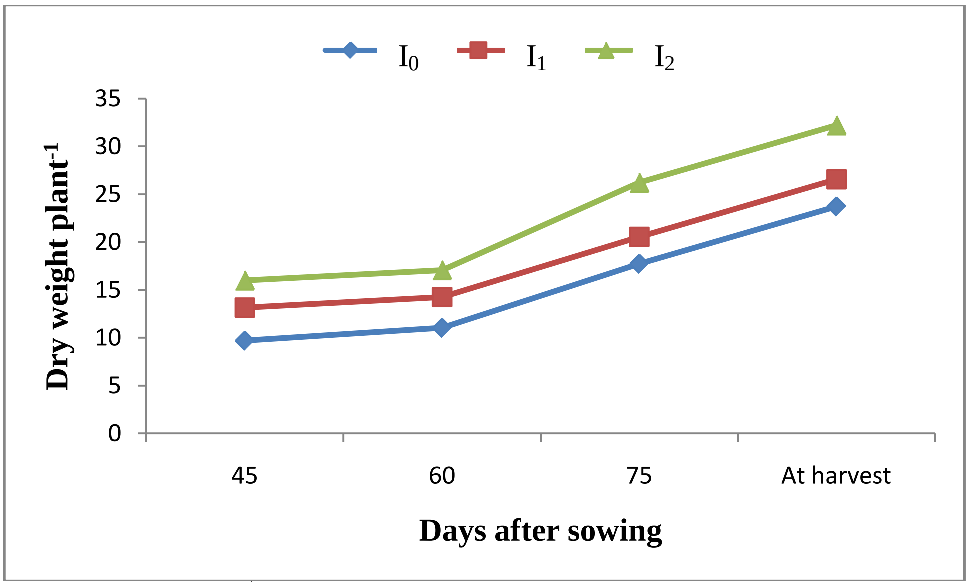

Fig. 9. Dry weight plant^{-1} at different growth stages with different time of irrigation

Here,

I_0 = No irrigation application I_1 = One irrigation I_2 = Two irrigations

4.1.5.2 Effect of nitrogen

Significant variation was observed in case of dry weight plant^{-1} with split application of nitrogen (Appendix VIII Fig. 10). It was observed that at 45, 60, 75 DAS and at harvest, the highest dry weight plant^{-1} were obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which were 16.19 g, 17.37 g, 27.02 g and 33.01 g respectively. On the other hand the lowest dry weight plant^{-1} at 45, 60, 75 DAS and at harvest were obtained with no nitrogen application which were 9.88 g, 10.88 g, 16.60 g and 22.59 g respectively. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. This was similar to that of Bellido *et al*. (2000) and Janusauskaite (2007).

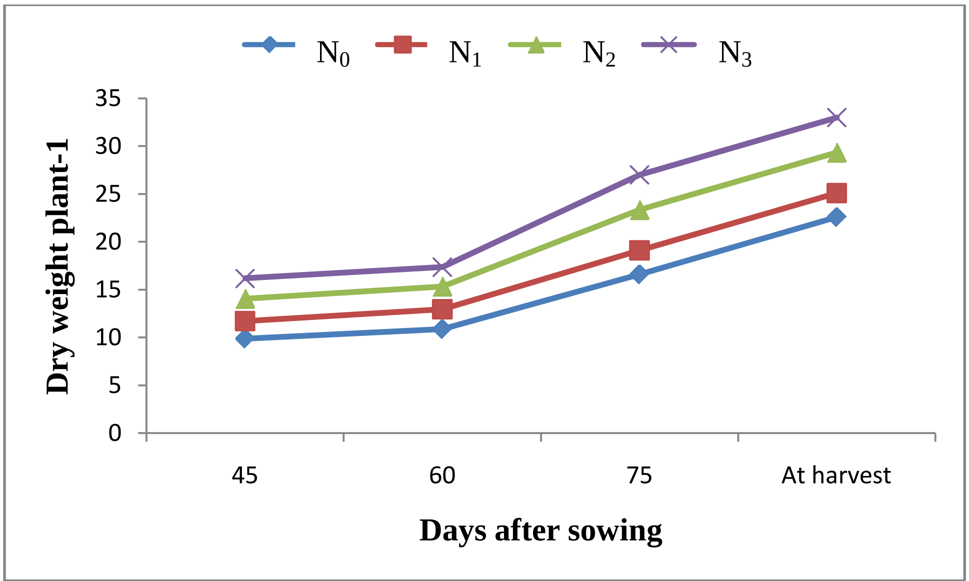

Fig. 10. Dry weight plant^{-1} at different growth stages with different split application of nitrogen

Here,

N_0	=	No nitrogen application	N_1	=	At basal application (175 Kg of urea ha^{-1})
N_2	=	Two equal split application of N_2	N_3	=	Three equal split application of N_2

4.1.5.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen were significant for the dry weight plant^{-1} at 45, 60 and 75 DAS and at harvest (Appendix VIII and Table 5). It was observed that the highest dry weight plant^{-1} at 45, 60, and 75 DAS and at harvest (19.23 g, 20.94 g, 30.58 g and 36.56 g respectively) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was significantly similar with I_2N_2 at 45 and 75 DAS. On the other hand the lowest dry weight plant^{-1} (7.53 g, 8.08 g, 13.05 g and 19.04 g) were obtained from no irrigation with no nitrogen application (I_0N_0) at 45, 60 and 75 DAS respectively which was not significantly different from I_0N_1 at 45, 75 DAS and at harvest but significantly similar at 60 DAS. The results obtained from all other treatments was significantly different compared to the highest and lowest dry weight plant^{-1}. This was similar to that of Jarwar *et al*. (2005).

Table 5. Dry weight plant^{-1} at different growth stages with different time of irrigation and different split application of nitrogen

Treatments	Dry weight plant^{-1}			
	45 DAS	60 DAS	75 DAS	At harvest
Interaction				
I_0N_0	7.53 e	8.08 i	13.05 i	19.04 i
I_0N_1	8.00 e	9.55 hi	14.17 i	20.15 i
I_0N_2	10.45 de	12.24 fg	19.67 fg	25.66 fg
I_0N_3	12.83 cd	14.29 d-f	24.09 c-e	30.08 c-e
I_1N_0	9.840 de	11.23 gh	15.37 hi	21.36 hi
I_1N_1	12.08 cd	13.38 e-g	17.93 gh	23.93 gh
I_1N_2	14.23 bc	15.56 c-e	22.57 d-f	28.57 de
I_1N_3	16.52 ab	16.89 bc	26.40 bc	32.39 bc
I_2N_0	12.30 cd	13.34 e-g	21.38 ef	27.37 ef
I_2N_1	15.06 bc	15.91 b-d	25.21 b-d	31.19 b-d
I_2N_2	17.51 ab	18.23 b	27.83 ab	33.82 b
I_2N_3	19.23 a	20.94 a	30.58 a	36.56 a
$LSD_{0.05}$	3.234	2.268	2.977	2.664
CV (%)	5.74	9.35	4.56	7.04

Here,

I_0 = No irrigation application

I_1 = One irrigation

I_2 = Two irrigations

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.1.6 Length of spike

4.1.6.1 Effect of irrigation

Length of spike at harvest was significantly influenced by different irrigation treatments (Appendix IX and Table 6). It was observed that the longest spike length at harvest (16.12 cm) was obtained with two irrigations which were not significantly different with the result obtained from one irrigation. On the other hand the shortest spike length (14.19 cm) at harvest was shown by no irrigation. This was similar to that of Alsohaibani (2007).

4.1.6.2 Effect of nitrogen

Significant variation was observed in case of spike length with split application of nitrogen (Appendix IX Table 6). It was observed that the longest spike length was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which was 16.19 cm. On the other hand the shortest spike length (14.17 cm) at harvest was obtained with no nitrogen application. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. This result is in accord with that Shen *et al*., (2007).

4.1.6.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen were significant for the spike length at harvest (Appendix IX and Table 6). It was observed that the longest spike length at harvest (17.35 cm) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was significantly similar with I_2N_2 at harvest. On the other hand the shortest spike length (13.27 cm) was obtained from no irrigation with no nitrogen application (I_0N_0) which was significantly similar with I_0N_1, I_0N_2 and I_1N_0 at harvest. The results obtained from all other treatments were significantly different compared to the highest and lowest spike length at harvest. The findings of the study are in accord with the findings Maqsood *et al*., (2007).

4.1.7 Number of spikelets spike^{-1}

4.1.7.1 Effect of irrigation

Number of spikelets spike^{-1} at harvest was significantly influenced by different irrigation treatments (Appendix IX and Table 6). It was observed that the highest number of spikelets spike^{-1} at harvest (53.78) was obtained with two irrigations. On the other hand the lowest number of spikelets spike^{-1} (45.09) at harvest was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This finding was supported by the findings of Ali and Amin (2007).

4.1.7.2 Effect of nitrogen

Significant variation was observed in case of number of spikelets spike^{-1} with split application of nitrogen (Appendix IX Table 6). It was observed that that the highest number of spikelets spike^{-1}was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which was 54.03. On the other hand the lowest number of spikelets spike^{-1} (44.64) at harvest was obtained with no nitrogen application. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. This finding was supported by the findings of Longnecker and Robson (2004).

4.1.7.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for the number of spikelets spike^{-1} at harvest (Appendix IX and Table 6). It was observed that the highest number of spikelets spike^{-1} at harvest (60.00) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) at harvest. On the other hand the lowest number of spikelets spike^{-1} (40.00) was obtained from no irrigation with no nitrogen application (I_0N_0) at harvest. The results obtained from all other treatments was significantly different compared to the highest and lowest number of spikelets spike^{-1} at harvest. This was similar to that of Maqsood *et al.*, (2007).

4.1.8 Number of grains spike^{-1}

4.1.8.1 Effect of irrigation

Number of grains spike^{-1} at harvest was significantly influenced by different irrigation treatments (Appendix IX and Table 6). It was observed that the highest number of grains spike^{-1} at harvest (37.08) was obtained with two irrigations. On the other hand the lowest number of grains spike^{-1} (30.92) at harvest was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This result is in accord with that of Sher and Parvender (2006).

4.1.8.2 Effect of nitrogen

Significant variation was observed in case of number of grains spike^{-1} with split application of nitrogen (Appendix IX Table 6). It was observed that the highest number of grains spike^{-1} was obtained with nitrogen application in three splits-one each at basal, 30 DAS and 60 DAS which was 37.04. On the other hand the lowest number of grains spike^{-1} (30.61) at harvest was obtained with no nitrogen application. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. The findings of the study is in accord with the findings of Chaturvedi (2006).

4.1.8.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for the number of grains spike^{-1} at harvest (Appendix IX and Table 6). It was observed that the highest number of grains spike^{-1} at harvest (39.33) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was significantly similar with I_2N_2 and I_2N_1 at harvest. On the other hand the lowest number of grains spike^{-1} (28.22) was obtained from no irrigation with no nitrogen application (I_0N_0) which was significantly similar with I_0N_1 at harvest. The results obtained from all other treatments was significantly different compared to the highest and lowest number of grains spike^{-1} at harvest. The results of the present study is in agreement with Maqsood *et al*. (2007) and Gecit and Cakr (2006).

Table 6. Effect of different time of irrigation and different split application of nitrogen and their interaction on length of spike, number of spikelets spike^{-1} and number of grains spike^{-1}

Treatments	Length of spike (cm)	Number of spikelets spike^{-1}	Number of grains spike^{-1}
Irrigation			
I_0	14.19 b	45.09 c	30.92 c
I_1	15.39 a	49.23 b	35.45 b
I_2	16.12 a	53.78 a	37.08 a
$LSD_{0.05}$	0.845	3.07	0.954
Nitrogen			
N_0	14.17 c	44.64 d	30.61 d
N_1	15.05 b	47.09 c	34.65 c
N_2	15.52 b	51.70 b	35.64 b
N_3	16.19 a	54.03 a	37.04 a
$LSD_{0.05}$	0.586	1.360	0.418
Interaction			
I_0N_0	13.27 f	40.00 h	28.22 e
I_0N_1	14.18 ef	43.13 g	30.38 de
I_0N_2	14.27 ef	47.80 d-f	31.82 cd
I_0N_3	15.04 de	49.43 de	33.24 c
I_1N_0	14.35 ef	46.33 f	30.67 c-e
I_1N_1	15.13 c-e	47.87 d-f	36.03 b
I_1N_2	15.92 b-d	50.07 de	36.57 ab
I_1N_3	16.18 bc	52.67 c	38.53 ab
I_2N_0	14.88 de	47.60 ef	32.94 cd
I_2N_1	15.85 b-d	50.27 d	37.53 ab
I_2N_2	16.38 ab	57.23 b	38.51 ab
I_2N_3	17.35 a	60.00 a	39.33 a
$LSD_{0.05}$	1.015	2.355	2.532
CV (%)	5.88	7.78	6.22

Here,

I_0 = No irrigation application

I_1 = One irrigation

I_2 = Two irrigations

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

4.2 Yield and yield contributing characters

4.2.1 Weight of 1000 seeds

4.2.1.1 Effect of irrigation

Weight of 1000 seeds was significantly influenced by different irrigation treatments (Appendix X and Table 7). It was observed that the highest 1000 seed weight (47.56 g) was obtained with two irrigations. On the other hand the lowest 1000 seed weight (42.22 g) was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. The result is in conformity with that Sher and Parvender (2006) who reported 1000 grain weight increased with more irrigation.

4.2.1.2 Effect of nitrogen

Significant variation was observed in case of number of 1000 seed weight with split application of nitrogen (Appendix X Table 7). It was observed that the highest 1000 seed weight (45.74 g) was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which was not significantly different from nitrogen application in two splits- one each at 10 DAS and 40 DAS. On the other hand the lowest 1000 seed weight (42.08 g) was obtained with no nitrogen application. It was also observed that one split application of nitrogen showed intermediate results compared to all other treatments. The result is in conformity with that of Chaturvedi, (2006) and Virender *et al.*, (2006).

4.2.1.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for 1000 seed weight (Appendix X and Table 7). It was observed that the highest 1000 seed weight (48.50 g) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was not significantly different from I_2N_2. On the other hand the lowest 1000 seed weight (41.15 g) was obtained from no irrigation with no nitrogen application (I_0N_0) which was statistically similar with I_0N_1. The results obtained from all other treatments was significantly different compared to the highest and lowest 1000 seed weight. The result is in conformity with that of Maqsood *et al*., (2007).

4.2.2 Grain yield

4.2.2.1 Effect of irrigation

Grain yield was significantly influenced by different irrigation treatments (Appendix X and Table 7). It was observed that the highest grain yield (3.73 t ha^{-1}) was obtained with two irrigations. On the other hand the lowest number of grain yield (1.92 t ha^{-1}) was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This result is in accord with that of Onyibe (2008), Sher and Parvender (2006) and Zhang *et al*., (2005).

4.2.2.2 Effect of nitrogen

Significant variation was observed in case of grain yield with split application of nitrogen (Appendix X Table 7). It was observed that that the highest grain yield was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which was 3.15 t ha^{-1}. On the other hand the lowest grain yield (2.42 t ha^{-1}) was obtained with no nitrogen application. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. The result is in conformity with that of Shen *et al*., (2007) and Cerny *et al*., (2005).

4.2.2.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for grain yield (Appendix X and Table 7). It was observed that the grain yield (4.30 t ha^{-1}) was obtained with two irrigations and three split applications of nitrogen (I_2N_3). On the other hand the lowest grain yield (1.70 t ha^{-1}) was obtained from no irrigation with no nitrogen application

(I_0N_0) which was significantly similar with I_0N_1. The results obtained from all other treatments were significantly different compared to the highest and lowest grain yield. The result is in conformity with that of Maqsood *et al.*, (2007) and Guler and Akbay (2007).

4.2.3 Straw yield

4.2.3.1 Effect of irrigation

Straw yield was significantly influenced by different irrigation treatments (Appendix X and Table 7). It was observed that the highest straw yield (5.70 t ha^{-1}) was obtained with two irrigations. On the other hand the lowest straw yield (4.85 t ha^{-1}) was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. The results of the present study is in agreement with Chaudhary and Dahatonde (2007).

4.2.3.2 Effect of nitrogen

Significant variation was observed in case of straw yield with split application of nitrogen (Appendix III Table 7). It was observed that that the highest straw yield (5.42 t ha^{-1}) was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS which was significantly similar with nitrogen application in two splits- one each at 10 DAS and 40 DAS. On the other hand the lowest straw yield (5.23 t ha^{-1}) was obtained with no nitrogen application. It was also observed that one split application of nitrogen showed intermediate results compared to all other treatments. This result is in accord with that of Hakoomat *et al.*, (2005) and Chandurkar *et al.*, (2007).

4.2.3.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for the straw yield (Appendix X and Table 7). It was observed that the highest straw yield (5.82 t ha^{-1}) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was significantly similar with I_2N_2. On the other hand the lowest straw yield (4.75 t ha^{-1}) was obtained from no irrigation with no nitrogen application (I_0N_0) which was significantly similar with I_0N_1 and I_0N_2. The results obtained from all other treatments were significantly different compared to the highest and lowest straw yield. The findings of the study are in accord with the findings Jarwar *et al*., (2005) and Sarkar (2005).

4.2.4 Harvest index

4.2.4.1 Effect of irrigation

Harvest index was significantly influenced by different irrigation treatments (Appendix X and Table 7). It was observed that the highest harvest index (39.40%) was obtained with two irrigations. On the other hand the lowest straw yield (28.25%) was shown by no irrigation. It was also observed that one irrigation showed intermediate results compared to all other treatments. This result is in accord with that of Ali and Amin (2007) and Abdorrahmani *et al*., 2005).

4.2.4.2 Effect of nitrogen

Significant variation was observed in case of harvest index with split application of nitrogen (Appendix X Table 7). It was observed that that the highest harvest index (36.05%) was obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS. On the other hand the lowest harvest index (31.12%) was obtained with no nitrogen application. It was also observed that one and two split application of nitrogen showed intermediate results compared to all other treatments. This result is in accord with that Chandurkar *et al*., (2007).

4.2.4.3 Interaction effect of irrigation and nitrogen

The interaction effect between time of irrigation and split application of nitrogen was significant for the harvest index (Appendix X and Table 7). It was observed that the highest harvest index (42.49%) was obtained with two irrigations and three split applications of nitrogen (I_2N_3) which was significantly similar with I_2N_2. On the other hand the lowest harvest index (26.35%) was obtained from no irrigation with no nitrogen application (I_0N_0) which was significantly similar with I_0N_1 and I_0N_2. The results obtained from all other treatments were significantly different compared to the highest and lowest harvest index. The result is in conformity with that of Tavakoli (2008) and Maqsood *et al*., (2007).

Table 7. Effect on yield and yield contributing characters showing 1000 seed weight, grain yield, straw yield and harvest index with different time of irrigation and different split application of nitrogen and their interaction

Treatments	**1000 seed weight**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Harvest index**
Irrigation				
I_0	42.22 b	1.92 c	4.85 c	28.25 c
I_1	42.90 b	2.67 b	5.37 b	33.07 b
I_2	47.56 a	3.73 a	5.70 a	39.40 a
$LSD_{0.05}$	1.046	0.036	0.124	0.275
Nitrogen				
N_0	42.08 c	2.42 d	5.23 b	31.12 d
N_1	43.65 b	2.64 c	5.28 b	32.75 c
N_2	45.44 a	2.88 b	5.33 ab	34.38 b
N_3	45.74 a	3.15 a	5.42 a	36.05 a
$LSD_{0.05}$	0.799	0.044	0.109	0.360
Interaction				
I_0N_0	41.15 e	1.70 j	4.75 f	26.35 h
I_0N_1	41.53 de	1.85 ij	4.82 ef	27.77 gh
I_0N_2	42.87 cd	1.96 h-j	4.86 ef	28.74 gh
I_0N_3	43.32 c	2.15 g-i	4.98 e	30.15 fg
I_1N_0	42.27 c-e	2.35 gh	5.32 d	30.61 fg
I_1N_1	42.72 cd	2.55 fg	5.37 d	32.17 ef
I_1N_2	43.21 c	2.78 ef	5.40 d	33.98 de
I_1N_3	43.42 c	3.01 de	5.45 cd	35.51 cd
I_2N_0	42.81 d	3.21 cd	5.61 bc	36.39 cd
I_2N_1	46.71 b	3.51 bc	5.65 a-c	38.32 bc
I_2N_2	48.23 a	3.88 b	5.72 ab	40.41 ab
I_2N_3	48.50 a	4.30 a	5.82 a	42.49 a

$LSD_{0.05}$	1.384	0.402	0.188	3.036
CV (%)	5.82	7.42	9.03	8.08

Here,

I_0 = No irrigation application

I_1 = One irrigation

I_2 = Two irrigations

N_0 = No nitrogen application

N_1 = At basal application (175 Kg of urea ha^{-1})

N_2 = Two equal split application of N_2

N_3 = Three equal split application of N_2

CHAPTER 5

SUMMARY AND CONCLUTION

The experiment was conducted at the experimental site of Sher-e-Bangla Agricultural University (SAU) during the period from December, 2007 to March, 2008 to study the growth and yield of wheat as influenced by time of irrigation and split application of nitrogen. Twelve treatments were included in the study viz. (i) No irrigation + no nitrogen application, coded as I_0N_0, (ii) No irrigation + one basal application of nitrogen at the time of sowing, coded as I_0N_1, (iii) No irrigation + two equal split- One at basal and another at 30 DAS, coded as I_0N_2, (iv) No irrigation + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as I_0N_3, (v) One irrigation given at crown root initiation stage + no nitrogen application, coded as, I_1N_0, (vi) One irrigation given at crown root initiation stage + one basal application of nitrogen at the time of sowing, coded as, I_1N_1, (vii) One irrigation given at crown root initiation stage + two equal split- One at basal and another at 30 DAS, coded as, I_1N_2, (viii) One irrigation given at crown root initiation stage + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as, I_1N_3, (ix) Two irrigations, one at crown root initiation stage and another at panicle initiation stage + no nitrogen application, coded as, I_2N_0, (x) Two irrigations, one at crown root initiation stage and another at panicle initiation stage + one basal application of nitrogen at the time of sowing, coded as, I_2N_1, (xi) Two irrigations, one at crown root initiation stage and another at panicle initiation stage + two equal split- One at basal and another at 30 DAS, coded as, I_2N_2 and (xii) Two irrigations, one at crown root initiation stage and another at panicle initiation stage + three equal split- One at basal, and the other at 30 DAS and 60 DAS, coded as, I_2N_3.

The land was prepared by power tiller and fertilized with 175, 110, 110 and 7 kg ha^{-1} of triple super phosphate, muriate of potash, gypsum and Boric acid respectively. Nitrogen was applied as per experimental specification through urea @ 175 kg ha^{-1}. Seeds of variety Bijoy were sown in furrows at the rate of 120 kg ha^{-1}. Data were collected on different growth characters, and yield and yield contributing characters. The experiment was conducted in split plot design with three replications. The collected and calculated data were analyzed statistically and mean differences were adjudged by DMRT.

The results showed that some of the crop characters in case of growth parameters such as plant height, number of tillers $plant^{-1}$, leaf area index (LAI), fresh weight $plant^{-1}$, dry weight $plant^{-1}$, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$ were significantly affected due to application of different times of irrigation and application of different split of nitrogen. The other parameters about yield and yield contributing characters such as 1000 seed weight, total grain yield, straw yield and harvest index were also significantly influenced by application of different times of irrigation and application of different split of nitrogen. It was also revealed that growth, yield and yield contributing parameters that were plant height, number of tillers $plant^{-1}$, leaf area index (LAI), fresh weight $plant^{-1}$, dry weight $plant^{-1}$, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, 1000 seed weight, total grain yield, straw yield and harvest index were significantly influenced with the interaction effect of different times of irrigation and application of different split of nitrogen.

Results showed that irrigation treatments significantly influenced all the growth parameters at all the stages of crop duration. The tallest plant (93.02 cm), highest number of tillers $plant^{-1}$ (4.05), highest leaf area index (2.52), highest fresh weight (59.60g) and dry weight (32.23g) $plant^{-1}$, longest spike length (16.12 cm), highest number of spikelets $spike^{-1}$ (53.78) and highest number of grains spike^{-1} (37.08) at the end of crop duration (at harvest) were obtained with two times of irrigation; one at crown root initiation (CRI) stage (18 DAS) and another at panicle initiation (55 DAS). Finally (after harvest) the highest value considering yield and yield contributing characters such as 1000 seed weight (47.56g), total grain yield (3.73 t ha^{-1}), straw yield (5.70 t ha^{-1}) and harvest index (39.40%) were also obtained with two irrigations given at CRI (18 DAS) and panicle initiation (55 DAS) stages. The corresponding lowest values were obtained from no irrigation.

Application of different split of nitrogen also revealed significant effect on all the growth parameters. Results showed that nitrogen applied in three split one each at basal, 30 DAS and 60 DAS produced the tallest plant (92.55 cm), highest number of tillers/plant (3.70), highest leaf area index (2.43), highest fresh weight (60.93g) and dry weight (33.01g) plant^{-1}, longest spike length (16.19 cm), highest number of spikelets spike^{-1} (54.03) and highest number of grains spike^{-1} (37.04). The highest value considering yield and yield contributing characters such as 1000 seed weight (45.74g), total grain yield (3.15 t ha^{-1}), straw yield (5.42 t ha^{-1}) and harvest index (36.05%) were also obtained with nitrogen application in three splits- one each at basal, 30 DAS and 60 DAS. The lowest values were observed at control treatment (N_0).

Interaction between level of times of irrigation and split application of nitrogen was significant for all the growth parameters. The treatment combination of two irrigation with three split application of nitrogen produced the tallest plant (96.37 cm), highest number of tillers plant^{-1} (4.50), highest leaf area index (2.71), highest fresh weight (66.97g) and dry weight (36.56g) plant^{-1}, longest spike length (17.35 cm), highest number of spikelets spike^{-1} (60.00) and highest number of grains spike^{-1} (39.33) at the time of harvest. Incase of yield and yield contributing characters, the treatment combination of two irrigations with three split application of nitrogen produced the highest 1000 seed weight (48.50g), total grain yield (4.30 t ha^{-1}), straw yield (5.82 t ha^{-1}) and harvest index (42.49%). The lowest values were obtained by no irrigation along with no nitrogen application.

It may be concluded within the scope and limitation of the present study that the optimum growth and higher yield of wheat cv. Bijoy could be obtained by applying two irrigations at crown root initiation and panicle initiation with three splits of nitrogen one each at basal, 30 DAS and 60 DAS. However, further studies are necessary to arrive at a definite conclusion.

CHAPTER 6

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APPENDICES

Appendix I. The experimental site is shown in the AEZ Map of Bangladesh

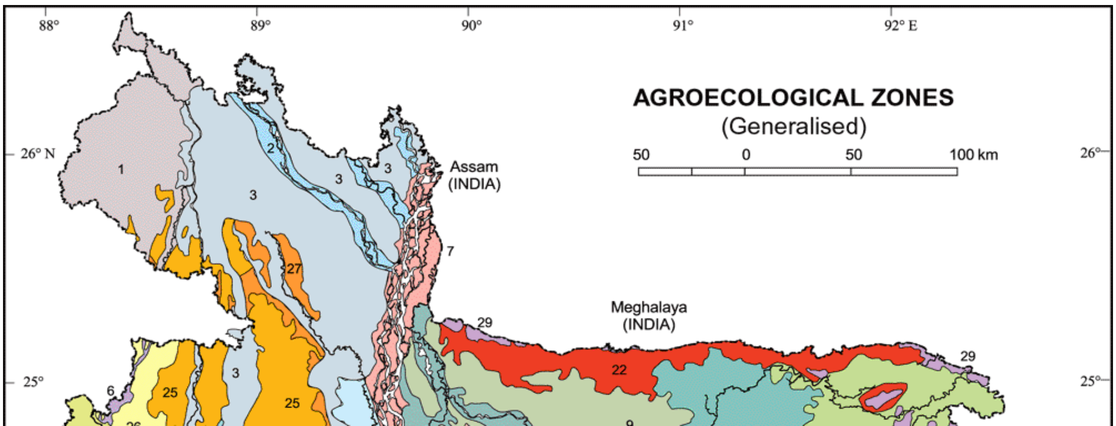

Fig. 11. Experimental site is in the AEZ Map of Bangladesh

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (December, 2007 to March, 2008) at Sher - e - Bangla Agricultural University campus

Month	Year	Monthly average air temperature (^0C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Dec.	2007	27.19	14.91	21.05	70.05	Trace	212.50
Jan.	2008	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2008	31.35	19.40	25.33	68.78	3.0	225.50
Mar.	2008	33.20	22.00	27.60	64.13	Trace	220.30

Appendix III. 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
Organic matter	0.82
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Appendix IV. Plant height at different growth stages with different time of irrigation and different split application of nitrogen

Source of variation	Degrees of freedom	Mean square values of plant height (cm)			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	5.782	45.28	29.06	14.72
Factor A	2	23.32*	83.67*	99.57*	121.38*
Error	4	3.020	8.585	3.256	1.209
Factor B	3	58.295*	93.68*	73.62*	56.97*
AB	6	1.076**	3.031*	1.573*	0.683**
Error	18	1.396	4.572	0.513	0.496

Appendix V. Number of tillers plant^{-1} at different growth stages with different time of irrigation and different split application of nitrogen

Source of variation	Degrees of freedom	Mean square value of number of tillers plant^{-1}			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.024	0.001	0.066	0.072
Factor A	2	4.166*	4.257*	10.36*	10.16*
Error	4	0.010	0.011	0.012	0.017
Factor B	3	2.104*	2.761*	2.503*	2.589*
AB	6	0.076**	0.038**	0.085**	0.081**
Error	18	0.019	0.021	0.044	0.030

Appendix VI. Leaf area index at different growth stages with different time of irrigation and different split application of nitrogen

Source of variation	Degrees of freedom	Mean square value of leaf area index			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.006	0.008	0.004	0.001
Factor A	2	0.127**	0.275*	1.183*	0.713*
Error	4	0.001	0.011	0.014	0.019
Factor B	3	0.053**	0.089**	0.378*	0.207*
AB	6	0.006**	0.009**	0.037**	0.017**
Error	18	0.016	0.020	0.018	0.024

Appendix VII. Fresh weight plant^{-1} at different growth stages with different time of irrigation and different split application of nitrogen

Source of variation	Degrees of freedom	Mean square value of fresh weight plant^{-1}			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	2.017	7.326	3.415	3.670
Factor A	2	484.73*	264.86*	573.36*	692.64*
Error	4	7.007	28.184	2.688	8.133
Factor B	3	204.27*	220.09*	477.09*	599.62*
AB	6	517.16*	158.82*	81.080*	9.096**
Error	18	8.009	36.740	18.089	6.050

Appendix VIII. Dry weight plant^{-1} at different growth stages with different time of irrigation and different split application of nitrogen

Source of variation	Degrees of freedom	Mean square value of dry weight plant^{-1}			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	2.901	8.090	0.848	3.572
Factor A	2	120.3*	110.5*	225.2*	224.9*
Error	4	1.437	0.519	0.011	0.112
Factor B	3	67.98*	71.76*	191.1*	191.3*
AB	6	0.954**	0.666**	2.155*	2.855*
Error	18	3.554	1.748	3.012	2.412

Appendix IX. Effect of different time of irrigation and different split application of nitrogen and their interaction on length of spike, number of spikelets spike^{-1} and number of grains spike^{-1}

Source of variation	Degrees of freedom	Mean square value		
		Spike length	number of spikelets spike^{-1}	number of grains spike^{-1}
Replication	2	0.201	112.9	7.838
Factor A	2	11.36*	226.4*	122.5*
Error	4	0.556	7.334	0.709
Factor B	3	6.518*	164.1*	68.72*
AB	6	0.158**	7.863*	1.798**
Error	18	0.350	1.885	2.178

Appendix X. Effect on yield and yield contributing characters showing 1000 seed weight, grain yield, straw yield and harvest index with different time of irrigation and different split application of nitrogen and their interaction

Source of variation	Degrees of freedom	Mean square value			
		1000 seed weight	Grain yield (t ha^{-2})	Straw yield (t ha^{-2})	Harvest index
Replication	2	1.509	0.012	0.022	0.019
Factor A	2	101.4*	9.911*	2.203*	375.4*

Error	4	0.852	1.001	0.042	0.059
Factor B	3	26.15*	0.891**	0.059**	40.48*
AB	6	8.486*	0.063**	0.002**	0.838*
Error	18	0.051	0.012	1.112	0.132