EFFECT OF IRRIGATION AT POST HEADING STAGE UNDER VARYING SOWING TIMES ON GROWTH AND YIELD OF WHEAT

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CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND YIELD OF WHEAT AS INFLUENCED BY IRRIGATION REGIMES UNDER VARING SOWING TIMES"** 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 (M.S.)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **S. M. RASHEDUL HASAN,** Registration. No. **14-06336** under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Md. Jafar Ullah)
Supervisor

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ABSTRACT

The experiment was conducted during the period from November 2014 to March 2015 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of different irrigation under varying sowing times on growth and yield of wheat. The experiment comprised of two factors; Factors A: Irrigation (3 times): I_1: Irrigation during heading stage; I_2: Irrigation after 10 days of I_1 and I_3: Irrigation after 10 days of I_2; Factor B: Sowing time (4 dates at 10 days interval): S_1: Sowing at 10 November, S_2: Sowing at 20 November, S_3: Sowing at 30 November and S_4: 10 December. The experiment was laid out in Split Plot Design with three replications. Different times of irrigation were assigned in the main plot and sowing date was assigned in the sub-plot. Irrigation after 10 days of heading stage showed better performance in all yield contributing and yield parameters except grain weight spike^{-1}. Combined action of irrigation after 10 days of heading stage and sowing at 20 November (I_2S_2) recorded the highest values in 1000 grain weight (60.30 g) and grain yield (4.06 t ha^{-1}) which however was not significantly different with those of I_1S_2, I_1S_3, I_3S_1 and I_3S_3.

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LIST OF ACRONYMS

%	Percentage
^0C	Degree Celsius
AEZ	Agro- Ecological Zone
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CGIAR	Consultative Group on International Agricultural Research
cm	Centi-meter
CV	Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
et al.	And others
FAO	Food and Agriculture Organization
OECD	Organization of Economic Cooperation and Development
HI	Harvest Index
hr	Hour(s)
IRRI	International Rice Research Institute
K_2O	Potassium Oxide
LAI	Leaf area Index
LSD	Least Significant Difference
m	Meter
m^2	Meter squares
mm	Millimeter
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
var.	Variety
Wt.	Weight

CHAPTERI
INTRODUCTION

Now-a-days, wheat (*Triticum aestivum* L.) is one of the most major cereal crops cultivated all over the world. Wheat production was increased 22% from 2000 to 2013 which was ranked below rice and maize in case of production (FAO, 2015).In the developing world, important of wheat will be increased 60% by 2050 (Rosegrant and Agcaoili, 2010).Wheat grain is the main staple food for about two thirds of the total population of the world (Hanson *et. al*., 1982). It supplies more nutrients compared with other food crops which contain 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006). Wheat is the second most important cereal crop and covers 0.64 million ha of land with an annual production of 1.2 million tons in Bangladesh (BBS, 2007). Present demand of wheat in the country is 3.0-3.5 million tons per year and consumption rate of wheat is increasing 3% per year (Roy and Pandit, 2007).So, it is imperious to increase the production of wheat to meet the food requirement of vast population of Bangladesh that will secure food safety. In Bangladesh, yield per hectare of wheat is lower than other wheat growing countries in the world due to various reasons. World wheat production will reduce in consequence of global warming and will also affect the developing countries like Bangladesh (CIMMYT- IPCC, 2007; ICARDA, 2011; CGIAR, 2009 and OECD, 2003). However, delayed sowing after the harvest of transplanted aman rice and time of irrigation facilities are major problems for wheat cultivation in Bangladesh.

Though wheat requires less amount of irrigation compared to other cereal crops like rice, irrigation plays a vital role for optimum growth and development of wheat at different growth stages. Wheat is grown in the driest months of the year when rainfall is scarce. The germination of seed and uptake of nutrients from the soil are negatively affected by insufficient soil moisture. Proper growth and development of wheat needs favorable soil moisture in the root zone and extractable water capacity of soil has significant influence on wheat grain yield and water productivity response to irrigation. Water use efficiency (WUE) was generally higher in lower frequencies of irrigation and maximum WUE is obtained when two irrigations were applied at crown-root initiation and flowering which are the most critical stages of irrigation, and therefore, water utilization was most efficient leading to high WUE (Prasad *et al*., 1988). Wheat yield was worsened by more than 50% allowable depletion of soil moisture stress (Islam and Islam,1991).Irrigation should be applied in different critical stages of wheat for successful wheat production. Shoot dry weight, number of grains, grain yield, biological yield and harvest index enhanced to a greater extent when irrigation was given at the anthesis stage while water was applied at booting stage caused a greater higher in plant height and number of tillers (Gupta *et al.,* 2001). The efficacy of irrigation at grain filling and under rain fed conditions provided a bottommost result (Bazza*et al*., 1999). In recent days, determination of perfect stage of irrigation to reduce cost as well as checks ground water waste is badly needed in recent days. The amount of irrigation varies depending on the stages of development and availability of water sources. The pick requirement is at CRI stage. In wheat, irrigation has been recommended at CRI, flowering and grain filling stages. The amount of irrigation water is shrinking day by day in Bangladesh. In addition, global climate change scenarios are also responsible for their scarcity of irrigation water. So, it is crucial to guess appropriate irrigation time in case of two irrigation facilities to have an economic estimate of irrigation water.

In Bangladesh best time of sowing of spring wheat ranges from15 to 30 November but it can be sown up to 7 December in Northern part of Bangladesh due to cold weather compared to other parts of the country (Ansary *et al.*,1989). Farmers can't sow seeds in optimum time as they cultivate wheat in winter season after harvesting of transplanted (T) aman rice. Wheat is sown up to January in some areas as wheat is followed by transplant aman rice or soil remains wet (BARI, 2006). Too early sowing establishes weak plant having poor root system. In late sowing circumstance, wheat crop experiences high temperature stress. High temperature results in irregular germination, death of embryo and decomposition of endosperm for increasing activities of bacteria or fungi. Late sowing reduced the yield, caused by decline in the yield contributing traits like number of tillers, grain weight, number of grains spike^{-1}and grain yield (Ansary *et al.*,1989).Commonly, wheat is sown in November to confirm optimum crop growth and escape from high temperature. Temperature is one of the major environmental factor that affect grain yields in wheat. In industrialized globe, heat is the top most threat to food security in Bangladesh as a populated where wheat ranks second position among most food grains. However major wheat area under rice-wheat cropping system is late planted including Bangladesh (Badruddin *et al*., 1994). In present time, it is necessary to reveal appropriate sowing time and enumerate the losses or reduction in yield and different yield attributes due to early or delayed sowing. Information on the impeccable time of irrigation as well as the exact sowing time of wheat with change in climate to speed up wheat production within the farmer's limited resources is inadequate in Bangladesh. The number and time of irrigation also varies with sowing times as the soil moisture exhausts with the days after sowing in Bangladesh as there is scanty rainfall after sowing (November) of wheat.

With above considerations, the present research work was conducted with the following objectives:

- To find out the time of irrigation needed for optimum growth and yield of wheat
- To detect optimum sowing time of wheat in this agro-climatic zone.
- To determine the interaction effect of time of irrigation and sowing time on growth and yield of wheat.

CHAPTER II

REVIEW OF LITERATURE

Different sowing times and number of irrigations in different stage received much attention to the researchers throughout Bangladesh to develop apposite production technology of wheat. The attempt has been made in this chapter to review the relevant research information to wheat cultivation in the different countries of the world especially in the context of Bangladesh. Literature on the influence of irrigation scheduling and sowing time on growth and yield of wheat is particularly less available. Sufficient information is not available from the research works of the different scientists of the world in regard to the sowing time with their relationship patterns in support of the present piece of research conducted in the university. It is therefore, apparent find out real significant information on the two mentioned factors. Little information which is currently available relates mostly to the effect of irrigation time and sowing time on the agronomical characters and also total yield of crops have been reviewed in this chapter.

2.1 Influence of irrigation on the growth and yield of wheat

Many experiments related to irrigation were conducted on the growth, yield and yield contributing character of wheat in different wheat growing countries of the world. Some of the findings of those experiments were reviewed below:

Mueen-ud-din *et al.* (2015) conducted a field experiment to study the response of wheat to different irrigation levels at Adaptive Research Farm, Vehari, India. Four irrigations @ 4 acre-inch, 3 acre-inch, and 2 acre-inch and farmers practice were applied. Results revealed that application of different irrigation levels to wheat affected number of grain spike^{-1}, 1000 grain weight, and grain yield (kg ha^{-1}) significantly. Maximum grain yield (4232.5 kg ha^{-1}), no. of grains spike^{-1} (51), 1000 grain weight (46.5 g) were recorded from the plots where 3 acre inch water was applied. Highest water use efficiency of 20, 19.89 kg ha^{-1} mm^{-1} was observed from the plots where 2 acre inch water was applied.

Islam *et al*. (2015) conducted an experiment with four irrigation stages viz. I_0: No irrigation; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) and I_3: Irrigation at both CRI and pre-flowering stage. Maximum number of tillers hill^{-1} (5.2), CGR (6.7 gm-2day^{-1}), RGR (0.03 gm^{-1} day^{-1}), dry matter content (28.7%), number of spikes hill^{-1} (4.5), number of spikeletsspike^{-1} (19.0), ear length (17.5), filled grains spike^{-1} (30.8), total grains spike^{-1} (32.9), weight of 1000-grains (47.1 g), grain yield (3.9 t ha^{-1}), straw yield (4.9 t ha^{-1}), biological yield (8.8 t ha^{-1}) and harvest index (45.9%) were obtained from I_3 whereas lowest occurred in I_0. They also stated that early flowering (70.6 days), maturity (107.2 days) and minimum number of unfilled grains spike^{-1} (2.1) were also obtained from I_3.

Chouhan *et al*. (2015) observed that water saving of about 28.42% higher when drip irrigation was applied rather than the border irrigation system. They also stated that water productivity of drip irrigated wheat was 24.24% higher compared with the border irrigated wheat. But, there was a slightly reduction of 10.8% in the grain yield because of severe water deficit during the growing stages.

Atikulla *et al.* (2014) showed that maximum dry matter content (18.8g/plant), crop growth rate (CGR) (13.5 g m^{-1} day^{-1}), relative growth rate (RGR) (0.024 g m^{-1} day^{-1}) were obtained from I_1 which was statistically same as I_2 while lowest obtained from I_0. They also reported that Plant height (80.7 cm), number of tillers/hill (4.9), number of spikes/hill (4.7), number of spikelets/spike (18.5), spike length (19.2 cm), filled grains/spike (29.3), total grains/spike (31.3), 1000-grains weight (44.4 g), yield (grain 3.4 t/ha, straw 5.7 t/ha and biological 9.1 t/ha) and harvest index were observed better in $I_{1.}$

Mekkei and Haggan (2014) conducted two field experiment in the successive winter seasons 2011/2012 and 2012/2013 at the Agricultural Experiment and Research Station, Faculty of Agriculture, Cairo University to study the effect of irrigation regime (I_1: full irrigation 5 irrigation, I_2: skipping 2nd irrigation, I_3: skipping 3rd irrigation, I_4: skipping 4th irrigation and I_5: skipping 5th irrigation) on yield and quality of five wheat cultivars. Results showed that skipping irrigation at various growth stages had significant effect on days to heading, days to maturity and days from heading to maturity. Skipping the second or the third irrigation led to early heading and early maturity. Results also showed that skipping irrigation at various growth stages significantly decreased plant height, number of tillers m^{-2}, number of spikes m^{-2}, spike length, 1000-kernel weight, grain, straw and biological yields and harvest index in both seasons.

Khan *et al*. (2013) reported that the higher yield of wheat the crop may be irrigated after five weeks interval. Excessive and earlier irrigation time can be harmful for the optimum yield of wheat if seasonal rainfall is >330mm.

Atikulla (2013) evaluated that irrigation hastened the maturity period of wheat and as a result maturity of 121.56 days was found for no irrigation (I_0) and that of 115.33 days was found for irrigation at 20 DAS (I_1) treatment.

Ngwakoand Mashiqa (2013) showed that irrigation significantly affected days to maturity, number of tillers, number of grains per spike and grain yield. Irrigation throughout the growth stages increased number of tillers, number of grains per spike, grain yield, harvest index and grain protein by 20.58%, 26.07%, 42.72%, 16.71% and 3.31% respectively over no irrigation.

Monwar (2012) reported that the two irrigations one at crown root initiation (CRI) and on at grain filling stage (GF) showed the best performance by wheat crop.

Asif *et al.* (2012) conducted an experiment to study the effect of different levels of irrigation on growth and radiation use efficiency of wheat crop. The results exhibited variation in the crop growth rate (g $m^{-2}d^{-1}$), leaf area index, leaf area duration, number of grains spike^{-1}and harvest index.

Wang *et al.* (2012) observed that a significant irrigation effect was observed on grain yield, kernel numbers and straw yield. The highest levels were achieved with a high irrigation supply, although WUE generally decreased linearly with increasing seasonal irrigation rates in 2 years. The low irrigation treatment (0.6 ET) produced significantly lower grain yield (20.7 %), kernels number (9.3 %) and straw yield (12.2 %) compared to high irrigation treatment (1.0 ET). The low irrigation treatment had a higher WUE (4.25kg ha^{-1} mm^{-1}) rather than that of 3.25kg ha^{-1} mm^{-1} with high irrigation over the 2 years.

Zhang-Xu Cheng *et al.* (2011) reported that water supplied at booting to heading stages promoted both spike and grain development.

Wu *et al.* (2011) showed that the effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province and found that the effect of irrigation on plant height, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better. The wheat yield was increased by 2.54%-13.61% compared to control and the treatments, irrigation of 900 m^3ha^{-1} at the elongation stage and of 450 m3 ha^{-1} at the booting stage or separate irrigation of 900 m3 ha^{-1} at the two stage were the highest.

Sarkar *et al*. (2009) expressed that an average 33, 43, 52 and 51 percent higher yield were achieved at I_1, I_2, I_3 and I_4 irrigation levels, respectively where five irrigation treatments were I_o (No irrigation), I_1 (17-21 DAS), I_2 (17-21 DAS+50-55 DAS), I_3 (17-21 DAS+50-55 DAS+75-80 DAS) and I_4 (17-21 DAS+35-40 DAS+50-55 DAS+75-80 DAS).

Kabir *et al.*(2009) showed that the highest plant height (82.33 cm), spike length (8.37 cm), filled grain spike-^{1} (31.90), effective tillers plant-^{1} (3.31), grain yield (3.30 t ha-^{1}), straw yield (4.09 t ha-^{1}), biological yield(7.39 t ha-^{1}) and harvest index (44.47%) were obtained from single irrigation applied at CRI stage.

Sarkar *et al.* (2009) conducted an experiment of wheat with five irrigation treatments which were I_0 (No irrigation), I_1 (17-21 DAS), I_2 (17-21 DAS+50-55 DAS), I_3 (17-21 DAS+50-55 DAS+75-80 DAS) and I_4 (17-21 DAS+35-40 DAS+50-55 DAS+75-80 DAS). They reported that on an average 33, 43, 52 and 51 percent higher yield were obtained over farmer's practice at I_1, I_2, I_3 and I_4 irrigation levels, respectively.

Wang *et al*. (2009) reported that the application of different irrigation on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farm lands with an accurate management system with irrigation systems. Water utilization enhanced due to irrigation. Water consumption in high irrigation treatment was enhanced by 16.68% and 36.88% rather than intermediate irrigation treatment and low irrigation treatment respectively.

Mangan *et al*. (2008) observed that grain yield of wheat varieties were significantly influenced under water stress conditions. Grain yield increased from 3731 kg ha^{-1} in single irrigation treatment to 3931 kg ha^{-1} in four irrigations.

Sarkar *et al*. (2008) carried out an experiment at Wheat Research Centre (WRC), Nashipur, Dinajpur for detecting irrigation scheduling of wheat based on cumulative pan evaporation (CPE). Irrigation water was given to wheat using IW: CPE ratios of 0.60, 0.85 and 1.10 applied at 17-21 days after sowing (DAS), 45-50 DAS, 75-80 DAS respectively where highest grain of wheat was attained at IW: CPE of 0.85.

Chaudhary and Dahatonde (2007) detected the performance of wheat on the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I_4; I_4 + irrigation at the tillering stage or I_5; and I_5 + 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).Irrigation frequency exaggerated grain yield insignificantly. Irrigation at 100% of the net irrigation requirement produced the highest grain yield (27.32 quintal/ha). Water consumption augmented with the rise in irrigation frequency and quantity. Water use efficiency was obtained higher under I_5 (87.74 kg ha^{-1} cm^{-1}) and irrigation at 100% of the net irrigation requirement (85.29 kg ha^{-1} cm^{-1}).

Pal and Upasani (2007) reveled that different irrigation levels (2, 3 or 4 times) applied at critical growth stages (crown-root initiation, highest tillering, booting and milking). As four irrigations were applied at the crown root initiation, highest tillering, booting and milking stages, highest yield obtained. Non-irrigation at the highest tillering stage declined yield (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 were lessened due to the non-irrigation at the time of the highest tillering, milking and booting stage.

Chaudhary and Dahatonde (2007) detected the performance of wheat on the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I_4; I_4 + irrigation at the tillering stage or I_5; and I_5 + 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).Irrigation frequency exaggerated grain yield insignificantly. Irrigation at 100% of the net irrigation requirement produced the highest grain yield (27.32 quintal/ha). Water consumption augmented with the rise in irrigation frequency and quantity. Water use efficiency was obtained higher under I_5 (87.74 kg ha^{-1} cm^{-1}) and irrigation at 100% of the net irrigation requirement (85.29 kg ha^{-1} cm^{-1}).

Ali and Amin (2007) carried out a trail using irrigation treatments which prearranged 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). Plant height, number of effective tillers per hill, spike length, number of spikelets per spike, filled grains per spike obtained significantly by applying irrigation at different levels. The growth, yield attributes and yield of wheat increased significantly when two irrigations were given at 21 and 45 DAS over the other treatments.

Rajput and Pandey (2007) experimented and reported that grain yield, ear length, number of grains per ear, 1000- grain weight, water use efficiency, leaf area index, crop growth rate, relative growth rate, net assimilation rate were highest with 55% soil moisture.

Shuquin *et al.* (2006) reported that the effect of irrigation on yield and quality of various gluten wheat cultivars. They also added that enhancing the number of irrigation increased yield, quality and water use efficiency whereas the yield and quality decreased when applied least number of irrigation.

Jiamin *et al.* (2005) expressed that three irrigation schedules, pre-sowing irrigation only, pre-sowing irrigation and irrigation at booting stage, and also pre-sowing irrigation, irrigation at booting stage and flowering stages were selected. Pre-sowing irrigation, irrigation at booting stage and flowering stages were advised for winter wheat cultivation in the North China Basin.

Mushtaq and Muhammad (2005) reported that taller plants and maximum number of fertile tillers per unit area were obtained when five irrigations were applied at crown root + tiller + boot + milk + grain development stages. It was not significantly superior to 4 irrigations given 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 attained higher under 4 irrigations given at crown root + boot + grain development and crown root + boot stages of plant growth, respectively. Grain yield was declined 6.63 and 12.20% and enhanced 1.45% when applied 3, 2 and 5 irrigations respectively over 4 irrigations.

Abdorrahmani *et al*. (2005) observed that dry matter production, crop growth rate and relative growth rate were decreased due to drought stress. All but the number of grains per ear and harvest index was influenced by water deficit.

Zarea and Ghodsi (2004) noticed that twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in Iran and found that number of spike m^{-2} and 1000-kernel weight decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied, number of spike m^{-2} were higher in cultivars C-75-14 and C-75-9.

Jana and Mitra (2004) expressed that irrigation enhanced plant height, number of effective tillers, ear $plant^{-1}$ and grain and straw yields when applied irrigation at crown root initiation, tillering, flowering and dough stages.

Zarea and Ghodsi (2004) conducted an experiment and revealed that grain yield declined due to increasing irrigation intervals. When a 20 and 30-day irrigation intervals were given in field yield was increasing. Wheat has different critical growth stages of water stress. These stages are tillering, shooting, booting, heading, flowering and grain filling.

Rasol (2003) carried out an experiment which showed that irrigation water amount significantly affected yield, the high yields were obtained from 500 and 600mm whereas the lowest was obtained from the 300mm treatment.

Gupta *et al*. (2001) conducted an experiment in which they found that plant height reduced to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in plant height. Among the yield attributes plant height were positively correlated with grain and biological yield irrigation at the anthesis stage.

Gupta *et al*. (2001) carried out an experiment in which they that grain yield and biological yield decreased to a greater amount when water stress was imposed at the anthesis stage and irrigation at the anthesis stage where leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

Islam (1997) observed that plant height increased with increasing number of irrigations. The maximum plant height was obtained by three irrigations applied at 25, 50 and 70 days after sowing.

Islam (1996) carried out an experiment that irrigation significantly affected the plant heights, number of effective tillers per plant, grain and straw yields but it had no effect on grains per ear and 1000-grain weight. Grain yield (3.71 t ha^{-1}) became highest with three irrigations (25, 45 and 60 DAS) and became lowest with no irrigations (2.61t ha^{-1}).

Naser (1996) conducted an experiment that the effect of different irrigations on yield and yield contributing characters were statistically significant. Two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. Maximum number of tillers per plant, highest spike length, maximum number of grains per spike, highest grain yield and straw yields were obtained, when two irrigations were applied. The lowest result was observed in all plant parameters under control.

Razi-us-Shams (1996) conducted an experiment that the effect of irrigation treatments on yield and yield contributing characters (cv. Sonalika) were statistically significant. Irrigation increased the grain and straw yields, number of tillers and panicle.

Jana *et al*. (1995) observed that irrigation was applied at crown-root initiation, tillering, flowering and dough stages in wheat cv. Sonalika including all combinations, in a trial at Cooch-Behar, West Bengal in the rabi (winter) seasons of 1979-80 and 1982-83. Irrigation increased plant height, number on effective tillers, grains ear^{-1} and grain and straw yields comparing with rain fed control. Two irrigations at the tillering and flowering stages produced the highest grain yield (3.03 t ha^{-1}). Water use increased and water use efficiency narrowed with increase in number of irrigations. Two irrigations at tillering and flowering used 296 mm of water with use efficiency of 10.12 kg ha^{-1} per mm.

Yadav *et al*. (1995) reported that plant height (1.026 m), number of grains/ear (65), straw (4500kg ha-^{1}) and grain (3158kg ha^{-1}) yield of wheat were obtained highest from two irrigations applying at CRI and milk stages.

Upadhyaya and Dubey (1991) confirmed that three irrigation frequencies as- one irrigation (at CRI stage), two irrigations (on each at CRI and booting stage) and four irrigation (one each at CRI, booting, flowering and milking stages). Four irrigations produced the maximum grain yield, which was significantly higher than one to two irrigations. The increased yield was due to the favourable effect of treatments on yield attributing characters.

Sharma *et al*. (1990) obtained higher grain yield with three irrigations given at CRI, tillering and milking stages than other treatment with three irrigations. They also found maximum water use efficiency with three irrigations given at CRI, tillering and milking stages.

Sah *et al*. (1990) reported that when two irrigations were applied, the utmost grain yield of wheat was obtained whereas the maximum grain protein content was obtained with three irrigations.

BARI (1982) observed that wheat crop required irrigation at three different stages, e.g., crown root initiation, heading and grain filling, and crown root initiation stage is the most critical one out of these stages. The first irrigation should be given at crown root initiation stage which appeared between 17-21 days after germination.Mian and Khan (1978) found that three irrigations were applied for obtaining maximum grain yield and grain yields increased with the increase of irrigation frequency.

From reviewed information it was found that in the case of wheat, irrigation during these stages was the most beneficial for the crop. One water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations. Irrigation during the stage of grain filling caused the kernel weight to be as high as under three irrigations.

2.2 Influence of sowing date on growth and yield of wheat

The major non-monitory inputs for enhancing wheat production is optimum sowing time which is the most important agronomic factor affecting the growth and development of plants. Research works experimented at home and abroad revealed that late sowing after the optimum time which coincides with the onset of seasonal rains, consistently reduced yields. Yield of crop is the function of some yield contributing parameters. Sowing time has a remarkable effect on yield of wheat. The yield and yield parameters of wheat varied from location to location due to the prevailing weather situation during pre-anthesis and post-anthesis development. Some of the pertinent literatures regarding effect of sowing time in different location of the world were presented below:

Alam *et al*. (2014) experimented that the highest DM (19.5 g m^{-2}) was obtained from the variety BARI Gom-28 at 20 DAS in normal sowing (30 November), but the lowest (8.0 g m^{-2}) in late sowing (30 December) condition.

Suleiman *et al*. (2014) experimented and reported that yield and yield components were condensed due to delay in sowing date and when cultivars were sown on 1^{st} November and 15^{th} November, the highest values were observed. They also showed that late sowing shortened the development phases of wheat and adversely influenced the grain development and ultimately the grain yield.

Atikulla (2013) conducted an experiment that out of 3 different sowing dates November 19, (S_1) and November 29 (S_2) sowing was found to record statistically the higher results than that of December sowing (S_3). Again between 2 sowings in November, November 19 sowing (S_1) showed better performance than that of November 29 sowing (S_2).

Hakim *et al*. (2012) showed that all genotypes were significantly influenced by high temperature stress in late and very late sowing conditions shortening days to heading and maturity resulting in lowering yield of wheat. They also reported that genotype ‘E-8’ obtained maximum yield (6245 kg ha^{-1}) whereas lowest yield was observed in late (5220 kg ha^{-1}) and very late sowing (4657 kg ha^{-1}) conditions.

Hossain *et al*. (2011) stated that highest yield was obtained wheat sown in November 22 to December 20 compared to November 08, 15 and December 27.

Tahir *et al.* (2009) observed that higher grain yield (4.29 t ha^{-1}) was attained as wheat was sown on 1st December as well as lowest grain yield (2.11 t ha^{-1}) obtained because of late sowing (30th December).

Rahman (2009) recorded that grain yield, biomass at anthesis, ground cover at 4-5 leaf stage, days to anthesis, maturity and flag leaf emergence, plant height, grain filling duration and 1000-grain weight were obtained significantly due to sowing in optimum time (November 17).

Haider (2007) carried out an experiment with three different sowing dates on growth of four varieties of wheat that crop growth rate (CGR), relative leaf growth rate (RLGR) and specific leaf area (SLA) were higher in the early sown plants compared to late sown plants.

Ahmed *et al*. (2006) observed that grain and straw yields amplified significantly with early sowing (30 November) in all varieties. The highest grain (2.55 t ha^{-1}) and straw yield (4.28 t ha^{-1}) produced due to early sowing (30 November), whereas the lowest grain yield (1.23 t ha^{-1}) and straw yield (3.21 t ha^{-1}) was obtained from delay sowing.

Ahmed *et al*. (2006) reported that number of tiller enhanced significantly with early sowing (30 November) in all varieties in both the years. Zende *et al*. (2005) revealed that the growth, yield and yield attributes, excluding for the spike length significantly increased when durum wheat crops were sown on 15 November compared with those sown on 1 December and 15 December.

Shafiq (2004) revealed that early sowing increased germination per unit area, plant height, spikelets $spike^{-1}$, grains $spike^{-1}$ and 100-grain weight compared to late sowing.

Chowdhury (2002) stated that plant height reduced for late sowing. The highest plant height was obtained in plant sown in first November at the final harvest. But at 60 DAS highest plant height was observed in plant sown on 15 December. He also observed that average tillers $plant^{-1}$ became higher when wheat was sown in 15 November and the second highest number were produced by November 30 sown plants. The lowest number of tillers $plant^{-1}$ obtained when sown on 15 December.

Samuel *et al*. (2000) found that the harvest index was declined from (41.5%) of normal sowing condition to (36.1%) (29 November) late sowing condition (6 January) in wheat.

BARI (1997) revealed the result that wheat produced the lowest grain yield sown on 20 December. Grain yield reduced severely when the crop was sown on December 5 or later.

Eissa *et al*. (1994) stated that spikes m^{-2} and grains $spike^{-1}$ were increased significantly while grain weight non-significantly reduced as wheat was sown lately from November to December.

Sharma (1993) revealed the results saying that due to delayed sowing harvest index was declined by late sowing whereas maximum harvest index of 41.1% obtained on 25 November sown plants.

Sekhon *et al*. (1991) revealed the result that early sowing reduced the number of spikelet's $spike^{-1}$, grains $spike^{-1}$ whereas 1000-grain weight and yield of wheat were increased. They also reported that 1000 grain weight and yield were declined for sowing lately.

Hossain *et al*. (1990) observed that utmost grain yield was obtained when the wheat was sown November 20 due to higher number of grains spike-^{1} and the highest 1000-grain weight.

Saunders (1988) observed that, yield is decreased in 1.2% ha^{-1} day^{-1} for delayed wheat sowing after December 1 compared to optimum time (November 15 to 1st week of December) for potential yield.

BARI (1984) conducted an experiment in Joydebpur and Jessore that the tallest plant (76.83 cm) of the cultivar Balaka was obtained at Jessore when sowing was done on 20 November and shortest with 30 December sowing.

It is proved that sowing time has a direct influence on yield and yield components of wheat by reviewing above cited literature. The literature provides information that early or late sowing other than optimum time reduces the yield of wheat compared to optimum sowing. In respect to early or late the growing period of the crop is adversely affected by the temperature. Grain yield is decreased due to reduction of number of spike $plant^{-1}$, grains $spike^{-1}$ and thousand grain weights for short period of the development of these parameters.

2.3 Combination influence of irrigation and sowing time on growth and yield of wheat

Atikulla (2013) observed that each of the 3 different dated irrigated plots gave better performance than that of the non-irrigated plot in all the parameters studied. Among the 3 different dates of irrigation, irrigation at crown root initiation stage (I_1), recorded the maximum values in all the parameters studied but it was statistically similar with irrigation at flowering (I_2) and irrigation at grain filling stage of wheat (I_3) and out of 3 different sowing dates including November 19, 2012 (S_1) , November 29, 2012 (S_2) sowing and December 9 sowing date (S_3) the highest biological yield (8.94 t ha^{-1}) was observed from S_1, while the lowest biological yield (8.25 t ha^{-1}) was recorded from S_3 which was statistically similar with S_2 (8.38 t ha^{-1}).

Hassanein *et al.* (2012) conducted a field experiments to study the effects of two sowing dates and three irrigation levels (60, 80 and 100% of the full water requirements) on grain yield and its attributes of four bread wheat, *Triticum aestivum*, cultivars (Gemmeiza 9, Giza 168, Sakha 93 and Misr 1). Two climate change scenarios have been employed with changes in temperature. The first scenario supposed that increasing in temperature of 1.5°C would happen, and the second scenario supposed that increasing of 3.5°C would happen. The results showed that by comparing results obtained from CERES-Wheat model and actual observations in the field enabled us to reach very good calibration and validation of the model for predicting phonological stages as well as grain yield at different locations using different treatments. The future impacts of climate change on wheat showed that increasing in temperature will reduce length of growing cycle and the time needed to full tillering in addition to the final yield. This subsequently will reduce the amount of grain yield; accelerate time for maturity and harvesting. For +1.5°C scenario, reduction in grain yield, as predicted by the model, will be in average among cultivars of 12% at Sakha location, 9% at Sids location and 11% at Shandaweel location. Scenario of +3.5°C will reduce grain yield within an average of 27% at both Sakha , Sids locations, and 31% at Shandaweel location. We can conclude that reduction in wheat grain yield at the three locations has high probability in the future with accelerating growing cycle, especially at +3.5°C, which needs to define earlier sowing suitable dates and adaptive agronomical practices.

CHAPTER III
MATERIALS AND METHODS

The present study was undertaken to compare different times of irrigation along with CRI stage (only for crop management) and different sowing times in wheat. The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2014 to April, 2015. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.1.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area had sub-tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March).Monthly mean air temperature, relative humidity and rainfall of the experimental site during the period from November 2014 to March 2015 is shown Appendix II.

3.1.4 Soil

The soil of the experimental site 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. Soil pH ranges from 5.4-5.6 and had organic carbon 0.82%. The experimental area was flat having available irrigation and drainage system and above flood level is shown in Appendix III.

3.2 Details of the Experiment

3.2.1 Treatments

The experiment will be undertaken to study the effect of three irrigation times(as main plot) and four sowing times(as sub-plot).

A. Main plot (Time of irrigation-3):

1. I_1=Irrigation at heading stage
2. I_2=Irrigation after 10 days of I_1
3. I_3=Irrigation after 10 days of I_2

B. Sub-plot (sowing time -4):

1. S_1= 1st sowing on 10 November
2. S_2= 2nd sowing on 20 November
3. S_3= 3rd sowing on 30 November
4. S_4= 4th sowing on 10 December

3.2.2 Experimental design

The experiment was laid in a split-plot design with three replications having time of irrigation in the main plots and different sowing times in the sub-plots. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 2.75 m by 1.8 m. The distance between plot to plot 0.5 m and distance between replication to replication were maintained 1 m. The layout of the experiment has been shown in Appendix IV.

3.3 Description of materials

3.3.1 Source of seed

Seeds of BARI Gom25 were collected from BARI, Joydebpur, Gazipur, Bangladesh. It is a high yielding variety and suits better as a late variety. Plant height ranges 90-96 cm producing 5-6 tillers plant^{-1}. seeds spike^{-1} is 45-50 containing seed whitish in colour. BARI

Gom 25 matures within 104-110 days and yield varies between 3500-4500 kg ha^{-1}. The cultivar is claimed to be resistant to leaf rust and leaf spot.

3.3.2Source of irrigation

Irrigation water was supplied from the ground water by pump near the experimental field.

3.4 Crop management

3.4.1 Preparation of experimental land

The land was first ploughed on 18 October, 2014 by disc plough. The land was then harrowed again on 26 and 28 October to bring the soil in a good tilth condition. The final land preparation was done by disc harrow on 30 October, 2014. The land was prepared thoroughly and leveled by a ladder. Weeds and stubbles were removed from the field. The experiment was laid out on 10 November, 2014 according to the design adopted.

3.4.2 Fertilizer application

Fertilizer dose and methods of application

Urea, TSP, MoP and Gypsum fertilizers respectively were applied. The whole amount of TSP, MP and Gypsum, 2/3rd of urea were applied at the time of the final land preparation. Rest of urea was top dressed after first irrigation (BARI, 2006). Two third of urea, the entire amounts of TSP, MoP and gypsum were applied at final land preparation as a basal dose.

Table 1. Doses and method of application of fertilizers in wheat field

Fertilizers	Dose (per ha)	Application (%)	
		Basal	1st installment
Nitrogen	101.2 kg	30.66	15.33
Phosphorus	86.4 kg	48	--
Potassium	30 kg	60	--
Sulphur	96 kg	18	--
Cowdung	10 ton	100	--

Source: Krishi Projukti Hatboi, BARI, Joydebpur, Gazipur, 2011

3.4.3 Sowing of seeds

Seeds were sown on 10th November,20th November,30th November and 10th December, 2014 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 5 cm shade**.**

3.5Intercultural operations

3.5.1 Weeding

During plant growth period two hand weeding were done. First weeding was done at 20 days after sowing followed by second weeding at 15 days after first weeding. Identified weeds were Kakpaya ghash (*Dactyloctenium aegyptium* L.), Shama (*Echinocloa crussgalli*), Durba (*Cynodon dactylon*), Mutha (*Cyperus rotundus L*.) Bathua (*Chenopodium album*), Shaknatey (*Amaranthus viridis*) and Tita begun (*Solanum torvum*).

3.5.2 Plant protection measures

The wheat crop was infested by Aphid. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times.

3.5.3 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.

3.5.4 Harvesting and post-harvest operation

Maturity of crop was determined when 90% of the spike became golden yellow in color. Five plants per plot were preselected randomly from which different 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.

3.5.5 Thinning and gap filling

Thinning was done as and where necessary with finger. No gap filling was done for any treatment.

3.6 Recording of data

Experimental data were recorded from40 days after sowing duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of hills at different dates from the inner rows leaving border rows and harvest area for grain. The followings data were recorded during the experiment.

A. Crop growth characters

i. Plant height (cm) with 25 days interval from 40 DAS to harvest
ii. Number of tillers hill^{-1} with 25 days interval from 40 DAS to harvest
iii. Leaf area index with 25 days interval from 40 DAS to harvest
iv. Dry weight of plant with 25 days interval from 40 DAS to harvest

B. Yield and other crop characters

i. Days to flowering
ii. Days to maturity
iii. Spike length (cm)
iv. Number of spikelets spike^{-1}
v. Number of grains spike^{-1}
vi. Weight of 1000 grains (g)
vii. Grain yield (t ha^{-1})
viii. Straw yield (t ha^{-1})
ix. Biological yield (t ha^{-1})
x. Harvest index (%)

3.7 Detailed procedures of recording data

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

A. Crop growth characters

i. Plant height (cm)

Plant height was measured at 25 days interval starting from 40 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.

ii. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 25 days interval starting from 40 DAS and up to harvest and finally averaged as their number hill^{-1}.

iii. Leaf Area Index (LAI)

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

iv. Dry weight of plant^{-1}

Three plants at different days after sowing (40, 65, 90 DAS and at harvest) were collected and oven dried at70°C for 72hours.The dried samples were then weighed and averaged.

B. Yield and other crop characters

i. Days to flowering

Days to flowering were recorded by calculating the number of days from sowing to starting of flowering by eye observation of the experimental plots during the experimental period.

ii. Days to maturity

Days to maturity were recorded by calculating the number of days from sowing to beginning of maturity when spikes become brown in colour by eye observation of the experimental plot.

iii. Spike length (cm)

Spike length was recorded from the basal code of the rachis to the apex of each spike.

iv. Number of spikelets spike^{-1}

Total number of spikelets in a spike was counted. It included both sterile and non-sterile spikelets.

v. Number of grainsspike^{-1}

The number of grains spike^{-1} was counted from 5 spikes and number of grains spike^{-1} was measured by following formula:

Number of grains spike^{-1} =$\frac{TotalNo.\ of grains}{No.\ of spike}$

vi. Weight of grains spike^{-1} (g)

The weight of grains spike^{-1} was weighed from 5 spikes and weight of grains spike^{-1} was measured by following formula:

Weight of grains spike^{-1}=$\frac{Totalweightofgrains}{No.ofspike}$

vii. Weight of 1000grains

One thousand grains were counted randomly from the total cleaned and dried harvested grains of each individual plot and then weighed and recorded which was expressed in grams.

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

Grain yield was determined from the central 1m^{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.

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

Straw yield was determined from the central 1m^2 area of each plot, after separating the grains. Straws were sun dried, weighed to determine the straw yield plot^{-1} and was expressed in t ha^{-1}.

x. Biological yield (t ha^{-1})

Biological yield of a crop is defined as the sum of grain yield and straw yield. The biological yield of wheat was measured for each plot and express in t ha^{-1}.

The biological yield was estimated with the following formula:

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

xi. Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula. (Gardner *et al*., 1985).

Harvest index (%)=$\frac{Total\ grain\ yield\ (t/ha)}{Total\ biological\ yield\ (t/ha)}\times 100$

3.8. Statistical analysis

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using STATISTICS-10 computer package program and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

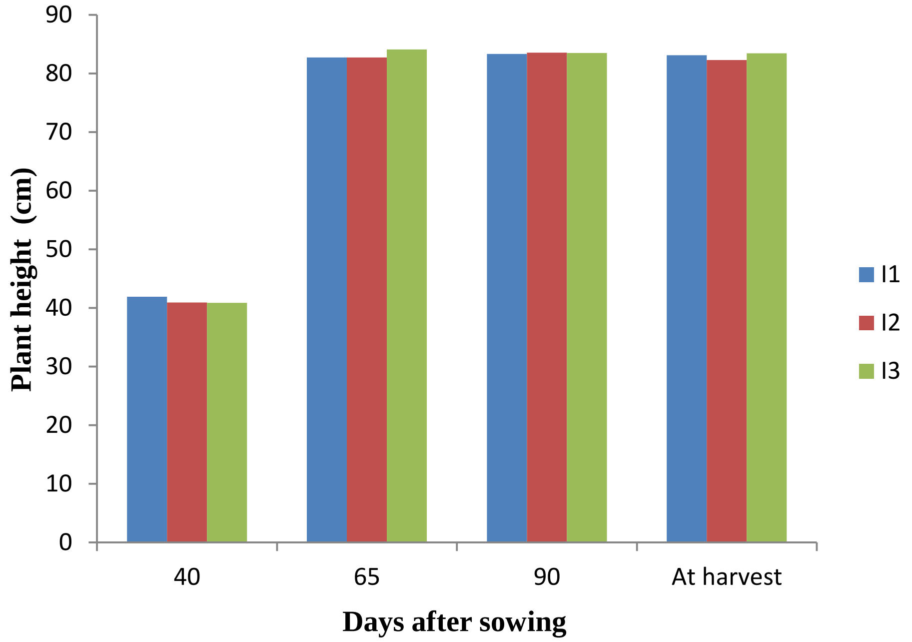
The results obtained from the present study regarding the effects of single irrigation and time of sowing and their interaction on the yield and yield components have been presented, discussed and compared in this chapter under the following headings:

4.1. Crop Growth Characters

4.1.1. Plant height

Effect of irrigation

Plant height of wheat observed significant at 40 DAS and insignificant at 65, 90 DAS and at harvest due to time of single irrigation (Figure 01, Appendix V). At 40 DAS, the tallest plant (41.92cm) was recorded from I_1 while the shortest plant (40.89 cm) was observed from I_3. Similar result was found by Sarkar (2015) who recorded 8.51% higher plant height from irrigation before heading stage. At 65 DAS, the tallest plant (84.10 cm) was found from I_3 followed by I_2 (82.74) while the shortest plant (82.70 cm) was observed from I_1 all of these were statistically similar. Tallest plant (83.56 cm) was recorded from I_2 at 90 DAS while the shortest plant (83.35 cm) was obtained from I_3 which was statistically similar to I_3 (83.49). At harvest, the tallest plant (83.45 cm) was observed from I_3 followed by I_1 (83.10) similar to the shortest plant (82.31 cm) from I_2.Sultana (2013) stated that increasing water stress declined the plant height.

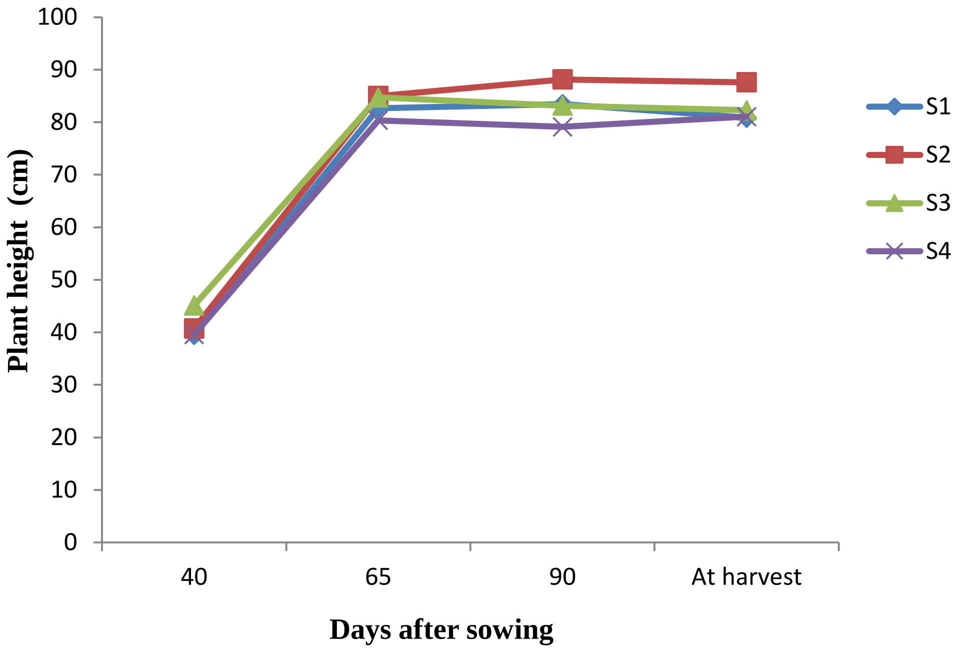


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.01 Effect of time of irrigation on plant height of wheat ($LSD_{(0.05)}$= 0.50at 40DAS)

Effect of sowing time

Significant variation for plant height of wheat at 40, 65, 90 DAS and at harvest was observed due to different sowing time (Figure 02, Appendix V). The highest plant height at 40 days (45.13 cm) obtained from S_3 statistically dissimilar to other and the lowest (39.50 cm) observed in S_1 statistically similar to other except S_1. At 65 days, highest plant height (84.99 cm) was obtained from S_2 followed by S_3 (84.71 cm) was statistically similar and lowest (80.35 cm) was observed in S_4. At 90 days, same trend of 65 DAS was observed. The highest plant height (88.16cm) at 90 days was obtained from S_2 and lowest (79.12 cm) was observed in S_4. The highest plant height (85.07 cm) at harvest was obtained from S_2 and lowest (87.61 cm) was observed in S_1 which was statistically similar to all except S_2. BARI (1984) reported a similar report supporting to present studies that the tallest plant (76.83 cm) when sowing was done on 20 November and shortest with 30 December sowing.



S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

Fig.02 Effect of sowing time on plant height of wheat ($LSD_{(0.05)}$ = 2.24, 1.96, 1.23 and 1.81 at 40, 65, 90 DAS and at harvest, respectively).

Interaction effect of irrigation and sowing time

Interaction effect of irrigation time and sowing time showed significant differences on plant height of wheat at 40, 65, 90 DAS and at harvest (Table 01, Appendix V). The highest plant height (45.69 cm) at 40 DAS was obtained from I_2S_3 which was statistically similar with I_1S_3 (44.88 cm), I_3S_2 (42.46 cm) and I_3S_3 (44.82 cm). At 65 DAS and at harvest the tallest plant (87.53 cm and 89.50 cm) was obtained from I_3S_2 and the lowest (79.31cm and 77.87 cm) was obtained from I_2S_4 with a significant variation. At 90 DAS, the highest plant height (88.26cm) observed in I_2S_2 and lowest (77.93 cm) observed in I_3S_3.

Table 01. Interaction effects of irrigation and sowing time on plant height at different days

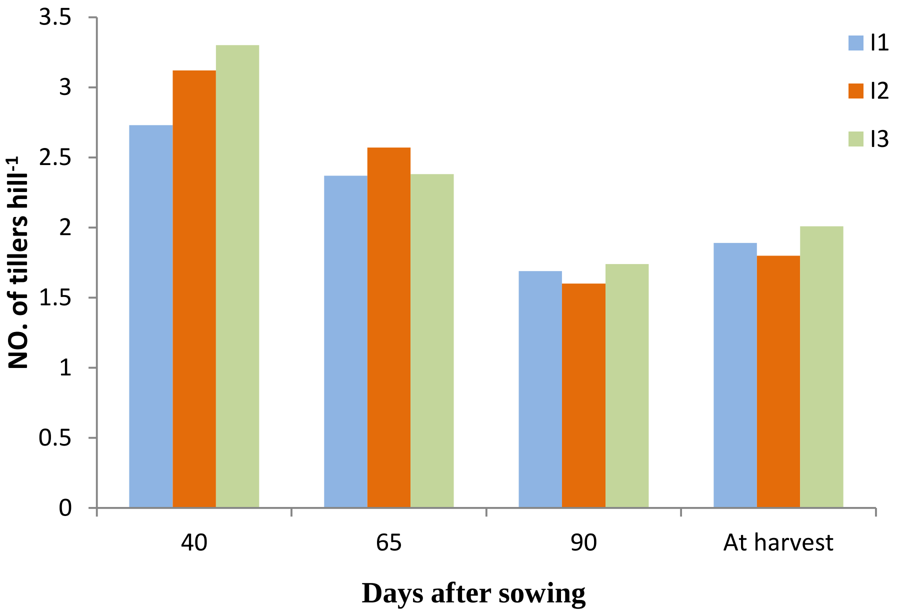
Treatments		Plant height (cm) at DAS			
		40	65	90	At harvest
I_1	S_1	40.06	83.15	83.12	80.25
	S_2	41.06	83.54	88.10	85.77
	S_3	44.88	84.42	83.81	83.26
	S_4	41.65	79.67	78.38	83.11
I_2	S_1	41.25	81.73	84.66	80.90
	S_2	38.77	83.92	88.26	87.57
	S_3	45.69	86.01	83.40	82.90
	S_4	37.98	79.31	77.93	77.87
I_3	S_1	37.17	83.12	82.54	81.49
	S_2	42.46	87.53	88.11	89.50
	S_3	44.82	83.68	82.27	80.65
	S_4	39.13	82.07	81.03	82.17
$LSD_{(0.05)}$		3.88	3.40	2.14	3.13
CV (%)		5.49	2.38	1.49	2.20

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2 and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

4.1.2Number of tillers hill^{-1}

Effect of irrigation

Effect of different time of irrigation was insignificant in terms of number of tillers hill^{-1} of wheat at 40, 90 DAS and at harvest except 60 DAS (Figure 03, Appendix VI). At 40, 90 and at harvest, the highest number of tillers hill^{-1} (3.30, 1.74 and 2.01 respectively) were recorded from I_3, while the corresponding lowest number of tillers hill^{-1} (2.73, 1.60 and 1.80 respectively) was observed in I_1, I_2 and I_2 respectively. At 65 DAS, the highest number of tillers hill^{-1} (2.57) was recorded from I_2 but lowest number of tillers hill^{-1} (2.37) was observed in I_1 which was statistically similar with I_3 (2.38). Sultana (2013) stated that increasing water stress reduced the number of tillers hill^{-1}.

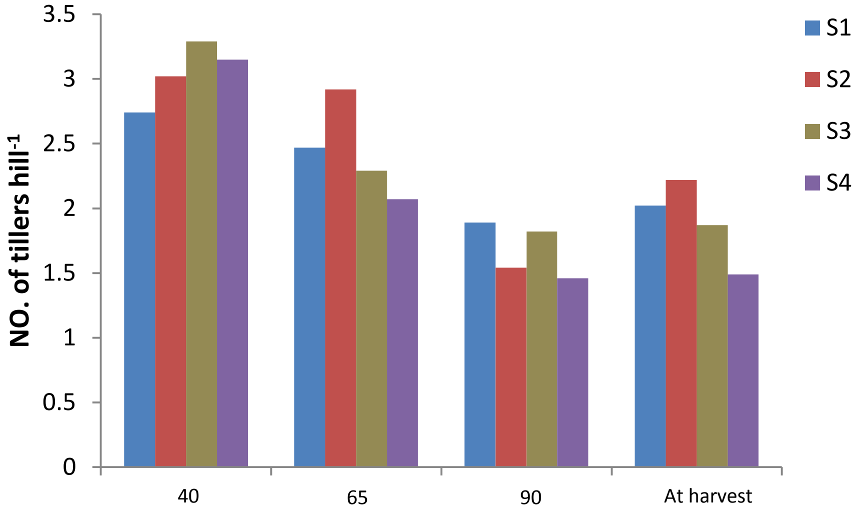


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.03 Effect of time of irrigation on number of tillers hill^{-1} (LSD$_{(0.05)}$ = 0.18at 65DAS).

Effect of sowing time

Number of tillers hill^{-1} of wheat showed statistically significant variation at 40, 65, and at harvest due to different sowing date (Figure 04, Appendix VI). At 40 DAS, the highest number of tillers hill^{-1} (2.92) was found in S_3 was statistically similar with all except the lowest tillers hill^{-1} from S_1 (2.74). At 65 DAS and at harvest, the highest and the lowest tillers hill^{-1} (2.92, 2.22 and 2.07, 1.49 respectively) were found statistically dissimilar. At 90 DAS, the highest and the lowest tillers hill^{-1} (1.89 and 1.46 respectively) were observed from S_1 and S_4 respectively, were statistically similar with all other treatments. BARI (1984) reported that 20 November sowing produced the highest number of effective tillers hill^{-1}.



Days after sowing

S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.04 Effect of sowing times on number of tillers hill^{-1} (LSD$_{(0.05)}$ = 0.40, 0.35 and 0.30 at 40, 65DAS and at harvest, respectively)

Interaction of irrigation and sowing time

Time of irrigation and sowing date showed significant differences on number of tillers hill^{-1} of wheat due to interaction effect at 40, 65 and at harvest except 90 DAS (Table 02, Appendix VI). At 40 DAS, the highest number of tillers hill^{-1} (3.47) was observed from I_3S_3 which was statistically similar with all combination of treatments except I_1S_1 and I_2S_2 while the lowest number of tillers hill^{-1} (2.20) was recorded from I_1S_1. At 65 DAS, the highest number of tillers hill^{-1} (3.50) was observed from I_1S_2 which was statistically similar with I_2S_2 (3.00) and I_3S_1 (2.90) and the lowest number of tillers hill^{-1} (1.70) was recorded from I_1S_1. At 90 DAS, tillers hill^{-1}was insignificant due to interaction effect of irrigation and sowing time but numerically the highest number of tillers hill^{-1} (2.00) was observed from I_3S_1 and the lowest number of tillers hill^{-1} (1.30) was recorded from I_3S_4. At harvest, the highest number of tillers hill^{-1} (2.70) was observed from I_3S_2 which was statistically significant to all other combination and the lowest number of tillers hill^{-1} (1.40) was recorded from I_2S_4.

Table 02. Interaction effects of amount of irrigation and sowing time on number of tillers hill^{-1} at days after sowing

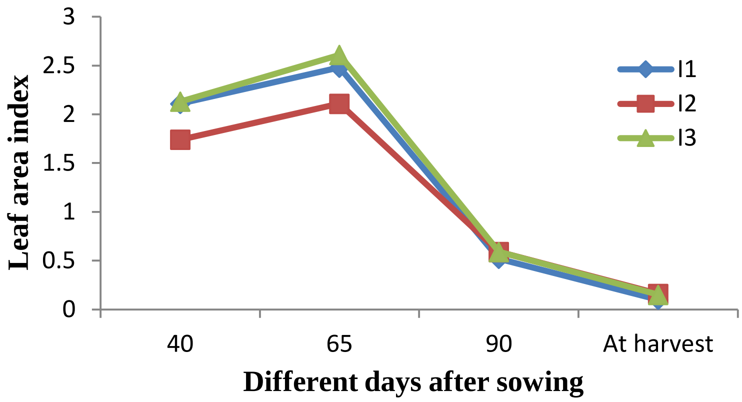
Treatments		Number of tillers hill^{-1} at DAS			
		40	65	90	At harvest
I_1	S_1	2.20	1.70	1.93	2.07
	S_2	2.60	3.50	1.30	2.10
	S_3	3.00	2.27	1.93	1.87
	S_4	3.13	2.00	1.60	1.53
I_2	S_1	3.01	2.80	1.73	2.07
	S_2	3.07	3.00	1.47	1.87
	S_3	3.40	2.47	1.73	1.87
	S_4	3.00	2.00	1.47	1.40
I_3	S_1	3.00	2.90	2.00	1.93
	S_2	3.40	2.27	1.87	2.70
	S_3	3.47	2.13	1.80	1.87
	S_4	3.33	2.20	1.30	1.53
$LSD_{(0.05)}$		0.69	0.61	NS	0.51
CV (%)		13.16	14.65	27.14	15.68

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2 and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

4.1.3 Leaf area index at different days after sowing

Effect of irrigation

Leaf area index (LAI) was not significantly influenced by time of irrigation except the area measured at harvest (Figure 05, Appendix VII). The result revealed at 40 and 65 DAS, higher LAI (2.13 and 2.61 respectively) was produced by I_3 where lower LAI (1.74 and 2.11 respectively) were observed in I_2 that were statistically similar to each other. At 90 DAS, numerically higher LAI (0.59) from I_2 and I_3 but the lowest LAI was documented from Irrigation during heading stage (I_1). At harvest, the effect of irrigation time on LAI was significant and higher LAI (0.16) from I_2.

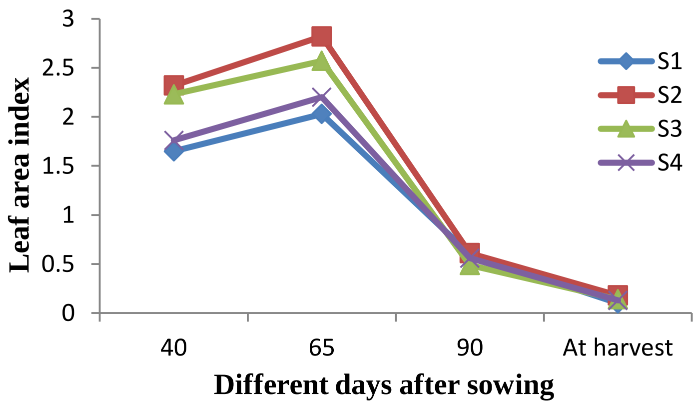


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.05 Effect of time of irrigation on leaf area index ($LSD_{(0.05)}$ = 0.04at harvest)

Effect of sowing time

Leaf area index (LAI) was influenced significantly by time of sowing except the leaf area index measured at 90 DAS (Figure 06, Appendix VII). The result revealed at 40, 65 and 90 DAS and at harvest, the highest LAI (2.32, 2.82, 0.61 and 0.18 respectively) was produced by S_2 where lower LAI (1.65, 2.03 and 0.10) were observed at 40 DAS, 65 DAS and at harvest from S_1 but lower LAI (0.49) was calculated from S_3 at 90 DAS.



S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

Fig.06 Effect of sowing times on leaf area index ($LSD_{(0.05)}$ = 0.33, 3.40 and 0.06 at 40, 65 DAS and at harvest, respectively).

Interaction of irrigation and sowing time

Time of irrigation and sowing date showed significant differences on LAI of wheat due to interaction effect at 40, 65 and at harvest except 90 DAS (Table03, Appendix VII). At 40 DAS, the higher LAI (2.75) was observed from I_1S_2 which was statistically similar with all combination of treatments except I_1S_1 (1.65), I_1S_4 (1.65), I_2S_1 (1.41) and I_2S_4 (1.67) while the lowest LAI (1.41) was recorded from I_2S_1 which were statistically similar with all interaction except I_1S_2 (2.75), I_1S_3 (2.38) and I_3S_3 (2.40). At 65 DAS, the highest LAI (2.99) was observed from I_1S_2 and the lowest LAI (1.61) was recorded from I_2S_1. At 90 DAS, LAI was insignificant due to interaction effect of irrigation and sowing time but numerically the higher LAI (0.67) was observed from I_2S_2 and the lowest LAI (0.47) was recorded from I_2S_3. At harvest, the higher LAI (0.23) and the lower LAI (0.08) was produced from I_3S_2 and I_1S_4 respectively.

Table 03. Interaction effects of irrigation and sowing time on leaf area index at different days after sowing

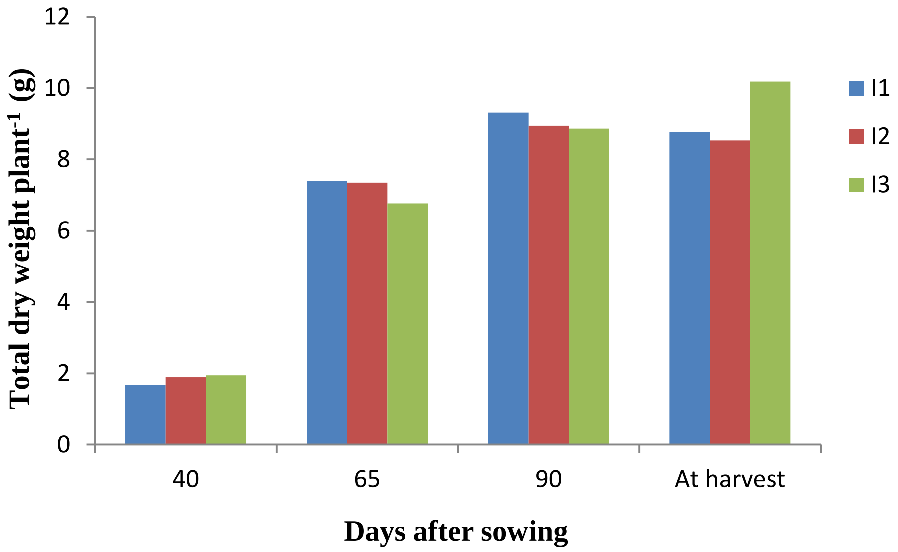
Treatments		Leaf area index at DAS			
		40	65	90	At harvest
I_1	S_1	1.65	2.22	0.59	0.09
	S_2	2.75	2.99	0.48	0.10
	S_3	2.38	2.81	0.52	0.13
	S_4	1.65	1.89	0.50	0.08
I_2	S_1	1.41	1.61	0.66	0.11
	S_2	1.97	2.51	0.67	0.20
	S_3	1.90	2.26	0.47	0.18
	S_4	1.67	2.09	0.53	0.17
I_3	S_1	1.89	2.24	0.56	0.12
	S_2	2.25	2.95	0.67	0.23
	S_3	2.40	2.63	0.48	0.12
	S_4	1.96	2.61	0.64	0.15
$LSD_{(0.05)}$		0.57	0.69	NS	0.09
CV (%)		16.78	16.68	37.11	41.47

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2 and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

4.1.4 Dry weight plant^{-1}

Effect of irrigation time

Dry weight plant^{-1} was not significantly influenced by different irrigation treatments at all stages except 90 DAS (Figure 07, Appendix VIII). The highest dry weight (1.94g plant^{-1}) at 40 days was obtained from I_3 and the lowest (1.67g plant^{-1}) was observed in I_1.The highest dry weight (7.39 g plant^{-1}) at 65 days was obtained from I_1 and lowest (6.76g plant^{-1}) was observed in I_3.The highest dry weight (9.31 g plant^{-1}) at 90 days was obtained from I_1 and lowest (8.86g plant^{-1}) was observed in I_3.The highest dry weight (10.18g plant^{-1}) at harvest was accumulated from I_3 and lowest (8.53g plant^{-1}) was weighed in I_2. Abdorrahmani *et al*. (2005) observed that dry matter production was reduced due to drought stress.

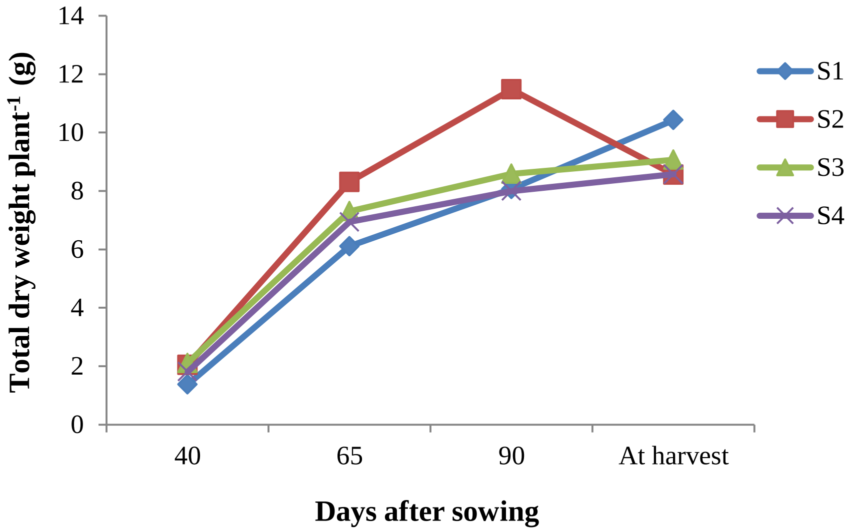


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.07 Effect of time of irrigation on dry weight plant^{-1} (LSD$_{(0.05)}$ = 0.89at harvest).

Effect of sowing time

Significant variation was observed in case of dry weight plant^{-1} with sowing time at all stage of growing time (Figure 08, Appendix VII).The highest dry weight (2.11g plant^{-1}) at 40 days was weighted from S_3 which was statistically similar with all except S_1 (1.37 g plant^{-1}) was weighted lowest. .The highest dry weight (8.31 g plant^{-1}) at 65 days was obtained from S_2 which was statistically similar to S_3 (7.31 g plant^{-1}) and S_4 (6.94g plant^{-1}) and the lowest (6.11 g plant^{-1}) was observed in S_1.At 90 DAS, the highest dry weight (11.48 g plant^{-1}) was obtained from S_2 and lowest (8.00 g plant^{-1}) was observed in S_4.The highest dry weight plant^{-1} at harvest obtained from S_4 (10.43 g plant^{-1}) and lowest (8.56 g plant^{-1}) observed in S_2.But, Alam *et al*. (2014) found that the highest DM (19.5 g m^{-2}) was obtained from the variety BARI Gom28 at 20 DAS in normal sowing (30 November), but the lowest (8.0 g m^{-2}) in late sowing (30 December) condition.



S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.08 Effect of sowing times on total dry weight plant^{-1} (LSD$_{(0.05)}$ = 0.33, 1.54, 1.56 and 0.87at 40, 65, 90 DAS and at harvest, respectively)

Interaction effect of irrigation and sowing time

The interaction effects between irrigation time and sowing time were significant for the dry weight plant^{-1} at 40,65, 90 DAS and at harvest (Table 05, Appendix VIII).The highest dry weight (2.22 g plant^{-1}) at 40 days was obtained from I_2S_2 which was statistically similar to all interaction except I_1S_1 (1.33 g plant^{-1}) and I_2S_1 (1.22 g plant^{-1}).The highest dry weight at 65 days, (8.78g plant^{-1}) was obtained from I_3S_2, at 90 DAS (11.78g plant^{-1}) was obtained from

I_3S_2 and at harvest (11.83g plant^{-1}) was obtained from I_3S_1.The lowest dry weight (5.72 g plant^{-1}) was obtained from I_3S_4 at 65 days. At 90 DAS lowest (7.33g plant^{-1}) obtained from I_3S_4 and at harvest, lowest (7.33g plant^{-1}) was obtained from I_1S_2.

Table 04. Interaction effects of irrigation time and sowing time on dry weight plant^{-1} at days after sowing

Treatments		Dry weight plant^{-1} at DAS			
		40	65	90	At harvest
I_1	S_1	1.33	6.22	8.33	10.45
	S_2	1.78	8.67	11.33	7.33
	S_3	2.11	7.49	9.33	8.49
	S_4	1.44	7.19	8.22	8.80
I_2	S_1	1.22	6.11 c	8.33	9.00
	S_2	2.22	7.50	11.33	8.58
	S_3	2.11	7.89	7.66	8.89
	S_4	2.00	7.90	8.44	7.65
I_3	S_1	1.56	6.00	7.55	11.83
	S_2	2.11	8.78	11.78	9.78
	S_3	2.11	6.54	8.78	9.83
	S_4	2.00	5.72	7.33	9.26
$LSD_{(0.05)}$		0.57	2.67	2.71	1.50
CV (%)		18.25	21.70	17.48	9.58

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of $I_2$and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

4.2. Yield contributing character

4.2.1 Days to flowering and maturity

Effect of time of irrigation on days to flowering and maturity

Days to flowering

Days to flowering of wheat showed statistically significant variation due to different time of irrigation (Table 6, Appendix IX). The maximum days to flowering (68.50) was recorded from I_3 followed by I_2 (61.33) and the minimum days to flowering (54.17) was observed from I_1.

Days to maturity

Statistically significant variation was recorded in terms of days to maturity of wheat due to different time of irrigation (Table 6, Appendix IX). The highest days to maturity (113.67) was recorded from I_3while the lowest days to maturity (99.67) was observed from I_3.On the other hand, 107.67 days to maturity was observed from I_2.Sarker (2015) reported that irrigation hastened the maturity period of wheat.

Table 05. Effect of irrigation time on days to flowering and days to maturity of wheat

Irrigation	Days to flowering	Days to maturity
I_1	54.17	99.67
I_2	61.33	107.92
I_3	68.5 0	113.67
$LSD_{(0.05)}$	2.64	3.71
CV (%)	3.79	3.06

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Effect of sowing time on days to flowering and maturity

Days to flowering

Statistically significant variation was found from days to flowering of wheat due to different sowing times (Table 07, Appendix IX). The highest day to flowering (62.89) was observed from S_2 which was statistically similar with S_4 (62.56) while the lowest days to flowering (59.22) were recorded from S_3. Due to high temperature stress days to flowering were shortened on 10 December sowing (S_4). Hakim *et al.* (2012) showed that all genotypes of wheat were significantly influenced by high temperature stress in late and very late sowing conditions shortening days to heading. Spink *et al.* (1993) also found that delayed sowing curtails the duration of each development phase due to increase in temperature.

Days to maturity

Different sowing date showed statistically significant variation for days to maturity of wheat (Table 07, Appendix IX). The highest days (108.89) to maturity was observed from the treatment S_2 which was statistically similar with S_4 (106.89) and the lowest days to maturity S_1 (106.00) which was statistically similar to S_3 (106.56). High temperature stress was responsible for reducing maturity period.

Table 06. Effect of sowing time on days to flowering and days to maturity of wheat

Irrigation	Days to flowering	Days to maturity
S_1	60.67	106.00
S_2	62.89	108.89
S_3	59.22	106.56
S_4	62.56	106.89
$LSD_{(0.05)}$	1.73	2.02
CV (%)	2.85	1.91

S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

Interaction effect of irrigation time and sowing time on days to flowering and maturity

Days to flowering

Interaction effect of different date of irrigation and sowing date showed significant differences on days to flowering of wheat (Table 8, Appendix IX). The highest days to flowering (73.67) was observed from I_3S_4 while the lowest days to flowering (51.67) was recorded from I_1S_3.

Days to maturity

Interaction effect of different time of irrigation and sowing date showed significant differences on days to flowering of wheat (Table 8, Appendix IX). The highest days to maturity (115.00) was observed from I_3S_4 while the lowest days to maturity (98.00) were recorded from I_1S_3.

Table 07. Interaction effect of irrigation time and sowing time on days to flowering and days to maturity of wheat

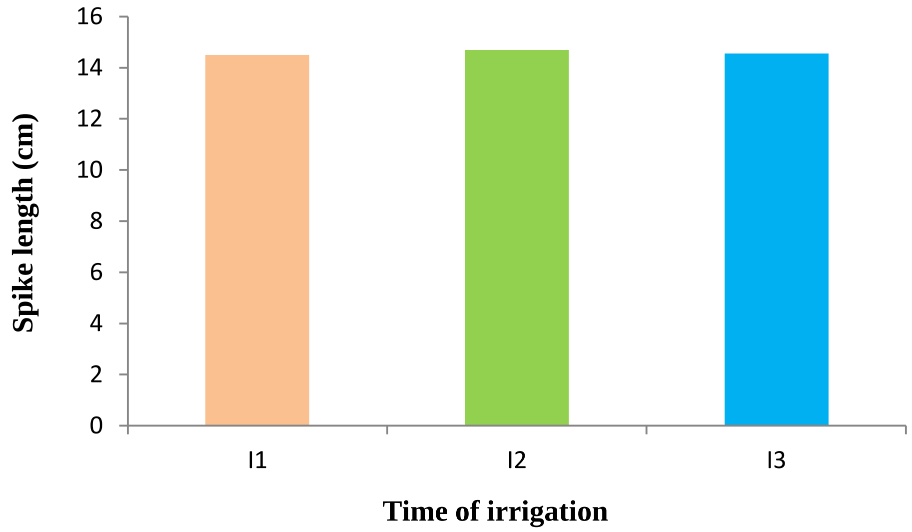
Treatments		Days to flowering	Days to maturity
I_1	S_1	53.00	99.33
	S_2	58.33	102.00
	S_3	51.67	98.00
	S_4	53.67	99.33
I_2	S_1	64.33	107.67
	S_2	62.67	110.67
	S_3	58.00	107.00
	S_4	60.33	106.33
I_3	S_1	64.67	111.00
	S_2	67.67	114.00
	S_3	68.00	114.67
	S_4	73.67	115.00
$LSD_{(0.05)}$		3.00	3.50
CV (%)		2.85	1.91

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of $I_2$and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December.

4.2.2 Spike length (cm)

Effect of irrigation

Effect of irrigation on spike length of wheat was statistically insignificant (Figure 09, Appendix X)). Numerically the highest spike length (14.68 cm) was recorded from I_2 followed by I_3 (14.55) while the lowest spike length (14.50 cm) was observed from irrigation during heading stage (I_1).

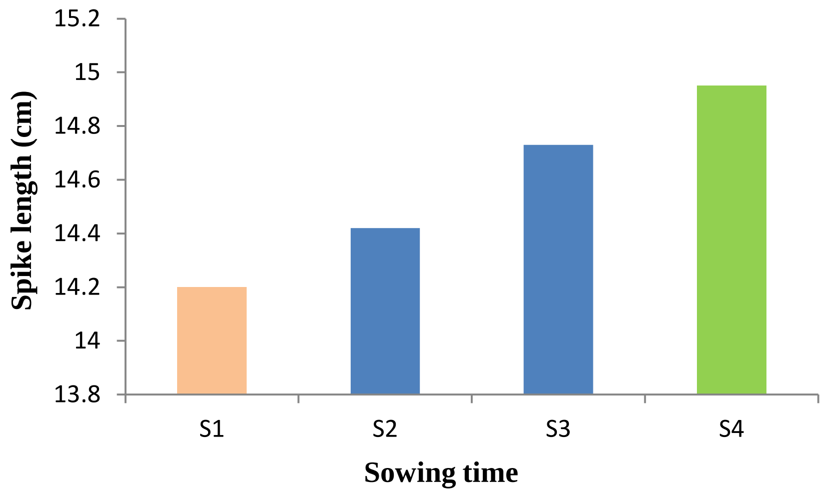


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.09 Effect of time of irrigation on spike length

Effect of sowing time

Spike length of wheat showed statistically significant variation due to varying sowing times (Figure 10, Appendix X). The highest spike length (14.95 cm) was observed in S_4, which was statistically similar to S_3 (14.42 cm) and S_3 (14.73 cm) and the lowest spike length (14.20 cm) was recorded from S_1. Spike length was reduced 5.28 % in early sowing, S_1 (10 November) than highest length. But, Chowdhury (2002) conducted an experiment with four sowing dates and reported that spike length decreased with delay in sowing date from November 15 and the lowest spike length was recorded in December 15 sown plants, is opposite to these study.



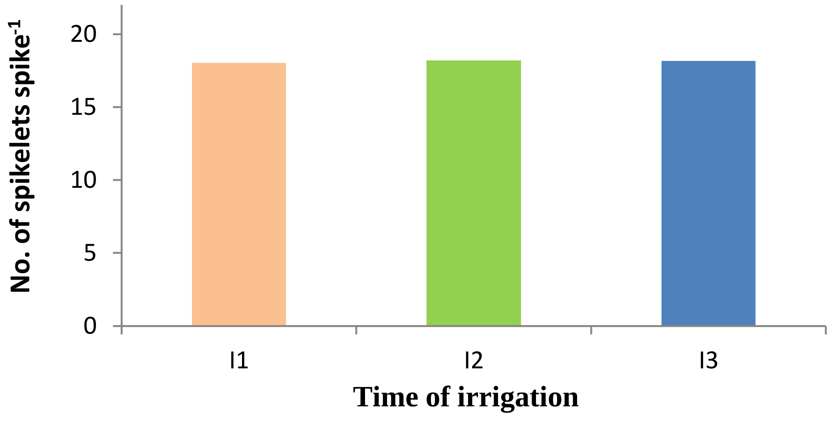
S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.10Effect of sowing times on spike length (LSD$_{(0.05)}$ = 0.74)

4.2.3 Number of spikelets spike^{-1}

Effect of irrigation time

Different time of irrigation showed insignificant variation in terms of number of spikelets spike^{-1} of wheat under the present trial (Figure 11, Appendix X). Numerically the highest number of spikelets spike^{-1} (18.17) obtained from I_2 followed by I_3 (18.15) but the lowest numbers of spikelets spike^{-1} (18.03) was observed in I_1.

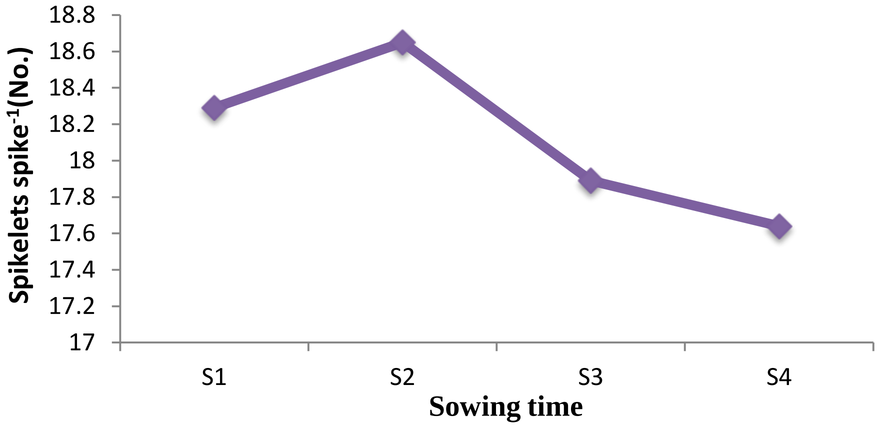


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.11 Effect of time of irrigation on no. of spikelets spike^{-1}

Effect of sowing time

Significant variation was found for number of spikelets spike^{-1} of wheat due to varying sowing times (Figure 12, Appendix X). The highest number of spikelets spike^{-1} (18.65) was observed in S_2 which was statistically similar to S_3 (17.89) and S_1 (18.29) but the lowest number of spikelets spike^{-1} (17.64) was recorded from S_4. In order to optimum sowing time (20 November), S_2 produced highest number of spikelets spike^{-1}compared to late sowing (10 December), S_4. But Shafiq (2004) revealed that early sowing increased spikelets spike^{-1} compared to late sowing.



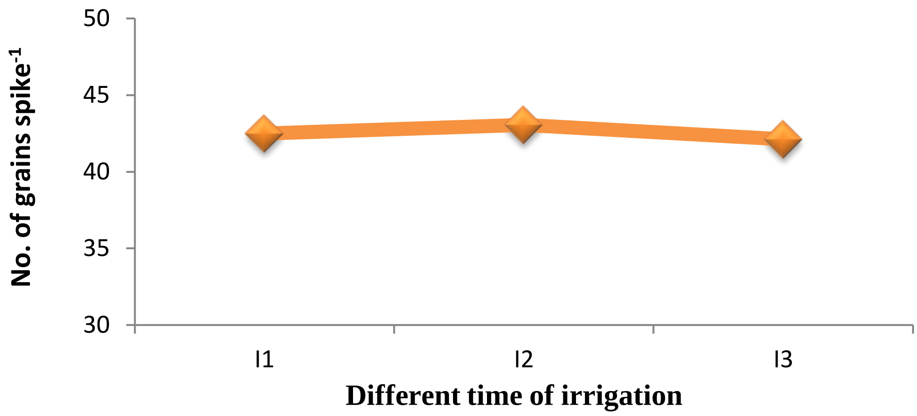
S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.12 Effect of sowing times on no. of spikelets spike^{-1}(LSD$_{(0.05)}$ = 0.95)

4.2.4 Number of grains spike^{-1}

Effect of irrigation

Insignificant effect of irrigation time on number of grains spike^{-1} of wheat was observed (Figure 13, Appendix X). The highest numbers of grains spike^{-1} (43.05) was recorded from I_2 followed by I_1 (42.49) and the lowest (45.92) numbers of grains spike^{-1} was counted from I_3. Razi-us-Shams (1996) observed that irrigation increased number of grains spike^{-1}over the control in wheat.

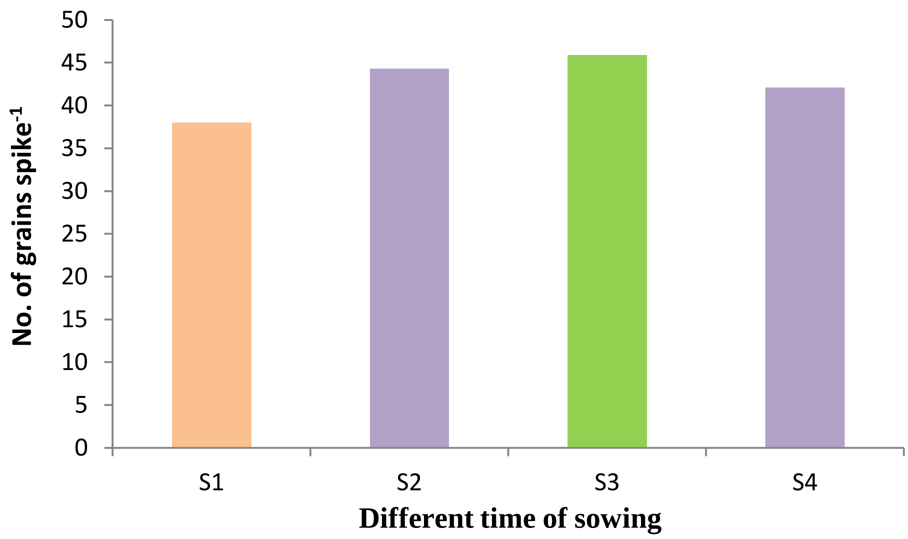


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.13 Effect of time of irrigation on no. of grains spike^{-1}

Effect of sowing time

Statistically significant variation was recorded for number of grains spike^{-1} of wheat under varying sowing times (Figure 14, Appendix X). The highest number of grains spike^{-1} (45.87) was obtained from S_3 which was statistically similar with S_2 (44.29). Sarkar (2015) also found similar result.



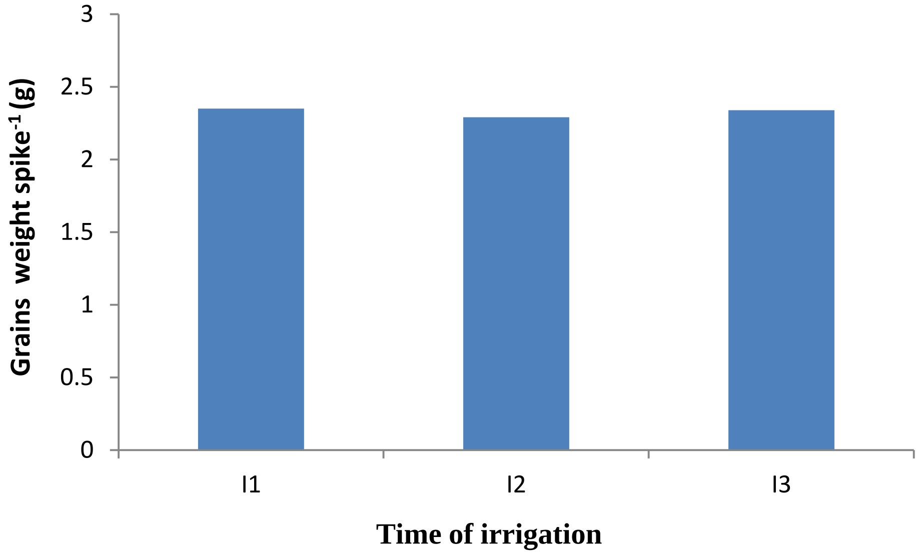
S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.14 Effect of sowing times on no. of grains spike^{-1} (LSD$_{(0.05)}$ = 3.59)

4.2.5 Weight of grains spike^{-1}

Effect of irrigation

It was found that weight of grains spike^{-1} of wheat due to different time of irrigation was insignificant (Figure 15, Appendix X). The treatment I_1 produced the highest (2.35 g) grain weight spike^{-1} whereas I_3 produced lowest (2.29 g) grain weight spike^{-1}.

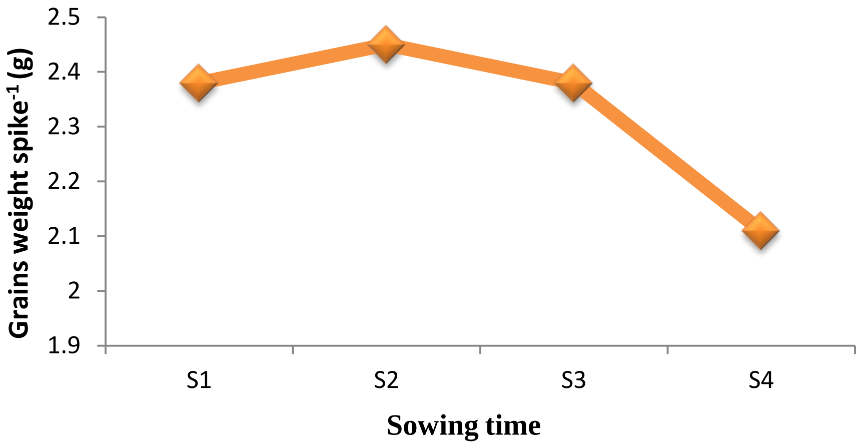


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.15 Effect of time of irrigation on grains weight spike^{-1}

Effect of sowing time

Statistically significant variation was recorded for weight grain spike^{-1} of wheat due to varying sowing times (Figure 16, Appendix X). The treatment S_2 produced significantly the highest (2.45 g) weight of grain spike^{-1} which was statistically similar to all except S_4 while S_4 produced significantly the lowest (2.11 g) grain weight spike^{-1}.



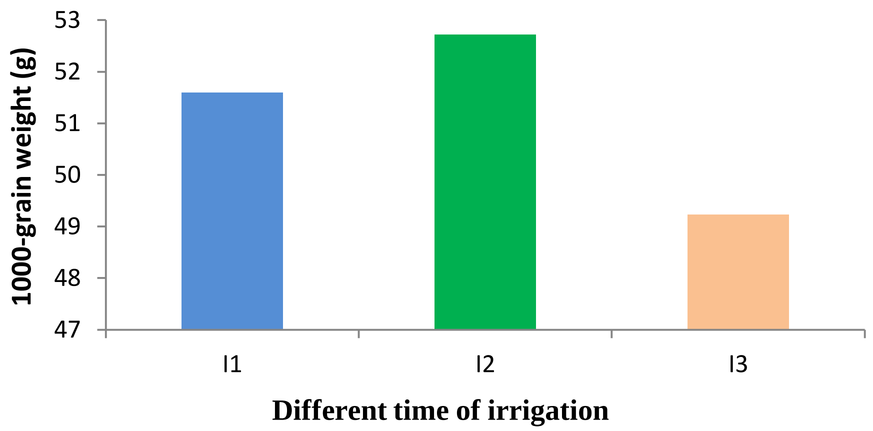
S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.16 Effect of sowing times on grains weight spike^{-1} (LSD$_{(0.05)}$ = 0.27)

4.2.6 Weight of 1000-grain (g)

Effect of irrigation

It was found that weight of 1000-grain of wheat varied significantly due to different time of irrigation under the present trial (Figure 17, Appendix X). The treatment I_2 produced the highest (49.65 g) 1000-grain weight which was statistically similar with I_1 (51.60 g) whereas the treatment I_3 produced lowest (45.81g) 1000-grain weight. Islam (1996) observed that irrigation had no influence of 1000-grain weight.

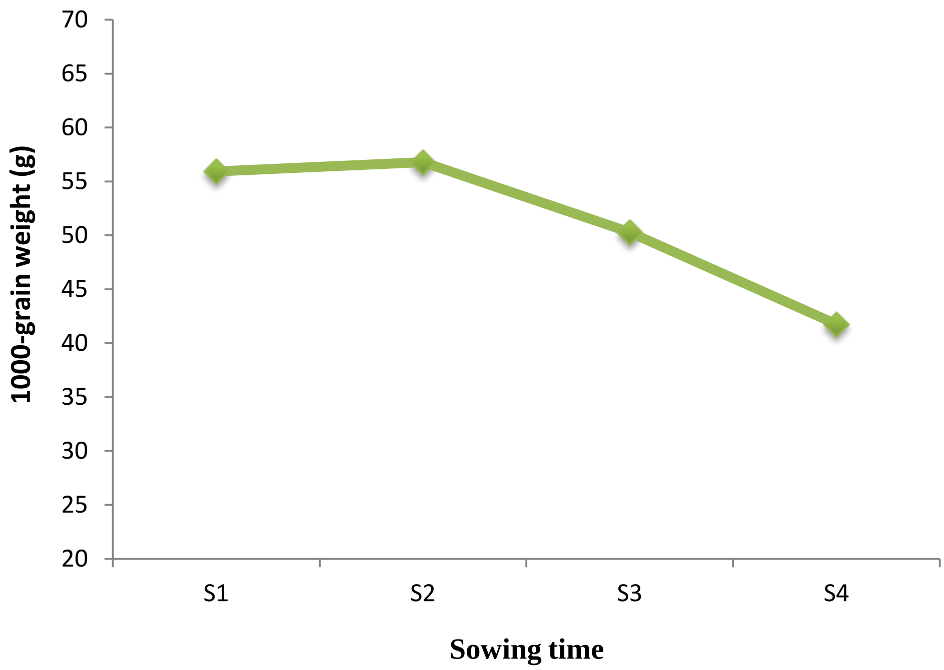


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.17 Effect of time of irrigation on 1000-grains weight (LSD$_{(0.05)}$ = 1.46)

Effect of sowing time

Statistically significant variation was recorded for weight of 1000-grain of wheat due to varying sowing times (Figure 18, Appendix X). The treatment S_2 produced significantly the highest (56.78 g) weight of 1000 grain while S_4 produced significantly the lowest (41.74 g) weight of 1000-grain. The treatment S_3 produced 50.28 g weight of 1000 grain and 55.93 g was found in S_1. Due to optimum sowing (20 November), highest 1000 grain weight was recorded from S_2 compared to other (early and late sowing). But Shafiq (2004) revealed that early sowing increased 100-grain weight compared to late sowing.



S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.18 Effect of sowing times on 1000-grains weight ($LSD_{(0.05)}$ = 1.96)

4.2.7 Interaction effect of yield contributing characters

Spike length

Different time of irrigation and sowing date showed significant differences on spike length of wheat due to interaction effect (Table 09, Appendix X). The highest spike length (15.63 cm) was observed from I_2S_4 which was statistically similar to all combined interaction except I_1S_4

(14.23 cm), I_2S_2 (14.23 cm) and I_3S_1 (13.83 cm) while the lowest spike length (13.83 cm) was documented from I_3S_1.

Number of spikelets spike^{-1}

There was no significant interaction effect of irrigation time and sowing time on number of spikelets spike^{-1} of wheat (Table 09, Appendix X). Numerically the highest Number of spikelets spike^{-1} (19.20) was observed from I_3S_2, while the lowest Number of spikelets spike^{-1} (17.53) was recorded from I_2S_4.

Number of grains spike^{-1}

Interaction effect of time of irrigation and sowing time exhibited significant differences on number of grains spike^{-1} of wheat (Table 09, Appendix X). The highest number of grains spike^{-1} (47.93) was observed from I_1S_3, while the lowest number of grains spike^{-1}(37.33) was recorded from I_3S_1.

Weight of grains spike^{-1}

Interaction effect of time of irrigation and sowing time varied significantly on weight of grains spike^{-1} of wheat (Table 09, Appendix X). The highest weight of grains spike^{-1} (2.60 g) was observed from I_1S_1 which was statistically similar to all interaction effect except I_1S_4 (2.02) and I_2S_4 (2.01) while the lowest weight of grains spike^{-1} (2.01 g) was recorded from I_2S_4.

Weight of 1000-grain

Interaction effect of different time of irrigation and sowing time varied significantly on weight of 1000-grain of wheat (Table 09, Appendix X). The highest weight of 1000- grain (60.30 g) was observed from I_1S_2 while the lowest weight of 1000-grain (39.65 g) was recorded from I_1S_4.

Table 08. Interaction effects of amount of irrigation and sowing time on yield contributing characters of wheat

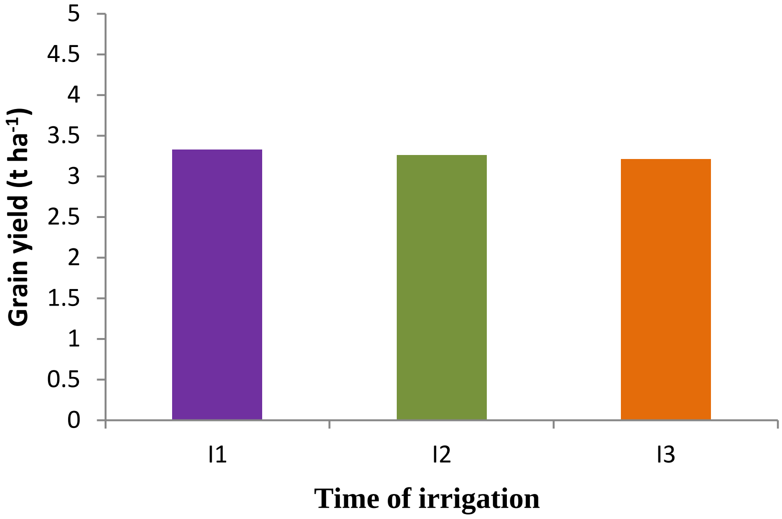
Treatments		Spike length (cm)	No. of spikelet spike^{-1}	No. of grains spike^{-1}	Weight of grains spike^{-1} (g)	1000-grains weight (g)
I_1	S_1	14.40	18.13	37.77	2.60	57.74
	S_2	14.43	18.33	43.33	2.31	58.91
	S_3	14.92	17.93	47.93	2.47	50.11
	S_4	14.23	17.73	40.93	2.02	39.65
I_2	S_1	14.37	18.60	38.80	2.35	58.55
	S_2	14.23	18.41	42.80	2.52	60.30
	S_3	14.50	18.13	46.80	2.31	46.85
	S_4	15.63	17.53	43.80	2.01	45.17
I_3	S_1	13.83	18.13	37.33	2.19	51.50
	S_2	14.60	19.20	46.73	2.	51.13
	S_3	14.77	17.60	42.87	2.36	53.89
	S_4	15.00	17.67	41.60	2.31	40.40
	$LSD_{(0.05)}$	1.28	NS	6.22	0.47	3.41
	CV (%)	5.14	5.28	8.53	11.76	3.88

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of $I_2$and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

4.2.8 Yield characters

Effect of irrigation on grain yield (t ha^{-1})

Grain yield of wheat significantly differed due to different of irrigation (Figure 19, Appendix XI). Grain yield was influenced insignificantly by different irrigation treatments. However, it was observed that the highest grain yield (3.33 t ha^{-1}) was obtained from I_1. On the other hand, the lowest grain yield (3.21 t ha^{-1}) was obtained from I_3. Maximum grain yield was obtained due to applying irrigation at heading stage (I_1).

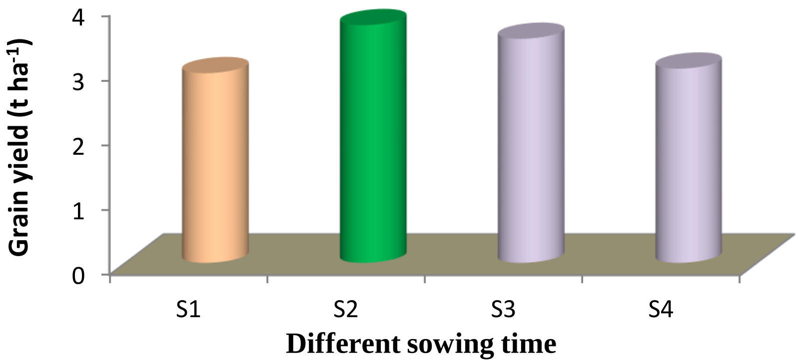


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.19 Effect of time of irrigation on grain yield

Effect of sowing time on grain yield (t ha^{-1})

Grain yield of wheat demonstrated statistically significant variation due to different sowing date (Figure 20, Appendix XI). The highest grain yield (4.06 t ha^{-1}) was observed from the treatment of S_2 which was statistically similar to S_3 and the lowest grain yield (2.93 t ha^{-1}) observed from S_1 was statistically similar to S_4 (3.00 t ha^{-1}). Maximum grain yield was produced in S_2 (20 November) compared to S_1 (10 November). Sarkar (2015) observed that highest yield was obtained wheat sown in November 20 to November 10.

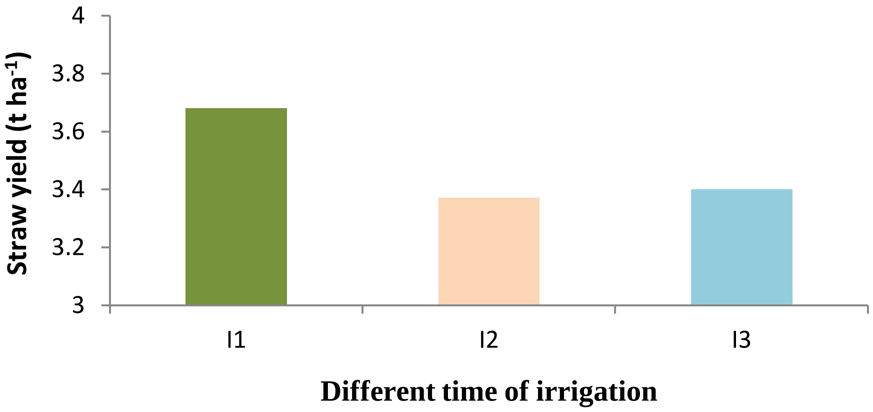


S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.20 Effect of sowing times on grain yield (LSD$_{(0.05)}$ = 0.41)

Effect of irrigation on straw yield (t ha^{-1})

Straw yield of wheat showed statistically significant variation due to different levels of irrigation (Figure 21, Appendix XI). The highest straw yield (3.68 t ha^{-1}) was recorded from I_1. On the other hand, the lowest straw yield (3.37 t ha^{-1}) was observed from I_2. Straw yield was maximum when irrigation applied at heading stage (I_1) rather than panicle initiation stage (I_3). Razi-us-Shams (1996) observed that irrigation increased the straw yields over the control.

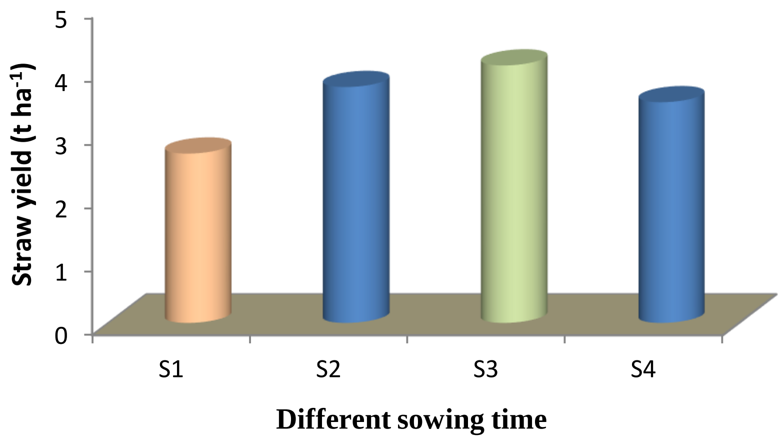


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.21 Effect of time of irrigation on straw yield ($LSD_{(0.05)}$ = 0.26)

Effect of sowing time on straw yield (t ha^{-1})

Significant variation was recorded for straw yield of wheat due to different sowing date under the present trial (Figure 22, Appendix XI). The highest straw yield (4.06 t ha-[1]) was observed from S_3 and the lowest straw yield (2.67 t ha-[1]) was recorded from S_1. Ahmed *et al*. (2006) also found a similar result where the highest straw yield (4.28 t ha^{-1}) produced due to early sowing (30 November), whereas the lowest straw yield (3.21 tha^{-1}) was obtained from delay sowing.

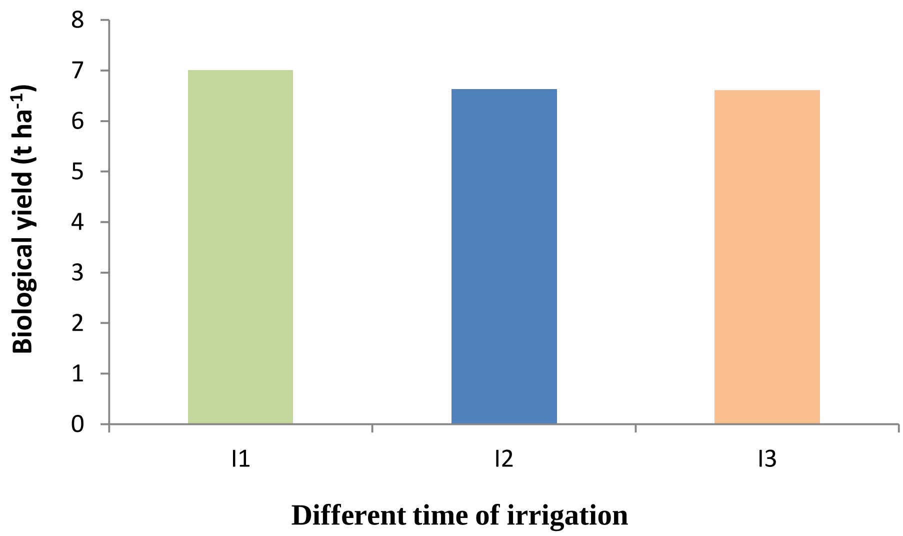


S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.22 Effect of sowing times on straw yield (LSD$_{(0.05)}$ = 0.29)

Effect of irrigation time on biological yield of wheat

It was recorded from the experiment that biological yield of wheat resulted was not significant due to different time of irrigation (Figure 23, Appendix XI). The highest biological yield (7.01 t ha^{-1}) was recorded from I_1 followed by I_2 (6.63 t ha^{-1}) and the lowest biological yield (6.63 t ha^{-1}) was observed from I_3.

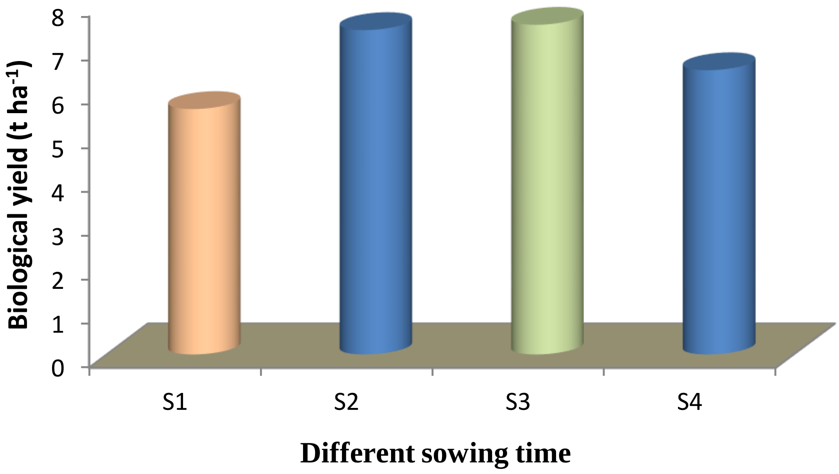


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2.

Fig.23 Effect of time of irrigation on biological yield

Effect of sowing time on biological yield of wheat

There were significant variation was observed for biological yield of wheat because of varying sowing date (Figure 24, Appendix XI). The highest biological yield (7.51 t ha^{-1}) was obtained from S_3 which was statistically similar with S_2 (7.39 t ha^{-1}) followed by S_4 (6.48 t ha^{-1}), while the lowest biological yield (5.60 t ha^{-1}) was recorded from S_1. Atikulla (2013) observed similar result that the highest biological yield (8.94 t ha^{-1}) obtained from November 19, 2012 (S_1).

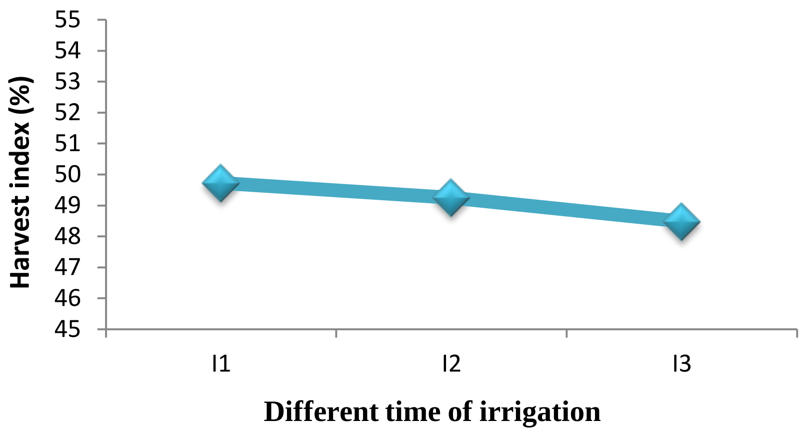


S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.24 Effect of sowing times on biological yield ($LSD_{(0.05)}$ = 0.58)

Effect of irrigation time on Harvest index (%) of wheat

Harvest index of wheat showed statistically non significant variation due to time of irrigation (Figure 25, Appendix XI). Numerically, the highest harvest index (49.72%) was recorded from I_1 and the lowest harvest index (48.48%) from I_3.

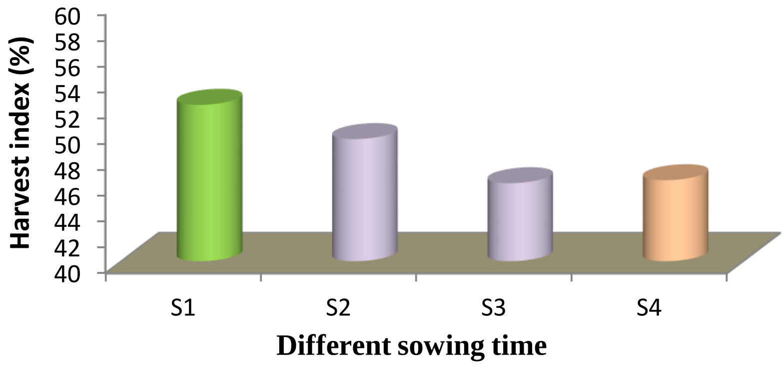


I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of I_2

Fig.25 Effect of time of irrigation on harvest index

Effect of sowing time on Harvest index (%) of wheat

Data revealed that there was significant variation for harvest index of wheat due to varying sowing times (Figure 26, Appendix XI). The highest harvest index (52.12%) was observed from S_1 statistically similar with S_2 (49.47%) and the lowest (46.05%) was calculated from S_3 which was statistically similar to S_4 (46.28%). A contradictory observation was revealed by Ehdaie *et al*. (2001) stated that harvest index was reduced by early sowing. This might be due to geographical variation, climatic and adaphic factors



S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

Fig.26 Effect of sowing times on harvest index ($LSD_{(0.05)}$ = 2.95)

Interaction effect of time of irrigation and sowing time on yield characters of wheat

Grain yield

Data revealed that interaction effect of different time of irrigation and sowing times showed significant difference on grain yield of wheat (Table 10, Appendix XI). The highest grain yield ha^{-1} of wheat (4.06 t ha^{-1}) was obtained from the treatment combination of irrigation during flowering with 20 November sowing time (I_2S_2) which was statistically similar with S_2 (3.77 t ha^{-1}) and S_3 (3.69 t ha^{-1}) of I_1, S_1 (3.32 t ha^{-1}) and S_3 (3.37 t ha^{-1}) of I_3 and the lowest grain yield (2.54 t ha^{-1}) was obtained from the treatment combination of irrigation during flowering with 10 November (I_3S_1).

Straw yield

Interaction effect of time of irrigation and sowing time showed significant differences on straw yield of wheat (Table 10, Appendix XI). The highest straw yield (4.48 t ha-^{1}) was observed from I_1S_3, while the lowest straw yield (2.35 t ha^{-1}) was recorded from I_2S_1.

Biological yield

Time of irrigation and sowing date had significant effects on biological yield of wheat (Table 10, Appendix XI). The highest biological yield (8.17 t ha^{-1}) was observed from I_1S_3, while the lowest biological yield (5.51 t ha^{-1}) was recorded from I_1S_1.

Harvest index

Statistical significant difference of interaction effect of different time of irrigation and sowing time on harvest index of wheat were observed (Table 10, Appendix XI). The highest harvest index (52.97%) was observed from I_1S_1, while the lowest harvest index (43.95%) was recorded from I_1S_4.

Table 09. Interaction effects of irrigation dates and sowing time on yield characters of wheat

Treatments		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_1	S_1	2.92	2.58	5.51	52.97 s
	S_2	3.77	3.92	7.69	48.86
	S_3	3.69	4.48	8.17	45.08
	S_4	2.93	3.73	6.66	43.95
I_2	S_1	2.54	2.35	4.89	51.68
	S_2	4.06	3.82	7.88	51.49
	S_3	3.31	3.91	7.22	45.88
	S_4	3.13	3.37	6.52	47.93
I_3	S_1	3.32	3.08	6.40	51.72
	S_2	3.17	3.43	6.61	48.05
	S_3	3.37	3.77	7.14	47.19
	S_4	2.95	3.32	6.27	46.96
	$LSD_{(0.05)}$	0.71	0.50	1.01	5.11
	CV (%)	12.64	8.32	9.55	2.94

I_1 =Irrigation at heading stage, I_2 = Irrigation after 10 Days of I_1, I_3 = Irrigation after 10 Days of $I_2$and S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November 2014 to March 2015 to determine the effect of irrigation time and sowing time on growth and yield of wheat. The experiment was designed with two factors; Factors A: Irrigation (3 time): I_1: Irrigation during heading stage; I_2: Irrigation after 10 days of I_1 and I_3: Irrigation after 10 days of I_2; Factor B: Sowing time (4 levels at 10 days interval): S_1: Sowing at 10 November, 2014; S_2: Sowing at 20 November, 2014; S_3: Sowing at 30 November, 2014 and S_4: 10 December, 2014. The experiment was laid out in Split-plot design with three replications. Irrigation time was assigned in the main plot and sowing time in the sub-plot.

To determine the growth habit of the wheat crop under study, the characters such as plant height, number of tillers hill^{-1},dry weight plant^{-1} were measured at 25days interval starting from 40 DAS onwards to harvest. From the data recorded for plant height, it was revealed that the treatment I_1 (Irrigation at heading stage) produced the tallest plant height (41.92cm) at 40 DAS while I_3 produce the tallest plant (84.10cm and 83.45 cm) at 65 DAS and at harvest and the corresponding lowest plant height was found to be recorded under the treatment I_3 (Irrigation after 10 days of I_2) at 40 DAS whereas at 65 DAS and 90 DAS the lowest plant height (82.70 cm and 83.35 cm respectively) was observed from I_1 (Irrigation at heading stage). In respect of the effect of irrigation on number of tillers hill^{-1}, it was revealed from the collected data that I_3 (Irrigation after 10 days of I_2) produce the highest tiller number plant^{-1} (3.30, 1.74 and 2.01) at 40 DAS, 90 DAS and at harvest while I_1 (Irrigation at heading stage) produced the lowest tiller number (2.73 and 2.37) at 40 DAS and 65 DAS respectively and I_2 produce (1.60 and 1.80) at 90 DAS and at harvest. In case of leaf area index (LAI) highest LAI was recorded from I_3 (2.13, 2.61 and 0.59) was observed at all the time during experimentation (40, 65and 90 DAS respectively) except highest LAI (0.16) at harvest from I_2 whereas the lowest LAI (1.74 and 2.11) was observed in I_2 at 40 and 65 DAS respectively and in I_1 (0.52 and 0.10) was observed at 90 DAS and at harvest respectively. In respect of the effect of irrigation, the highest dry weight plant^{-1} at 40 days obtained from I_3 and lowest observed in irrigation I_1.The highest dry weight plant^{-1} at 65 and 90 DAS, obtained from I_1 and lowest observed in I_3.The highest dry weight plant^{-1} at harvest obtained from I_3 and lowest observed in I_2.

Flowering and Maturity of wheat was found to vary with irrigation and results indicate that I_1 (Irrigation at heading stage) in wheat field accelerated its flowering and maturity days which is contrary to irrigation I_3 (Irrigation after 10 days of I2) as such the highest flowering and maturity period (68.5 and 113.67 days respectively) was found in I_3 while the shortest (54.17 and 99.67 days) was found in I_1.

Data on yield contributing characters of wheat as spike length (cm), no. of spikelets per spike, no. of grains spike^{-1}, grain weight spike^{-1} and 1000 grain weight (g) were recorded at harvest. Results revealed that, time of irrigation had no significant effect on each of these parameters except 1000-grain weight. Data showed that, the highest spike length (14.68 cm), no. of spikelets spike^{-1} (18.17), no. of grains spike^{-1} (43.05) and 1000-grain weight (52.72 g) except grain weight spike^{-1} (2.35g from I_1). On the other hand, the lowest corresponding values was observed from varying time of irrigation was different in yield parameters. The lowest values recorded as spike length (14.50 cm) from I_1, no. of spikelets spike^{-1} (18.03) from I_1, no. of grains spike^{-1} (42.13) from I_3, grain weight spike^{-1} (2.29) from I_2 and 1000-grain weight (49.23g) from I_3.The effect of irrigation time may be summarized that, irrigation in I_2 (Irrigation after 10 days of heading stage) enhanced the yield of wheat.

The highest straw yield (3.68 t ha^{-1}) was observed from I_1 varied significantly on the other time of irrigation. The highest grain yield (3.33 t ha^{-1}), biological yield (7.01 t ha^{-1}) and harvest index (49.72 %) were recorded from I_1 whereas the lowest grain yield (3.21 t ha^{-1}) from I_3, biological yield (6.61 t ha^{-1}) from I_2 and harvest index (48.48 %) from I_3 were recorded, all of which were statistically similar to each other except straw yield.

Regarding the effect of different sowing times 10 November 2014 (S_1), 20 November 2014 (S_2), 30 November 2014 (S_3) and 10 December 2014 (S_4) on the growth habit of wheat under study, it was observed that highest plant height (45.13 cm) was observed in S_3 at 40 DAS and (84.99 cm, 88.16 cm and 87.61 cm) was observed in S_2at 65, 90 DAS and at harvest respectively. Lowest (39.50 cm and 80.88) was observed in S_1at 40 DAS and at harvest respectively and the lowest (80.35 cm and 79.12) was observed in S_4 at 65 and 90 DAS respectively. .Highest number of tillers plant^{-1}(3.29, 2.29, 1.89 and 2.22) was observed in S_3, S_2, S_1 and S_2 respectively whereas the lowest tillers plant^{-1} (2.74)at40 DAS was counted from

S_1 and (2.07, 1.46 and 1.49) was counted from S_4at 65, 90 DAS and at harvest respectively. Highest LAI were recorded under the treatment S_2 (November 20, 2014 sowing time) at 40, 65, 90 DAS and at harvest while the lowest values were observed (1.65, 2.03 and 0.10) under the treatment S_1 (November 10, 2014 sowing time) at 40, 65 DAS and at harvest respectively and (0.49) from S_3 at 90 DAS. Highest dry weight plant^{-1}(2.11g) was recorded under the treatment S_3 (November 20, 2014 sowing time) at 40 DAS and at 65 and 90 DAS the highest dry weight plant^{-1} (8.31g and 11.48g) was recorded under the treatment S_2 (November 20, 2014 sowing time) and at harvest the highest dry weight plant^{-1} (10.43g) while the lowest values were observed (1.37g, 6.11g, 8.00g and 10.43g) under the treatment S_1, S_1, S_4 and S_2 respectively at 40, 65, 90 DAS and at harvest respectively. The days required for flowering and maturity also varied significantly with sowing time and S_2 required the highest flowering (62.89) and maturity (108.89) days while S_3 required the lowest days (59.22) for flowering and S_1 required the lowest days (106) for maturity period. Yield contributing characters of wheat varied significantly on the effect of sowing time and the highest values (18.65, 2.45 and 56.78g) of number of spikelets spike^{-1}, weight of grains spike^{-1} and 1000-grain weight respectively were recorded from S_2 whereas the lowest values (17.64, 2.11 and 41.74g) were obtained from S_4 in case of number of spikelets spike^{-1} , weight of grains spike^{-1} and 1000-grain weight respectively.. As the yield contributing characters recorded the highest values in November 20, sowing (S_2) so the highest grain yield (3.67 t ha^{-1}) was recorded in November 20 sowing (S_2) and straw yield (4.06 t ha^{-1}), biological yield (7.51 t ah^{-1}) were observed from S_3 but highest harvest index (52.12%) calculated from S_1.

Interaction effect was also found to vary significantly. The highest values recorded as spike length (15.63 cm) from I_2S_4, no. of spikelets spike^{-1} (19.20) from I_3S_2, no. of grains spike^{-1} (47.93) from I_1S_3, grain weight spike^{-1} (2.60g) from I_1S_1 and 1000-grain weight (60.30 g) from I_2S_2. The highest grain yield (4.06 t ha^{-1}) from I_2S_2, straw yield (4.48 t ha^{-1}) and biological yield (8.17 t ha^{-1}) from I_1S_3 and harvest index (52.97%) from I_1S_1.

Based on the above experimental results, it may be concluded that;

- Growth, yield attributes and yield of wheat (Var. BARI Gom 25) were significantly affected with irrigation time and different sowing times.
- Yield was significantly highest with irrigation time 10 days after heading stage in 20 November sowing.

Recommendation:

This study needs to be further investigated and evaluated at different agro-ecological zones before drawing final recommendation.

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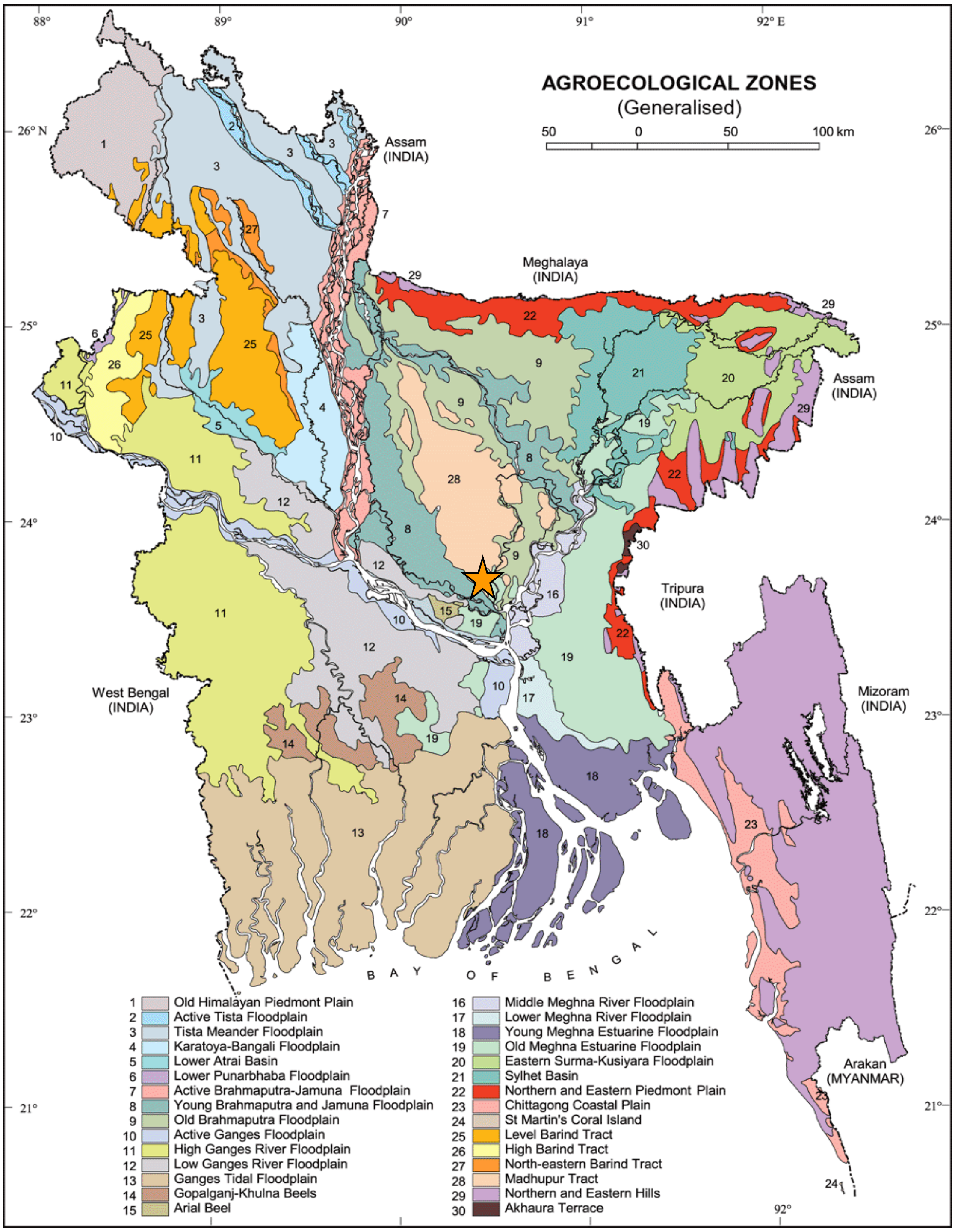
APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

Appendix II. Monthly mean air temperature, relative humidity and rainfall of the experimental site during the period from November 2014 to March 2015

Month	*Air temperature (^{0}C)		*Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2014	25.82	16.04	78	00
December, 2014	22.4	13.5	74	00
January, 2015	24.5	12.4	68	00
February, 2015	27.1	16.7	67	3
March, 2015	31.4	19.6	54	11

* Monthly average

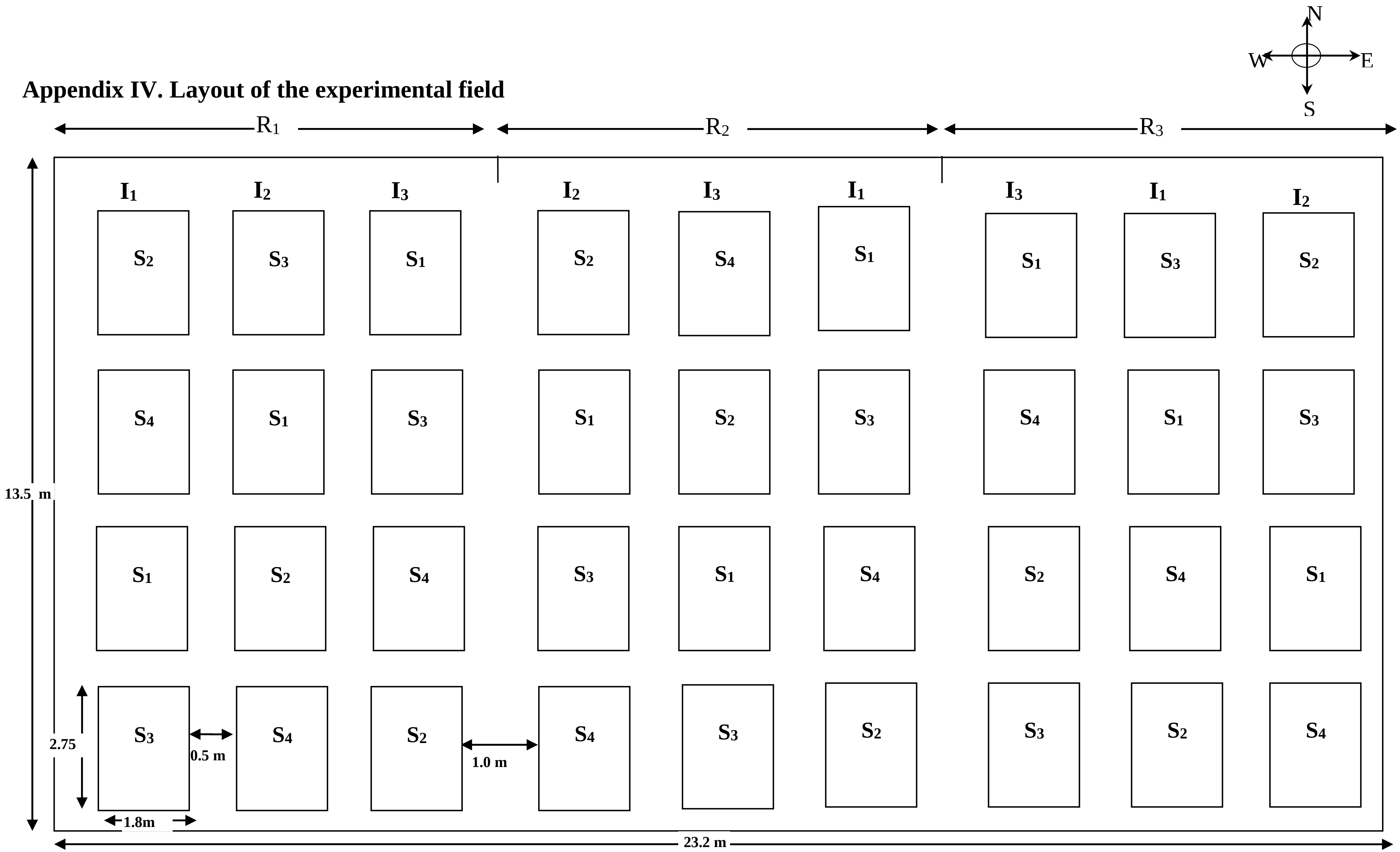
* Source: Meteorological Station, Field Laboratory, SAU.

Appendix III. Soil characteristics of experimental field

Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Appendix IV. Layout of the experimental field



I_1=Irrigation during heading stage , I_2=Irrigation after 10 days of I_1, I_3=Irrigation after 10 days of I_2
S_1= 1st sowing at 10 November, S_2= 2nd sowing at 20 November, S_3= 3rd sowing at 30 November, S_4= 4th sowing at 10 December

Appendix V. Analysis of variance (mean square) of the data for plant height at days after sowing

Source of variation	df	Mean square values for plant height at different days after sowing			
		40	65	90	At harvest
Replication	2	4.58	27.76	27.26	50.11
Irrigation (A)	2	4.07 *	7.63 NS	0.14 NS	4.12 NS
Error (a)	4	0.19	5.25	1.44	6.40
Sowing (B)	3	63.35 *	41.61 *	123.07 *	90.28 *
A x B	6	10.31 *	6.64 *	4.61 *	12.31 *
Error (b)	18	5.12	3.92	1.55	3.34

* = Significant at 5% level of probability, NS = Non significant

Appendix VI. Analysis of variance (mean square) of the data for number of tillers hill^{-1} at days after sowing

Source of variation	df	Mean square values for number of tillers hill^{-1} at different DAS			
		40	65	90	At harvest
Replication	2	0.17	0.01	0.24	0.45
Irrigation (A)	2	1.00 NS	0.15 *	0.06 NS	0.13 NS
Error	4	0.28	0.02	0.05	0.10
Sowing (B)	3	0.50 *	1.18 *	0.39 NS	0.87 *
A x B	6	0.13 *	0.82 *	0.12 NS	0.15 *
Error	18	0.16	0.13	0.21	0.09

* = Significant at 5% level of probability, NS = Non significant

Appendix VII. Analysis of variance (mean square) of the data for leaf area index at days after sowing

Source of variation	df	Mean square values for leaf area index at different DAS			
		40	65	90	At harvest
Replication	2	0.48	1.31	0.07	0.004
Irrigation (A)	2	0.58 NS	0.78 NS	0.01 NS	0.014 *
Error	4	0.42	0.50	0.04	0.001
Sowing (B)	3	1.01 *	1.16 *	0.03 NS	0.007 *
A x B	6	0.13 *	0.16 *	0.01 NS	0.003 *
Error	18	0.11	0.16	0.04	0.003

* = Significant at 5% level of probability, NS = Non significant

Appendix VIII. Analysis of variance (mean square) of the data for dry weight/plant at days after sowing

Source of variation	df	Mean square values for dry weight $plant^{-1}$ at different DAS			
		40	65	90	At harvest
Replication	2	0.04	8.62	0.09	0.26
Irrigation (A)	2	0.26 NS	1.50 NS	0.67 NS	9.48 *
Error	4	0.31	0.77	1.81	0.62
Sowing (B)	3	1.00 *	7.51 *	24.54 *	6.96 *
A x B	6	0.09 *	1.73 *	1.11 *	1.49 *
Error	18	0.11	2.42	2.50	0.77

* = Significant at 5% level of probability, NS = Non significant

Appendix IX. Analysis of variance (mean square) of the data for days to flowering and days to maturity of wheat

Source of variation	df	Mean square values	
		Days to flowering	Days to maturity
Replication	2	2.58	5.08
Irrigation (A)	2	616.33 *	594.25 *
Error	4	5.42	10.71
Sowing (B)	3	26.44 *	14.25 *
A x B	6	32.00 *	7.58 *
Error	18	3.07	4.17

* = Significant at 5% level of probability, NS = Non significant

Appendix X. Analysis of variance (mean square) of the data on yield contributing characters of wheat

Source of variation	df	Spike length (cm)	No. of spikelet spike^{-1}	No. of grains spike^{-1}	grains weight spike^{-1}	1000 grain wt. plot^{-1}
Replication	2	0.77	0.39	7.98	0.16	0.40
Irrigation (A)	2	0.12 NS	0.06 NS	2.56 NS	0.01 NS	37.99 *
Error (a)	4	0.32	0.63	15.37	0.09	1.66
Sowing (B)	3	0.99 *	0.76 *	105.67 *	0.20 *	431.63 *
A x B	6	0.63 *	0.37 NS	13.59 *	0.09 *	48.01 *
Error	18	0.56	0.91	13.17	0.07	3.94

* = Significant at 5% level of probability, NS = Non significant

Appendix XI. Analysis of variance (mean square) of the data on yield characters of wheat

Source of variation	df	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.27	0.27	0.45	13.37
Irrigation (A)	2	0.05^{NS}	0.35^{*}	0.53^{NS}	6.22^{NS}
Error	4	0.19	0.05	0.58	8.94
Sowing (B)	3	1.14^{*}	3.14^{*}	2.24^{*}	66.97^{*}
A x B	6	0.40^{*}	0.27^{*}	0.47^{*}	6.68^{*}
Error	18	0.17	0.08	0.42	2.04

* = Significant at 5% level of probability, NS = Non significant