GROWTH AND YIELD OF WHEAT AS AFFECTED BY AMOUNT OF IRRIGATED WATER UNDER VARYING SOWING TIMES

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This is to certify that the thesis entitled **"Growth and Yield of Wheat as Affected by Amount of Irrigated water under varying Sowing Times"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Shamim Ahmad Sarkar**, Registration number: **14-06359** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated:
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Dedicated to

My

Beloved Parents

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GROWTH AND YIELD OF WHEAT AS AFFECTED BY AMOUNT OF IRRIGATED WATER UNDER VARYING SOWING TIMES

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 ofamount of irrigated waterunder varying sowing times on growth and yield of wheat.The experiment comprised of two factors; Factors A: Irrigation (3 levels): I_1: Irrigation upto field capacity; I_2: Irrigation upto 1/2 of field capacity and I_3: Irrigation upto1/4th of field capacity(at crown root initiation, flowering and grain filling stage); 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, 2014and S_4: 10 December,2014. The experiment was laid out in Split Plot Design with three replications. Irrigation was assigned in the main plot and sowing date was assigned in the sub-plot.Irrigationupto fieldcapacity (I_1) recorded the highest plant height, tillers hill^{-1} and all yield contributing and yield parameters and the lowest in irrigation upto 1/4th of field capacity (I_3).November 20 sowing (S_2) produced the highest results than that of November10 sowing (S_1).Due to cumulative action of irrigation upto field capacity(I_1) and November 20 sowing (S_2) the combination effect (I_1S_2) recorded the highest values in spike length(36.72cm),number of spikelets spike^{-1} (17.60), number of grains spike^{-1} (54.13) , 1000 grain weight (55.15 g),grain yield (3.97 t ha^{-1}), straw yield (4.31 t ha^{-1}) , biological yield (8.280 t ha^{-1}) and harvest index(47.93%) respectively. Due to poor performance of individual treatment of irrigation upto 1/4th of capacity (I_3) and November 10 sowing time (S_1) the combination I_3S_1 recorded statistically the lowest grain yield (2.75 t ha^{-1}), straw yield (3.17 t ha^{-1}) , biological yield (5.92 t ha $^{-1}$) and harvest index (46.42%).

LIST OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACCRONYMS AND ABBREVIATIONS

%	Percentage
Adv	Advance
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
Appl.	Applied
Assoc	Association
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centi-meter
cm^2	Centi-meter square
CV	Coefficient of Variance
DAP	Days After Planting
Dev.	Devlopment
DMRT	Duncan's Multiple Range Test
Eng	Engineer*ing*
Environ.	Environmental
et al.	And others
Expt.	Experimental
FAO	Food and Agriculture Organization
g	Gram (s)
$hill^{-1}$	Per hill
i.e.	*id est* (L), that is
Intl.	International
j.	Journal
kg	Kilogram (s)

LIST OF ACCRONYMS AND ABBREVIATIONS (Cont'd)

M.S	Master of Science
m^2	Meter squares
mg	Milligram
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
t ha^{-1}	Ton per hectare
viz	Namely
Tech.	Technology
WHO	World Health Organization

INTRODUCTION

Wheat (*Triticumaestivum* L.) is one of the most important cereal crops cultivated all over the world. Wheat production was increased from 585,691 thousand tons in 2000 to 713,183 thousand tons in 2013 which was ranked below rice and maize in case of production (FAO, 2015). In the developing world, need for wheat will be increased 60 % by 2050 (Rosegrant and Agcaoili, 2010). The International Food Policy Research Institute projections revealed that world demand for wheat will increase from 552 million tons in 1993 to 775 million tons by 2020 (Rosegrant*et al*.,1997). Wheat grain is the main staple food for about two third of the total population of the world.(Hanson *et. al*., 1982).It supplies more nutrients compared with other food crops. Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006). It is the second most important cereal crop after rice in Bangladesh. So, it is imperative to increase the production of wheat to meet the food requirement of vast population of Bangladesh that will secure food security. During 2013-14 the cultivated area of wheat was 429607 ha having a total production of 1302998 metric tons with an average yield of 3.033metric tons ha-^{1} whereas during 2012-13 the cultivated area of wheat was 416522 ha having a total production of 1254778 metric tons with an average yield of 3.013 tons ha-1 (BBS, 2014). Current demand of wheat in the country is 3.0-3.5 million tons. Increasing rate of consumption of wheat is 3% per year (Roy and Pandit, 2007). Wheat production is about 1.0 milllion from 0.40 million hectares of land. Bangaladesh has to import about 2.0-2.5 million ton wheat every year. Wheat is grown all over Bangladesh but wheat grows more in Dhaka, Faridpur, Mymensingh, Rangpur, Dinajpur, Comilladistricts.Wheat has the umpteen potentiality in yield among other crops grown in Bangladesh. However, yield per hectare of wheat in Bangladesh is lower than other wheat growing countries in the world due to various problems. World wheat production will reduce owing to global warming and developing countries like Bangladesh will be adversely affected (CIMMYT- IPCC, 2007;ICARDA, 2011; CGIAR, 2009 and OECD, 2003). But major problems are delayed sowing after the harvest of transplanted aman rice and no or limited irrigation facilities.

Irrigation plays an imperative role for optimum growth and development of wheat. Idris*et al*. (1983) stated that uneven distribution is responsible for foiling synchronization with water requirement of wheat in the entire plain of the country. The germination of seed and uptake of nutrients from the soil are negatively affected by insufficient soil moisture. Water requirement for a crop depends on the variation in crop cover and climatic conditions all over the growing season (Doorenbos and Pruitt, 1977). The moisture available in a soil is the difference of moisture contents at the PWP (Permanent wilting point) and FC (Field capacity), levels which is available to the plant in the root zone. The field capacity is the amount of water remaining in the soil after having been wetted and after free drainage has ceased. The matric potential at this soil moisture condition is around - 1/10 to – 1/3 bar. The permanent wilting point is the water content of a soil when most plants (wheat, corn, sunflowers etc.) growing in that soil wilt and fail to recover their turgor upon rewetting. The matric potential at this soil moisture condition is commonly estimated at -15 bar. Irrigation requirement is the quantity of water needed above the existing moisture level. The difference between available moisture and irrigation requirements lies in the losses in conveyance, evaporation and seepage, which must be considered when reckoning the irrigation requirements. Available soil moisture is applied (Prasad *et al*., 1988). They also observed that water use efficiency (WUE) was generally higher in lower frequencies of irrigation. They reported that maximum WUE when two irrigations were applied at crown-root initiation and flowering because these are the most critical stages of irrigation, and therefore, water utilization was most efficient leading to high WUE. During crop-growth period total evapotranspiration was higher when more irrigation was given.

In Bangladesh the wheat growing season (November-March) is in the driest period of the year. Wheat yield was declined by 50% owing to soil moisture stress(Islam and Islam,1991).Irrigation water 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 decreased to a greater extent when water stress was imposed at the anthesis stage while water stress was imposed at booting stage caused a greater reduction in plant height and number of tillers (Gupta *et al.,* 2001). The lowest value corresponded to the treatment with irrigation during grain filling and under rainfed conditions (Bazza*et al*., 1999). Determination of accurate amount of water reduces irrigation cost as well as checks ground water waste.Water requirements vary depending on the stages of development.The pick requirement is at crown root initiation stage(CRI).In wheat, irrigation has been recommended at CRI,flowering and grain filling stages.However, the amount of irrigation water is shrinking day by day in Bangladesh which may be attributed to filling of pond river bottom. Moreover, global climate change scenarios are also responsible for their scarcity of irrigation water. So, it is essential to estimate water saving technique 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. Farmers can't sow seeds in optimum time as they cultivates wheat in winter season after harvesting of transplanted (T) amanrice.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 makes plant weak having poor root system. In late sowing condition, 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 checked the yield, caused by decline in the yield contributing traits like number of tillers, number of grains spike-1and grain yield (Ansary*et al.*,1989).Commonly, wheat is sown in November to ensure optimum crop growth and escape from high temperature. Temperature is one of the major environmental factors that affect grain yields in wheat. Indexmundi (2011) reported that heat is the greatest threat to food security in Bangladesh where wheat ranks second position among most food grains and where population is rapidly increasing .However major wheat area under rice-wheat cropping system is late planted including Bangladesh (Badruddin*et al*., 1994). Acevedo *et al*. (1991) stated that kernel weight was declined due to late sowing. It is necessary to detect appropriate sowing time and enumerate the losses or reduction in yield and different yield attributes due to early or delayed sowing. Information on the amount of irrigation water as well as the precise sowing time of wheat with change in climate to expedite wheat production within the farmer's limited resources is inadequate in Bangladesh. Theneed of water requirement also varies with sowing times as the soil moisture depletes with the days after sowing in Bangladesh as there is scanty rainfall after sowing season of wheat in general in the month of November.

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

- To find out the amount of irrigation needed for optimum growth and yield of wheat
- To detect optimum sowing time of wheat in this agro-climatic zone in

relation to climatic change

- To determine the relationship between amount of irrigation and time of sowing on growth and yield.

REVIEW OF LITERATURE

The growth and yield of wheat is very closely related to the adequate supply of water and time of sowing. Irrigation plays vital role for successful wheat production as well as early or late sowing also is responsible for declining growth and development of wheat. Limited research works were available on wheat and its response to amount of irrigation and sowing time in Bangladesh. Some of the relevant findings of the research with effect of irrigation and sowing time on the growth and yield of wheat were 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 characters of wheat in different wheat growing countries of the world. Some of the findings of those experiments were reviewed below:

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

Critical growth stages in wheat are tillering (Sekhon*et al*., 2010), shooting (Aamodt and Johnston, 2008), booting (Champbell*et a1*., 2009), flowering (Pope and Hay, 2007) and grain filling (Rahman*et al*., 2006).

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

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

Rajput and Pandev (2007) observed 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.

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.

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

Chaudhary and Dahatonde (2007) observed 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 affected 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}).

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 irrigation at crown root initiation, tillering, flowering and dough stages.

Shuquin et al. (2006) found 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.

Waraich et al. (2009) observed that the Reduction in grain yield under less irrigation treatment is the result of a significant reduction in number of effective tillers.

Pal and Upasani (2007) reported 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.

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.

Ali and Amin (2007) Irrigation treatments were given as: no irrigation, control (T0); 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.

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.

Sarkar*et al.* (2009) wheat with five irrigation treatments which were Io (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.

Quayyum and Kamal 2003) identified three stages of crown root initiation, maximum tillering and grain filling stages.

Kanwar*et al*. (2008) expressed that greater density, dry weight and nutrient uptake obtained higher applying irrigation 5 times (21, 45, 65, 85 and 105 DAS) over twice or three times.

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.

Sultana (2013) stated that increasing water stress declined the plant height, nos. of effective tillers per hill, grain yield and straw yield and maximum grain yield was obtained for the variety BARI Gam-26 that was 2.96t ha^{-1}.

Tomic*et al*. (2012) stated that the irrigation and drainage are essential for grain yield. Grain yield increases with the increase of irrigation levels at different critical levels.

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.

Pandey and Haque (1965) observed that three irrigations were applied in wheat crop at crown root initiation, tillering and heading stage for achieving higher yield.

Rajput (1975) found that when water stress was continued from crown-root initiation to flowering, grain yield of wheat was declined.

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.

Shirazi*et al*. (2014) observed that maximum grain yield of 2.27 t ha^{-1} by the application of 200mm irrigation treatment.

Tahir*et al*. (2009) observed that higher grain yield (4289.54 kg ha^{-1}) was attained as wheat was sown on 1st December as well as lowest grain yield (2109.50 kg ha^{-1}) obtained because of late sowing(30th December).

Atikulla (2013) observed that each of the 3 different dated irrigated plots showed 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 highest 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).

Uperty and Sirohi (1985) observed that LAI (leaf area index) of wheat was lessened due to the water stress significantly.

Islam *et al*. (2015) carried out 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 tiller hill^{-1} (5.2), CGR (6.7gm-2day-^{1}), RGR (0.03gg-^{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 tha-^{1}), straw yield (4.9t ha-^{1}), biological yield (8.8tha-^{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.

Zhai*et al*. (2003) reported that winter wheat to determine water stress on the growth, yield contributing characters and yield of wheat and they reported that water stress significantly inhibited the number of tillers of winter wheat.

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 rainfed control. Two irrigations at the tillering and flowering stages Produced the highest grain yield (3.03t ha^{-1}). Water use increased and water use efficiency lessened with increase in number of irrigations. Two irrigations at tillering and flowering used 296 mm of water with use efficiency of 10.12kg ha^{-1} per mm.

Wang *et al*. (2002) stated that the effects of water deficit and irrigation at different growing stages of winter wheat and observed that water deficiency retarded plant growth.

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.

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.

Abodorrahmani*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.

Gupta *et al*. (2001) conducted an experiment 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.

Wang *et al*. (2009) reported that the effects of different irrigation levels on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farmlands with an accurate management system with irrigation regimes.Water consumption 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.

Atikulla (2013) reported 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.

Wu *et al*. (2011) revealed 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.

Wang *et al.* (2012) reported 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.

Gupta *et al*. (2001) observed that number of tillers decreased 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 number of tillers. Among the yield attributes number of tillers were positively correlated with grain and biological yield irrigation at the anthesis stage.

Baser *et al*. (2004) found that the influence of water deficit on yield and yield components of winter wheat under Thrace conditions (Turkey). The treatments included an unstressed control (S_0), water stress at the late vegetative stage (S_1), at the flowering stage (S_2), or at the grain formation stage (S_3) and full stress (non-irrigation S_4). The effects of water stress treatments on yield components were statistically significant compared with non-stressed conditions.

Zarea and Ghodsi (2004) observed 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.

Fang *et al*. (2006) expressed that grain yield and its components of wheat declined when exposed to drought stress condition.

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

Upadhyaya and Dubey (1991) stated 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.

BARI (1993) conducted an experiment that maximum grain and straw yields were obtained applying three irrigations at CRI, maximum tillering and grain filling stages. Yadav*et al*. (1995) conducted an experiment that two irrigations scheduled at CRI (Crown Root

Initiation) and milk stages gave the maximum plant height (1.026m), maximum number of grain ear^{-1} (65), straw weight (4500kg ha^{-1}) and grain yield (3158 kg ha^{-1}) of wheat.

Islam (1996) conducted 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}).

Meena*et al*. (1998) observed that wheat grain yield was the highest with two irrigations.

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, panicle length and number of grains per panicle over the control.

Mueen-ud-din *et al*. (2015) conducted an experiment that maximum grain yield (4232.5 kg ha-^{1}), no. of grains spike-^{1}(51), 1000 grain weight (46.5 g) were observed due to application of 3 acre inch water and highest water use efficiency of 20, 19.89 kg ha-^{1}/mm was obtained where 2 acre inch water was given.

Debelo*et al*. (2001) reported that plant height and thousand-kernel weight showed positive and strong association with grain yield, indicating considerable direct or indirect contribution to grain yield under low moisture conditions.

Adjetey*et al*. (2001) revealed that grain yield response was greatly dependent on soil moisture or rainfall. Water availability at this time determined kernel weight and hence grain yield, even sufficient grain number had been found.

Gupta *et al*. (2001) conducted an experiment that grain yield and biological yield decreased to a greater extent when water stress was imposed at the anthesis stage and irrigation at the anthesis stage whereas leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

Khajanij and Swivedi 2007) reported that the growth and yield of wheat affected by irrigation frequency as well as the grain yield of wheat can be raised by increasing irrigation frequencies.

Banker (2008) observed that the values of growth characters were observed higher when applied five irrigations (at crown root initiation, tillering, jointing, flowering and milking stages).

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.

Yadav*et al*. (1995) stated 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.

Islam (2003) showed that the water requirement of wheat was 25.69cm at BINA farm, Mymensingh.

Ziaei*et al.* (2003) observed that water stress retarded the yield of wheat.

Maqsood*et al*. (2002) observed that three irrigations at critical growth stages provided the maximum number of productive tillers, number of grains per spike, 1000 grain weight and grain yield.

Wang *et al*. (2002) stated that water deficiency checked plant growth due to the effects of water deficit and irrigation at different growing stages of winter wheat.

Rasol,H.O.A.(2003) carried out an experiment 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.

Zhai*et al*. (2003) showed that water stress significantly inhibited the yield of winter wheat.

Faruque (2002) showed that the plant growth which relied partly on turgor pressure to sustain cell enlargement, was more sensitive to water applied grain yield were higher in cultivars C-75-14 and C-75-9.

Wang *et al*. (2002) observed that irrigation increased yield of wheat significantly than under control condition.

Atikullah, *et al.* (2014) showed that maximum dry matter content (18.8g/plant), crop growth rate (CGR) (13.5 g m-^{2}day-^{1}), relative growth rate (RGR) (0.024 g m-^{2}day-^{1}) were obtained from I_1 which was statistically same as I_2 whereas lowest obtained from I_0. They also reported that Plant height (80.7 cm), number of tiller (4.9/hill), number of spike (4.7/hill), number of spikelets (18.5/spike), spike length (19.2 cm), filled grains (29.3/spike), total grains (31.3/spike), 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 $I_{1.}$

Mangan*et al*. (2008) showed that grain yield of wheat varieties were significantly influenced under water stress conditions. Grain yield increased from 373 kg ha-^{1} in single irrigation treatment to 3931 kg ha-^{1} in four irrigations.

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).

Wu *et al*. (2011) reported that the effect of compensation irrigation was observed on the yield and water use efficiency of winter wheat in Henan province as well as the wheat yield was increased by 2.54%-13.61% compared to control.

Bergmann (1973) showed that yield reached to its optimal level owing to applying about two-third or three quarter of the quantities reckoned as water requirements. In contrary to, exorbitant application of water results in producing excess vegetative growth that leads to low yield.

Ngwako*et al*.(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.

Boogaard*et al*. (1996) observed that harvest index of wheat was increased under rainfed and irrigated conditions.

Zarea and Ghodsi (2004) carried out an experiment in Iran and showed that harvest index reduced due to increasing irrigation intervals. Harvest index were higher in cultivars C-75-14 and C-75-9 by applying irrigation at 20 and 30 day interval.

From reviewed information it was found that in the case of wheat, high water deficit occurred during the early stages and 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.

2.2Influence of sowing date on growth and yield of wheat

The major non-monitory inputs for enhancing wheat production is optimum time of sowing which is the most important agronomic factor affecting the growth and development of plants. Research works conducted 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-antesis and post-anthesis development. Some of the pertinent literatures regarding effect of sowing time in different location of the world were presented below-

BARI (1984) conducted an experiment in Joydepur 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.

Atikulla (2013) conducted an experiment that out of 3 different sowing dates November 19, 2012 (S_1) and November 29, 2012 (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).

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.

Alam*et al*. (2014) found 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.

Spink *et al*. (1993) also found that delayed sowing curtails the duration of each development phase due to increase in temperature.

Chowdhury (2002) stated that plant height reduced for late sowing. 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.

BARI (1984) carried out a trial with wheat in Joydebpur and Jessore that the highest number of effective tillers $plant^{-1}$ was obtained by sowing 20 November.

Haider (2002) conducted an experiment and observed that plants of all cultivars of wheat sown in 15 November became taller than December 5 sown wheat plants under each irrigation regimes.

Chowdhury (2002) 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.

Ahmed *et al*. (2006) reported that number of tiller enhanced significantly with early sowing (30 November) in all varieties in both the years.

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.

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.

Chowdhury (2002) found that spike length, grains $spike^{-1}$ and 1000-grain weight decreased with delay in sowing date from November 15 and the lowest spike length, grains $spike^{-1}$ and 1000-grain weight were recorded on December 15 sown plants.

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.

Ahmed *et al*. (2006) found that grain and straw yields augmented 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) and straw yield (3.21 t ha^{-1}) was obtained from delay sowing.

Zende*et al*. (2005) showed that the growth, yield and yield attributes, except 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.

Hossain*et al*. (1990) observed that maximum 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.

Haider (2002) reported that early sown plants (November 15) had the highest spike length, grains spike-1 and 100-grain weight and late sown plants (December 5) resulted the lowest values of these parameters of wheat.

Chowdhury (2002) found that the highest grain yield was obtained, plants sown on 15 November whereas the lowest yield was found on 15 December.

Haider (2002) observed that higher grain yield obtained in plants sown on 15 November whereas the lowest yield obtained on 5 December.

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) observed that highest yield was obtained wheat sown in November 22 to December 20 compared to November 08, 15 and December 27.

Shafiq (2004) revealed that early sowing increased germination per unit area, plant height, spikelets per spike, grainsper spike and 100-grain weight compared to late sowing.

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

Rahman (2009) reported 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) among genotypes Whereas because of the late sown condition (December 21) grain yield, biomass at anthesis, ground cover at 4-5 leaf stage were influenced non-significantly owing to differences among the treatments.

Saunders(1988) observedthat 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.

Ehdaie*et al*. (2001) stated that harvest index was reduced by early sowing.

Samuel *et al*. (2000) found that the harvest index was declined from (41.5%) of normal sowing condition to (36.1%) (29 November 1996) late sowing condition (6 January 1997) in wheat.

Atikulla (2013) conducted an experiment that 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}).

Sharma (1993) revealed the result 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

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.

MATERIALSANDMETHODS

The field experiment was designed to achieve the objectives of the study and executed following standard procedures and methods. The experiment was conducted at experimental field of Sher-e-Bangla Agricultural University, Bangladesh during the period from November 2014 to March 2015 to study the growth and yield of wheat as affected by amount of irrigated water under varying sowing times. This chapter deals with a short depiction on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1Site description

The experiment was carried out at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the Rabi season of 2014. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period.The details have been presented in Appendix II.

3.3 Climate

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

3.4 Treatments

The following treatments were included in this experiment.

a. Irrigation: 3
b. Sowing time :4

The following treatments were included in this experiment.

a. **Irrigation**: 3

- ❖ Irrigation upto field capacity, coded as I_1
- ❖ Irrigation upto 1/2 of the field capacity , coded as I_2
- ❖ Irrigation upto $1/4^{th}$ of the field capacity , coded as I_3

Irrigation was applied at three stages viz, crown root initiation ,flowering and grain filling stage.

b. **Time of sowing**: 4

- ❖ First sowing , coded as S_1=10 November
- ❖ Second sowing ,coded as S_2=20 November
- ❖ Third sowing ,coded as S_3 =30 November
- ❖ Fourth sowing ,coded as S_4 =10 December

There were on the whole 12(3×4) treatment combinations such as I_1S_1,I_1S_2,I_1S_3,I_1S_4,I_2S_1,I_2S_2,I_2S_3,I_2S_4,I_3S_1,I_3S_2,I_3S_3 and I_3S_4.

3.5 Determination of Field Capacity (FC)

Field capacity was determined for 1 m^2 area in my research field. Two canes of water were required to obtain field capacity of 1 m^2 area.According to this, 10 canes of water were required to have field capacity for each plot having 4.95 m^2. As such, 5 canes of water were given for having 1/2 of field capacity and 2.5 canes of water were given for having 1/4 of field capacity. A water cane contains 8.5 L of water. For field capacity, water required was 85 L for 4.95 m^2.Similarly, for 1/2 of the of field capacity, water required was 42.5 L. For $1/4^{th}$of the field capacity water required was 21.25 L.

3.6 Seed collection

Seeds of BARI Gam-26(Hashi) 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 colour white. BARI Gam- 26 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.

3.7 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.

3.8 Fertilizer dose and methods of application

Urea, TSP, MP 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 triple super phosphate, muriate of potash 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
Urea	220 kg	66.66	33.33
TSP	180 kg	100	--
MP	50 kg	100	--
Gypsum	120 kg	100	--
Cowdung	10 ton	100	--

Source: KrishiProjuktiHatboi, BARI, Joydebpur, Gazipur, 2006

3.9 Experimental design

The experiment was laid in a split-plot design with three replications. Each replication was first divided into three main plots on which the irrigation treatments were assigned. Each of the main plots was then subdivided into four unit plots to accommodate the sowing time. Thus the total number of unit plots was 3×3×4=36. The size of the unit plot was 2.75m × 1.8m. The distance maintained between two unit plots was 0.5m and between blocks was 1m. The treatments were randomly assigned to the plots within each replication.

3.10 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.

3.11 Intercultural operations

3.11.1 Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after sowing followed by second weeding at 15 days after first weeding. Identified weeds were kakpayaghash (Dactylocteniumaegyptium L.), Shama (Echinocloacrussgalli), Durba (Cynodondactylon), Arail (Leersiabexandra), Mutha (Cyperusrotundus L.) Bathua (Chenopodium album) Shaknatey (Amaranthusviridis), Foska begun (Physalisbeterophylls), Titabegun (Solanumtorvum).

3.11.2 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.

3.12 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.

3.13 Harvesting and post-harvest operation

Maturity of crop was determined when 90% of the spike became golden yellow in color. Five plantsper 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.

3.14 Recording of data

Experimental data were recorded from 40 days of sowing and continued up to harvest. The following data were recorded during the experimentation.

3.14.1 Crop growth characters

i. Plant height (cm)
ii. Number of tillers hill-^{1}
iii. Dry weight (g) plant-^{1}

3.14.2 Yield contributing characters

i. Days to flowering
ii. Days to maturity
iii. Plant height(cm)
iv. Spike length (cm)
v. Number of spikelets spike-^{1}
vi. Number of grains spike-^{1}
vii. Weight of 1000 grains (g)

3.15.3 Yield characters

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

ii. Straw yield (t ha^{-1})
iii. Biological yield
iv. Harvest index (%)

3.16 Detailed procedures of recording data

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

3.16.1 Crop growth characters

3.16.1.1Plant 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.

3.16.1.2Number 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 $hill^{-1}$.

3.16.1.3Dryweight of $plant^{-1}$

Threeplants at different daysaftersowing (40,65,90DAS andatharvest)were collected and ovendried at70°C for 72hours.The driedsampleswere thenweighed and averaged.

3.17 Yield contributing Characters

3.17.1 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.

3.17.2 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.

3.17.3 Spike length (cm):

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

3.17.4Number ofSpikelets per spike:

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

3.17.5Number 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:

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

3.17.6Weightof 1000grains

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

3.18 Yield characters

3.18.1 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.

3.18.2 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}.

3.18.3 Biological yield (t ha-^{1})

Biological yield of a crop is defined asthe sum of grain yield and straw yield. The biological yield of wheat was measured for each plot and express in t/ha.

The biological yield was estimated with the following formula:

Biological yield = Grain yield + Straw yield

3.18.4 Harvest index (%)

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

Economic yield (Grain weight)

HI (%) = ―――――――――――――――― × 100

Biological yield

3.19 Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT computer package program developed. Least Significant Difference (LSD) technique at 5% and 1% level of significance was used by Duncan's Multiple Range Test (DMRT)to compare the mean differences among the treatments (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The study was conducted to find out the effect of single irrigation and sowing date on growth and yield of wheat. Data on different growth and yield of wheat were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following headings:

4.1. Crop Growth Characters

4.1.1. Plant height

Effect of irrigation

Plant height of wheat showed statistically significant variation due to amount of irrigation at 40, 65, 90 DAS and at harvest under the present trial (Figure 1). At 40 DAS, the tallest plant (41.71cm) was recorded from I_1 while the shortest plant (38.16cm) was observed from I_3.At 65 DAS, the tallest plant (81.10 cm) was found from I_1 while the shortest plant (78.21 cm) was observed from I_3. At 90 DAS, the tallest plant (81.44 cm) was recorded from I_1, while the shortest plant (77.32 cm) was obtained from I_3 which was statistically similar to I_2. At harvest, the tallest plant (83.35 cm) was observed from I_1 which was statistically similar to I_2while the shortest plant (77.31 cm) from I_3.Plant height was likely increased due to applying higher amount of irrigation compared to less amount of irrigation. Sultana (2013) stated that increasing water stress declined the plant height.

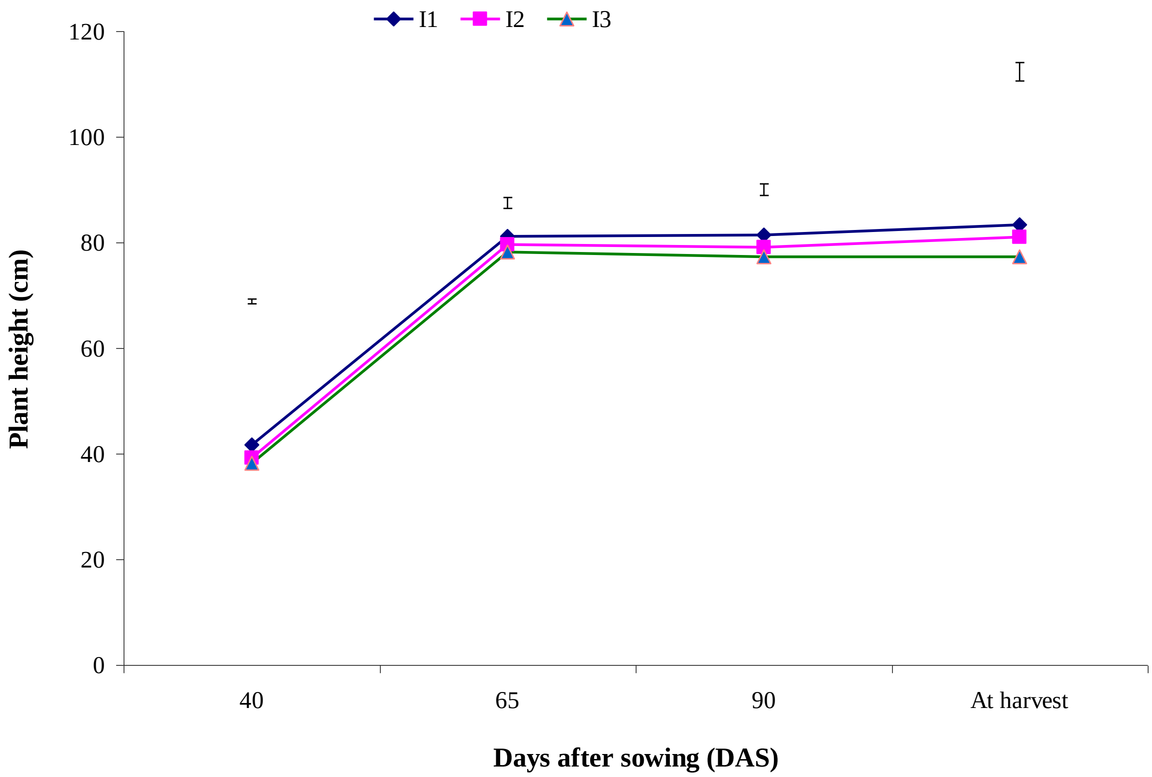

Fig.1Effect of amount of irrigation on plant height of wheat

Here,

I_1 =Irrigation upto field capacity

I_2 = Irrigation upto1/2 of the field capacity

I_3 = Irrigation upto 1/4th of the field capacity

Effect of sowing time

Statistically significant variation for plant height of wheat at 40, 65, 90 DAS and at harvest was observed due to different sowing date (Figure 2).The highest plant height at 40 days was 44.99cm obtained from S_1 and lowest was 36.91cm observed in $S_{2.}$ 38.74cm plant height was produced from S_3 which was statistically similar to S_4. At 65 days, highest plant height was 83.85 cm obtained from S_1 and lowest was 76.01 cm observed in S_3. At 90 days, plant height was not significant in relation to sowing time. Numerically, the highest plant height at 90 days was (80.04cm) obtained from S_2 and lowest was 78.20cm observed in $S_{4.}$ The highest plant height at harvest was 85.07cm obtained from S_1 and lowest was 76.42cm observed in S_3 which was statistically similar to $S_{4.}$BARI (1984) reported that the tallest plant (76.83 cm) when sowing was done on 20 November and shortest with 30 December sowing.

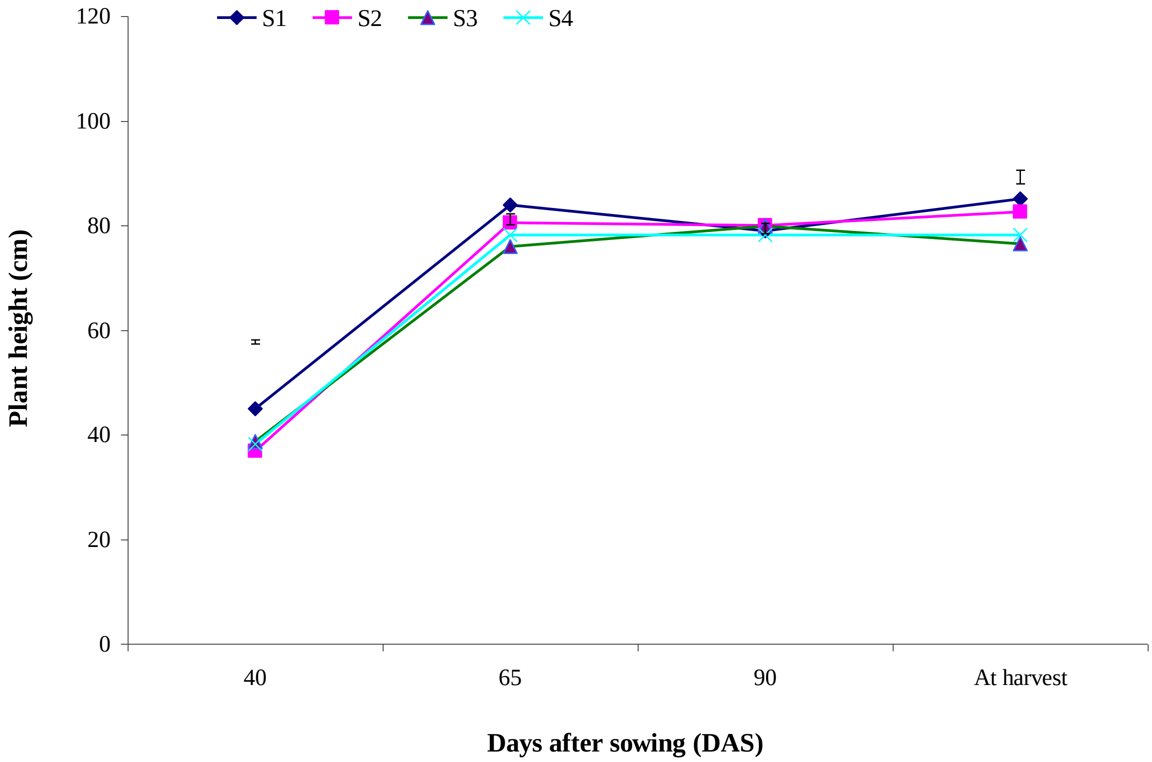

Fig.2 Effect of sowing time on plant height of wheat

Here,

S_1= 10 November

S_2 = 20 November

S_3 = 30 November

S_4 = 10 December

Interactioneffect of irrigationandsowing time

Interaction effect of different amount of irrigation and sowing date showed significant differences on plant height of wheat at 40, 65, 90 DAS and at harvest (Table 2). The highestplant heightat40 was 47.47cm obtained from $I_1S_{1.}$ There is no significant relationship at 65 days. At 90 DAS, plant height was 83.13cm obtained from I_1S_1 which was statistically similar to I_1S_2, I_1S_3.I_1S_4 and I_3S_3 and lowest was 74.24 cm obtained from $I_3S_{1.}$There was no significant relationshipatharvest. But numerically highest plant height was 88.23cm in I_1S_1 and lowest was 73.23cm in $I_3S_{3.}$

Table 2. Interaction effects of irrigation and sowing time on plant height at days after sowing

Irrigation x Sowing time	Plant height (cm) at DAS			
	40	**65**	**90**	**At harvest**
I_1S_1	47.47 a	85.90	83.13 a	88.23
I_1S_2	37.84 e	82.11	81.73 ab	85.59
I_1S_3	39.31 d	77.31	80.94 ab	78.69
I_1S_4	42.21 c	79.08	79.97 ab	80.90
I_2S_1	45.83 b	82.77	79.56 b	85.30
I_2S_2	36.01 f	79.93	79.34 b	83.37
I_2S_3	39.07 d	77.20	78.73 bc	77.33
I_2S_4	36.20 f	78.52	78.70 bc	77.90
I_3S_1	41.67 c	82.88	74.24 d	81.67
I_3S_2	36.89 ef	79.37	79.05 bc	78.69
I_3S_3	37.83 e	73.53	80.05 ab	73.23
I_3S_4	36.26 f	77.07	75.93 cd	75.63
SE	0.363	1.08	1.02	1.32
Level of significance	**	NS	*	NS
CV (%)	1.58	2.34	2.23	2.83

** = Significant at 1% level of probability, * = Significant at 5% level of probability

NS = Non significant

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% and 5% level of probability

4.1.2. Number of tillers hill^{-1}

Effect of irrigation

Different levels of irrigation varied significantly in terms of number of tillers hill^{-1} of wheat at 40, 65, 90 DAS and at harvest under the present trial (Figure 3). At 40, 65,90 and at harvest , the highest number of tillers hill^{-1} viz. 4.649, 3.53 and 2.17 and 2.02 respectively were recorded from I_1, while the corresponding lowest number of tillers hill^{-1} were 3.568, 2.42, 1.18 and 1.40 respectively observed in I_3. Sultana (2013) stated that increasing water stress reduced the number of tillers per hill.

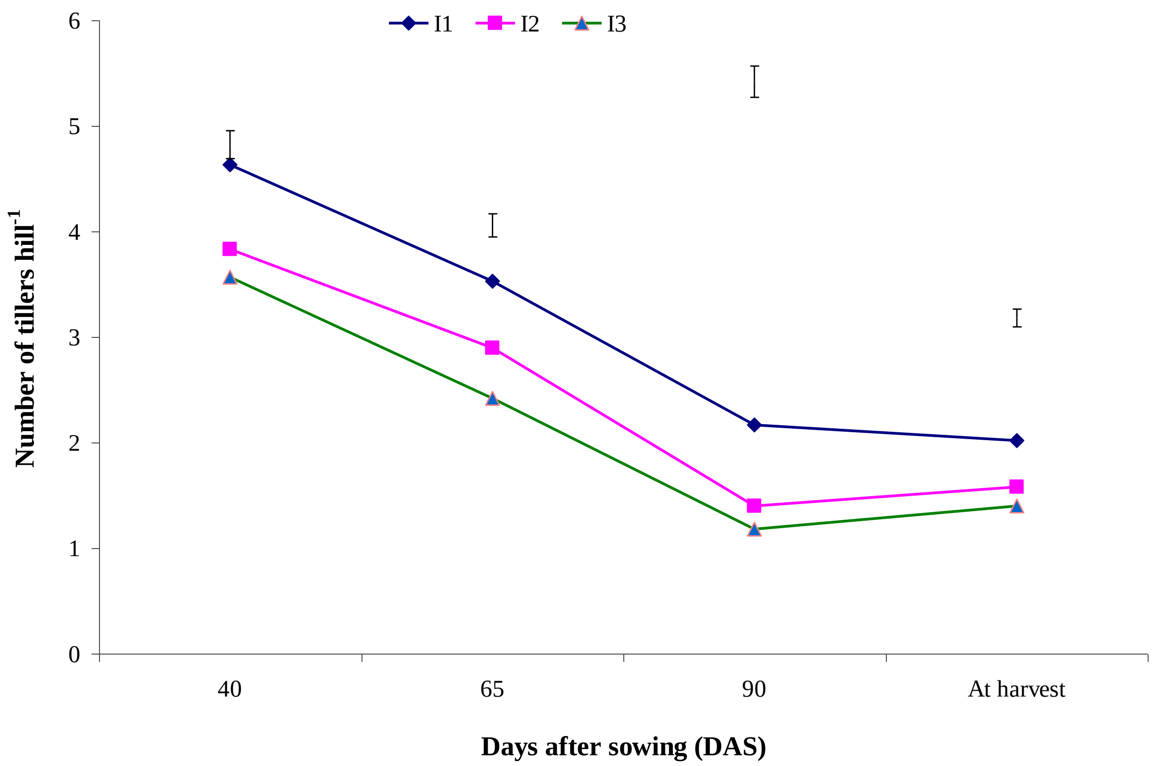

Fig.3.Effect of amount of irrigation on number oftillers hill^{-1}

Here,

I_1 =Irrigation upto field capacity

I_2 = Irrigation upto1/2 of the field capacity

I_3 = Irrigation upto 1/4th of the field capacity

Effect of sowing time

Number of tillers hill^{-1} of wheat showed statistically significant variation at 40, 65, 90 DAS and at harvest due to different sowing date (Figure 4). At 40, 65, 90 DAS and at harvest, the highest number of tillers hill^{-1} as 4.690, 3.377, 2.133 and 2.223 were found respectively in S_2 and the corresponding lowest number as 3.402, 2.267, 1.267 and 1.157 were recorded from S_1. BARI (1984) reported that 20 November sowing produced the highest number of effective tillers hill^{-1}.

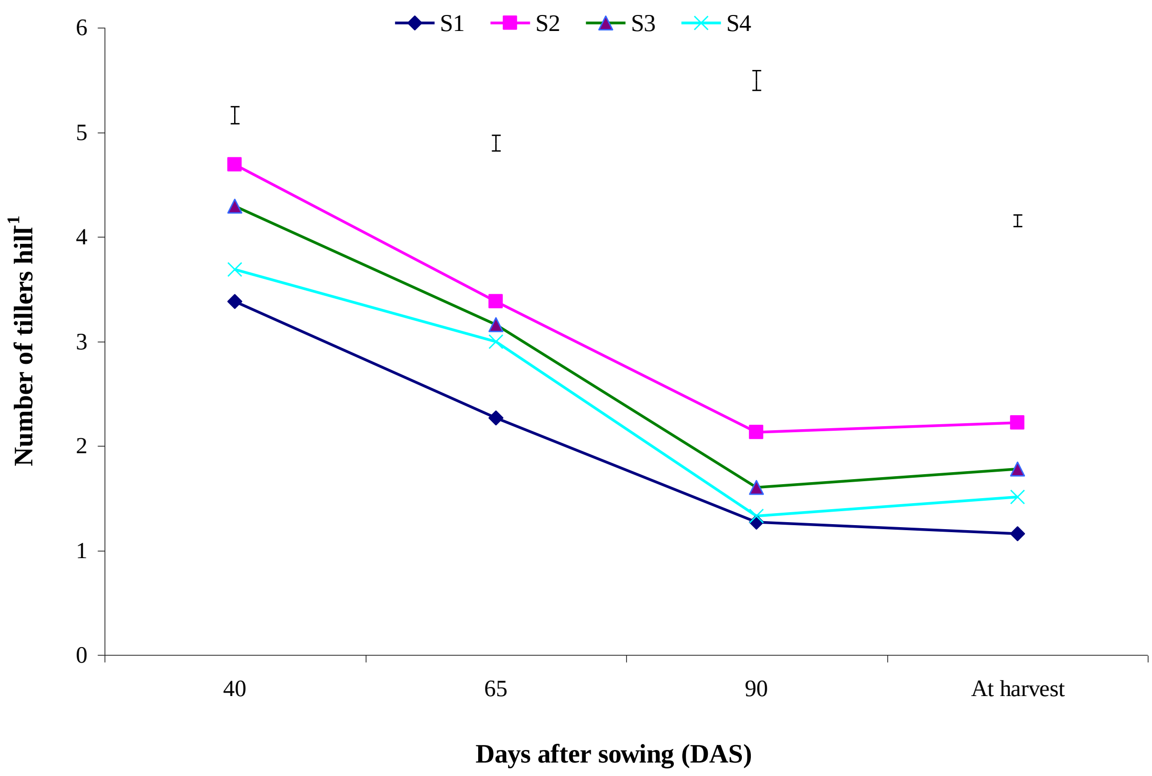

Fig.4Effect of sowing times onnumber oftillers hill^{-1}

Here,

S_1= 10 November

S_2 = 20 November

S_3 = 30 November

S_4 = 10 December

Interaction of irrigation and sowing time

Amount of irrigation and sowing date showed significant differences on number of tillers hill^{-1} of wheat due to interaction effect at 40, 65, 90 DAS and at harvest (Table 3). At 40, 65,90 DAS and at harvest, the highest number of tillers hill^{-1} viz., 5.530, 3.930, 3.330 and 2.800 respectively were observed from I_1S_2, while the corresponding lowest number of tillers hill^{-1} as 3.070, 2, 0.930 and 1 were recorded from I_3S_1 treatment combination. From the results of interaction effect it reveals that irrigation at field capacity with the combination of sowing in 20 November, 2014 showed better performance than all other combination of irrigation and sowing times.

Table 3. Interaction effects of amount of irrigation and sowing time on number of tillersplant^{-1} at days after sowing

Irrigation x Sowing time	Number of tillers hill^{-1} at DAS			
	40	**65**	**90**	**At harvest**
I_1S_1	4.067 c	2.600 de	1.600 cd	1.400 f
I_1S_2	5.530 a	3.930 a	3.330 a	2.800 a
I_1S_3	4.600 b	3.870 a	2.000 b	2.070 b
I_1S_4	4.400 b	3.730 a	1.730 bc	1.800 cd
I_2S_1	3.070 e	2.200 fg	1.270 def	1.070 g
I_2S_2	4.470 b	3.400 b	1.600 cd	2.000 bc
I_2S_3	4.270 bc	3.070 c	1.470 cd	1.730 de
I_2S_4	3.530 d	2.930 c	1.270 def	1.530 ef
I_3S_1	3.070 e	2.000 g	0.9300 f	1.000 g
I_3S_2	4.070 c	2.800 cd	1.470 cd	1.870 bcd
I_3S_3	4.000 c	2.530 de	1.330 de	1.530 f
I_3S_4	3.130 e	2.330 ef	1.000 ef	1.200 g
SE	0.103	0.093	0.116	0.066
Level of significance	**	**	**	**
CV (%)	4.42	5.46	12.69	6.85

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% level of probability

4.1.3 Dryweight plant^{-1}

Effect of irrigation

Dryweightplant^{-1} wassignificantlyinfluencedbydifferentirrigation treatmentsatallstages. The highest dry weight plant^{-1} at 40 days was 1.467g obtained from I_3 which was statistically similar to I_2 and lowest was 1.247g observed in $I_{1.}$The highest dry weight plant^{-1} at 65 days was 7.553g obtained from I_1 which was statistically similar toI_2 and lowest was 5.108g observed in $I_{3.}$The highest dry weight plant^{-1} at 90 days was 9.191g obtained from I_1 and lowest was 8.083g observed in I_2 which was statistically similar to $I_{3.}$ The highest dry weight plant^{-1} at harvest was 11.25g obtained from I_1 and lowest was 8.721g observed in $I_{3.}$Abodorrahmani*et al*. (2005) observed that dry matter productionwas reduced due to drought stress.

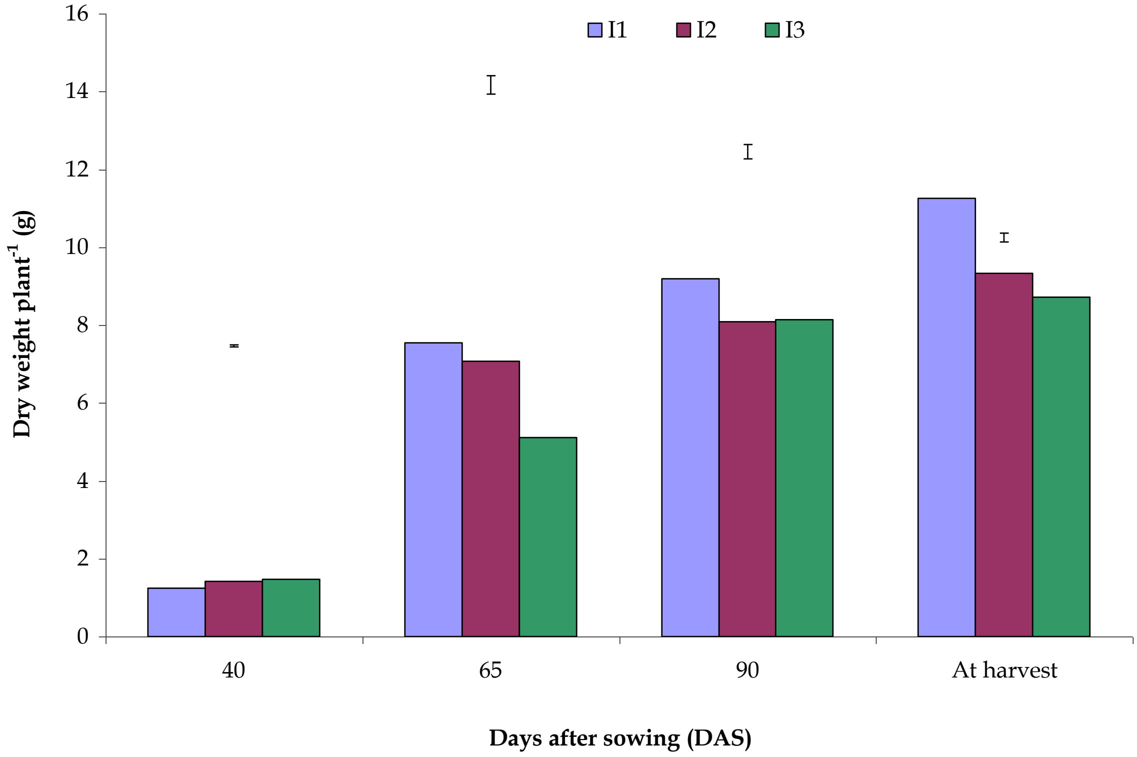

Fig. 5 Effect of amount of irrigation on dry weight plant-^{1}

Here,

I_1 =Irrigation upto field capacity

I_2 = Irrigation upto 1/2 of the field capacity

I_3 = Irrigation upto 1/4th of the field capacity

Effect of sowing time

Significantvariationwasobservedincaseofdryweightplant^{-1}withsowing timeThe highest dry weight plant^{-1} at 40 days was 1.7g obtained from S_3 and lowest was 0.9956g observed in S_1.The highest dry weight plant^{-1} at 65 days was 7.367g obtained from S_2 which was statistically similar to S_3 and S_4 and lowest was 4.993g observed in S_1.The highest dry weight plant^{-1} at 90 days was 10.03g obtained from S_3 and lowest was 5.811g observed in S_1.The highest dry weight plant^{-1} at harvest was 12.92g obtained from S_4 and lowest was 7.144g observed in S_1. 9.667g dry weight plant^{-1} was observed in S_3 which was statistically similar to S_2.In early sowing condition,10 November (S_1) dry weight plant^{-1} was reduced compared to other sowing times at 40, 65, 90 DAS and harvest. But,Alam*et al.* (2014) found that the highest DM (19.5 g m-2) was obtained fromthe variety BARI Gom-28 at 20 DAS in normal sowing (30 November), but the lowest (8.0g m-2) in late sowing(30 December) condition.

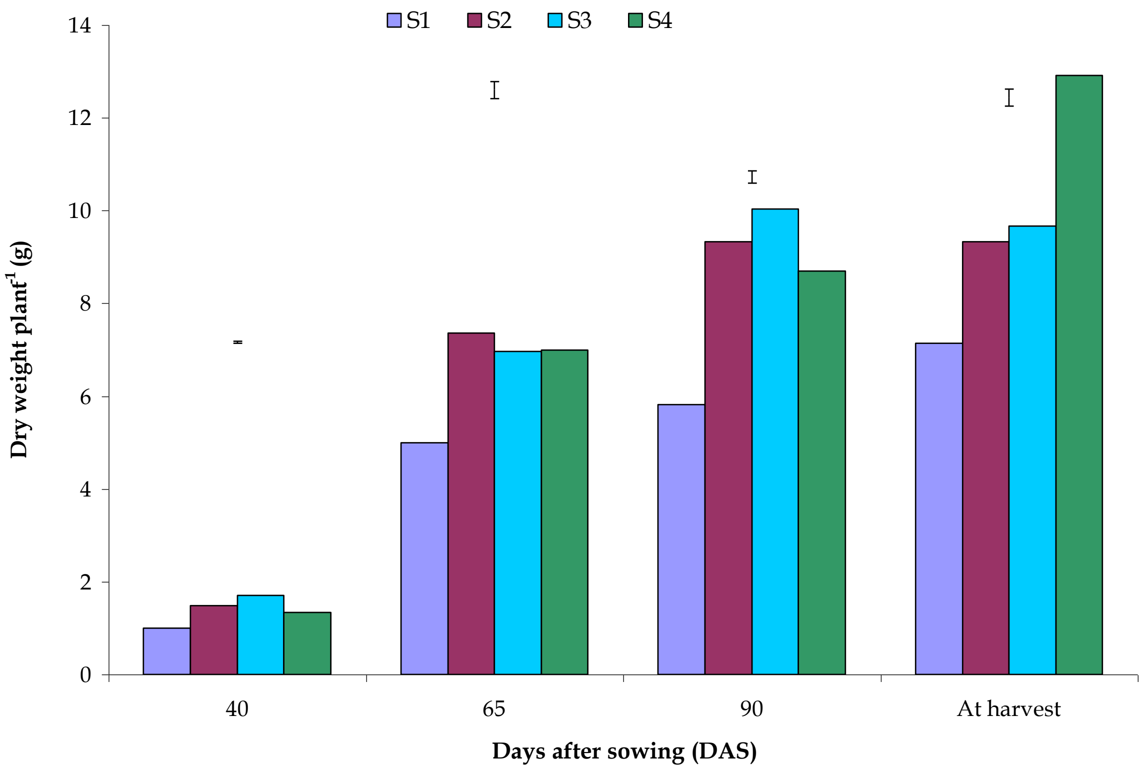

Fig. 6 Effect of sowing time on dry weight plant^{-1}

Here,

S_1= 10 November

S_2 = 20 November

S_3 = 30 November

S_4 = 10 December

Interaction effect of irrigation and sowing time

The interaction effects between irrigation treatment and sowing time were significant for the dry weight plant^{-1} at 40,65, 90DAS and at harvest. (table 5).The highest dry weight plant^{-1} at 40 days was 1.890g obtained from I_3S_3

which was statistically similar to I_1S_3 . At 65 days was 9.891g obtained from I_1S_2, at 90 DAS was 12.44g obtained from I_1S_2 and at harvest was15.22g was obtained from I_1S_4. The lowest dry weight plant^{-1} at40 was 0.88g obtained from I_3S_1 which was statistically similar to I_1S_1. At 65 days, lowest(2.88 g) obtained from I_3S_1, at 90 DAS, lowest (5.440g) obtained from I_3S_1 which was statistically similar to I_2S_1 and at harvest, lowest was(5.110g) was obtained from I_3S_1.

Table 5. Interaction effects of amount of irrigation and sowing time on dry weight plant^{-1} at days after sowing

Irrigation x Sowing time	Dry weight plant^{-1} (g) at DAS			
	40	65	90	At harvest
I_1S_1	0.8867 e	5.660 de	6.553 e	9.773 c
I_1S_2	1.660 b	9.891 a	12.44 a	10.11 c
I_1S_3	1.330 c	7.000 bc	8.770 c	9.891 c
I_1S_4	1.110 d	7.660 b	9.001 c	15.22 a
I_2S_1	1.220 cd	6.440 bcd	5.440 f	6.550 e
I_2S_2	1.220 cd	7.440 b	7.780 d	9.780 c
I_2S_3	1.880 a	7.217 bc	10.89 b	9.667 c
I_2S_4	1.330 c	7.220 bc	8.220 cd	11.33 b
I_3S_1	0.8800 e	2.880 f	5.440 f	5.110 f
I_3S_2	1.550 b	4.770 e	7.780 d	8.110 d
I_3S_3	1.890 a	6.670 bcd	10.44 b	9.443 c
I_3S_4	1.550 b	6.110 cd	8.890 c	12.22 b
SE	0.045	0.380	0.265	0.371
Level of significance	**	**	**	***
CV (%)	5.74	10.01	5.41	6.58

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at1% level of probability

4.2. Yield contributing characters

4.2.1. Effect of irrigation on days to flowering and maturity

Days to flowering

Days to flowering of wheat showed statistically significant variation due to different amount of irrigation under the present trial (Table 6). The highest days to flowering (56.25) was recorded from I_1. 53.50 days to flowering were obtained from I_2. The lowest days to flowering (50.83) was observed from I_3.

Days to maturity

Statistically significant variation was recorded in terms of days to maturity of wheat due to different amount of irrigation (Table 6). The highest days to maturity (105.70) was recorded from I_1while the lowest days to maturity (100.60) was observed from I_3.On the other hand, 103days to maturity was observed from I_2. But Atikulla (2013) reported that irrigation hastened the maturity period of wheat.

Table 6. Effect of irrigation on days to flowering and days to maturity of wheat

Irrigation	Days to flowering	Days to maturity
I_1	56.25 a	105.70 a
I_2	53.50 b	103.00 b
I_3	50.83 c	100.60 c
SE	0.221	0.587
Level of significance	**	**
CV (%)	1.40	1.96

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% level of probability

Here,

I_1 =Irrigation upto field capacity

I_2 = Irrigation upto 1/2 of the field capacity

I_3 = Irrigation upto 1/4th of the field capacity

4.2.2 Effect of sowing time on days to flowering and maturity

Days to flowering

Statistically significant variation from days to flowering of wheat was observed due to different sowing times (Table 7). The highest days to flowering (60) was observed from S_1 while the lowest days to flowering (49.67) was recorded from S_4. 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 times showed statistically significant variation for days to maturity of wheat (Table7). The highest days (111.8) to maturity was observed from the treatment $S_1$and 106.20 days required from S_2. But the lowest days to maturity S_4 (96.22) which was statistically similar to S_3 (98.11).High temperature stress was responsible for reducing maturity period. 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 maturity.

Table7. Effect of sowing time on days to flowering and days to maturity of wheat

Sowing time	Days to flowering	Days to maturity
S_1	60.00 a	111.8 a
S_2	53.78 b	106.20 b
S_3	50.67 c	98.11 c
S_4	49.67 d	96.22 c
SE	0.250	0.674
Level of significance	**	**
CV (%)	1.40	1.96

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% level of probability

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

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

Days to flowering

Interaction effect of different amount of irrigation and sowing date showed significant differences on days to flowering of wheat (Table 8). The highest days to flowering (62.67) was observed from I_1S_1 while the lowest days to flowering (46.67) was recorded from I_3S_4.

Days to maturity

There were no significant differences on the interaction effect of different amount of irrigation and sowing time in days to maturity of wheat (Table 8). Numerically, the highest days to maturity (114.33) was observed from I_1S_1 while the lowest days to maturity (93.67) were recorded from I_3S_4.

Table 8. Interaction effects of amount of irrigation and sowing time on days to flowering and days to maturity of wheat

Irrigation x Sowing time	Days to flowering	Days to maturity
I_1S_1	62.67 a	114.33
I_1S_2	56.67 c	108.67
I_1S_3	53.33 de	101.33
I_1S_4	52.33 e	98.33
I_2S_1	59.00 b	111.67
I_2S_2	54.33 d	106.33
I_2S_3	50.67 f	97.33
I_2S_4	50.00 f	96.67
I_3S_1	58.33 b	109.33
I_3S_2	50.33 f	103.67
I_3S_3	48.00 g	95.67
I_3S_4	46.67 h	93.67
SE	0.433	1.17
Level of significance	*	NS
CV (%)	1.40	1.96

* = Significant at 5% level of probability

NS = Non significant

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

4.2.4 Plant height (cm)

Effect of irrigation

Statistically significant variation was recorded for plant heightof wheat due to different amount of irrigation (Table 9). The highest plant height (80.96 cm) was recorded from I_1 which was statistically similar to I_2 (79.32 cm) whereas the lowest plant height (74.71cm) was observed from I_3.Shirazi*et al.* (2014) reported that maximum plant height was recorded in 300mm irrigation treatment and shortest in the control.

Effect of sowing time

Plant height of wheat showed statistically significant variation due to varying sowing times (Table 9). The highest plant height (81.95cm) was observed in S_2, which was statistically similar to S_3(80.61cm). 77.31 cm plant height was attained from S_4. The lowest plant height (73.44 cm) was recorded from S_1.

4.2.5Spike length (cm)

Effect of irrigation

Statistically significant variation was recorded for spike length of wheat due to different amount of irrigation (Table 9). The highest spike length (30.20 cm) was recorded from I_1 while the lowest spike length (15.14 cm) was observed from I_3 which was statistically similar with I_2 (15.40 cm).

Effect of sowing time

Spike length of wheat showed statistically significant variation due to varying sowing times (Table 9). The highest spike length (22.67 cm) was observed in S_2, which was statistically similar to S_3(22.39 cm) and closely followed by S_4(21.38 cm).The lowest spike length (14.57 cm) was recorded from S_1. Spike length was reduced in early sowing, S_1 (10 November). 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 were recorded in December 15 sown plants.

4.2.6 Number of spikelets spike^{-1}

Effect of irrigation

Different amount of irrigation showed statistically significant variation in terms of number of spikelets spike^{-1} of wheat under the present trial (Table 9). The highest number of spikelets spike^{-1} (16.93) obtained from I_1.16.53 numbers of spikelets per spike were obtained from I_2.The lowest numbers of spikelets spike^{-1} (16.25) was observed in I_3.

Effect of sowing time

Significant variation was found for number of spikelets spike^{-1} of wheat due to varying sowing times (Table 9). The highest numbers of spikelets spike^{-1} (17.20) was observed in S_2.In case of $S_{3,}$numbers of spikelets spike^{-1}were 17.02 andS_4produced 16.47 numbers of spikelets spike^{-1}. The lowest numbers of spikelets spike^{-1} (15.60) was recorded from S_1. In order to sowing early (10 November), S_1produced lowest numbers of spikelets spike^{-1}compared to late sowing (10 December), S_4. But Shafiq (2004) revealed that early sowing increased spikelets per spike compared to late sowing.

4.2.7 Number of grains spike^{-1}

Effect of irrigation

Number of grains spike^{-1} of wheat showed significant variation due to different amount of irrigation (Table 9). The highest numbers of grains spike^{-1} (49.92) were recorded from I_1. I_2 produced 45.92 numbers of grains per spike. The lowest numbers (42.78) were recorded from I_3. Numbers of grains spike^{-1} were enhanced owing to applying irrigation upto field capacity (I_1). Razi-us-Shams (1996) observed that irrigation increased number of grains per panicle over the control in wheat.

Effect of sowing time

Statistically significant variation was recorded for number of grains spike^{-1} of wheat under varying sowing times (Table 9). The highest numbersof grains spike^{-1} (51) was obtained from S_2 whereas the lowest numbersof grains spike^{-1} (38.29) were recorded from $S_{1.}$ S_3 produced 49.18 numbers of grains spike^{-1} and S_4 produced 46.36 numbers of grains spike^{-1}.Owing to early sowing (10 November), S1 produced lowest numbers of grains spike.$^{-1}$ButShafiq (2004) revealed that early sowing increased grains spike^{-1}compared to late sowing.

4.2.8 Weight of 1000-grain (g)

Effect of irrigation

It was found that weight of 1000-grain of wheat varied significantly due to different l amount of irrigation under the present trial (Table 9). The treatment I_1 produced the highest 1000-grain weight of 49.65 g whereas the treatment I_3 produced lowest 1000-grain weight of 45.81g. The treatment I_2produced 47.99 g wt. of 1000 grain of wheat.Weight of 1000-grain was increased due to applying irrigation upto field capacity (I_1). Islam (1996) observed that irrigation had no influence of 1000-grain weight.

Effect of sowing time

Statistically significant variation was recorded for weight of 1000-grain of wheat due to varyingsowing times (Table 9). The treatment S_2 produced significantly the highest 1000 grain weight of 53.30 g while S_1 produced significantly the lowest 1000-grain weight of 42.96g. The treatment S3 produced 48.41 gweight of 1000 grain and 46.59g was found in S_4. Due to early sowing (10 November), lowest 1000 grain weight was recorded from S_1 compared to S_4 (late sowing, 10 December). But Shafiq (2004) revealed that early sowing increased 100-grain weight compared to late sowing.

Table 9.Effect of amount of irrigation and sowing time on yield contributing characters of wheat

Treatment	Plant height (cm)	Spike length (cm)	No. of spikelet $spike^{-1}$	No. of grains $spike^{-1}$	1000 grain wt
Irrigation level					
I_1	80.96 a	30.20 a	16.93 a	49.92 a	49.65 a
I_2	79.32 a	15.40 b	16.53 b	45.92 b	47.99 b
I_3	74.71 b	15.14 b	16.25 c	42.78 c	45.81 c
SE	0.556	0.335	0.027	0.513	0.212
Level of significance	**	**	**	**	**
Sowing date					
S_1	73.44 c	14.57 c	15.60 d	38.29 d	42.96 d
S_2	81.95 a	22.67 a	17.20 a	51.00 a	53.30 a
S_3	80.61 a	22.39 ab	17.02 b	49.18 b	48.41 b
S_4	77.31 b	21.38 b	16.47 c	46.36 c	46.59 c
SE	0.624	0.384	0.028	0.572	0.244
Level of significance	**	**	**	**	**
CV (%)	2.39	5.68	0.52	3.72	1.53

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% level of probability

Here,

I_1 =Irrigation upto field capacity, I_2 = Irrigation upto 1/2 of the field capacity, I_3 = Irrigation upto $1/4^{th}$ of the field capacity

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

4.2.9 Interaction effect of yield contributing characters

Different levels of irrigation and sowing date showed significant differences on plant height of wheat due to interaction effect (Table 10). The highest plant height (84.07 cm) was observed from I_1S_2, while the lowest plant height (69.96 cm) was recorded from I_3S_1.

Different levels of irrigation and sowing date showed significant differences on spike length of wheat due to interaction effect (Table 10). The highest spike length (36.7 cm) was observed from I_1S_2, while the lowest spike length (14.17 cm) was recorded from I_3S_1.

Interaction effect of different amount of irrigation and sowing time showed significant differences on number of spikelets spike^{-1} of wheat (Table 10). The highest Number of spikelets spike^{-1} (17.60) was observed from I_1S_2, while the lowest Number of spikelets spike^{-1} (15.27) was recorded from I_3S_1.

Interaction effect of amount of irrigation and sowing date showed significant differences on number of grains spike^{-1} of wheat (Table 10). The highest numbers of grains spike^{-1} (54.13) was observed from I_1S_2, while the lowest numbers of grains spike^{-1}(33.07) was recorded from I_3S_1.

Interaction effect of different amount of irrigation and sowing time varied significantly on weight of 1000-grain of wheat (Table 10). The highest weight of 1000-wheat grain (55.15 g) was observed from I_1S_2, while the lowest weight of 1000-grain (40.99 g) was recorded from I_3S_1.

Table 10. Interaction effects of amount of irrigation and sowing time on yield contributing characters of wheat

Irrigation x Sowing time	Plant height (cm)	Spike length (cm)	No. of spikelet $spike^{-1}$	No. of grains $spike^{-1}$	1000 grain wt
I_1S_1	76.53 de	14.81 c	16.07 f	44.73 de	44.50 fg
I_1S_2	84.07 a	36.72 a	17.60 a	54.13 a	55.15 a
I_1S_3	82.96 ab	36.11 a	17.33 b	51.00 b	50.99 c
I_1S_4	80.27 bc	33.18 b	16.73 d	49.80 bc	47.97 d
I_2S_1	73.84 e	14.72 c	15.47 g	37.07 f	43.39 g
I_2S_2	83.81 a	15.65 c	17.27 b	51.40 ab	53.21 b
I_2S_3	81.61 ab	15.63 c	17.00 c	49.93 bc	48.89 d
I_2S_4	78.01 cd	15.62 c	16.40 e	45.27 de	46.45 e
I_3S_1	69.96 f	14.17 c	15.27 h	33.07 g	40.99 h
I_3S_2	77.97 cd	15.63 c	16.73 d	47.47 cd	51.54 c
I_3S_3	77.25 cd	15.43 c	16.73 d	46.60 de	45.35 ef
I_3S_4	73.65 e	15.33 c	16.27 e	44.00 e	45.34 ef
SE	1.08	0.666	0.048	0.992	0.423
Level of significance	**	**	**	*	*
CV (%)	2.39	5.68	0.52	3.72	1.53

** = Significant at 1% level of probability, * = Significant at 5% level of probability

NS = Not significant

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% and 5% level of probability

4.3 Yield characters

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

Grain yield

Grain yield of wheat ha^{-1} significantly differed from different levels of amount of irrigation (Fig.7). Grain yield was significantly influenced by different irrigation treatments. It was observed that the highest grain yield (3.380t ha^{-1}) was obtained from I_1. On the other hand, the lowest grain yield(2.858tha^{-1}) was obtained from I_3. Maximum grain yield was obtained due to applying irrigation upto field capacity (I_1). Rasol, H. O. A. (2003) stated that the high yields were obtained from 500 and 600mm whereas the lowest was obtained from the 300mm irrigation treatment.

Straw yield

Straw yield of wheat showed statistically significant variation due to different levels of irrigation (Fig. 7). The highest straw yield of 3.787 t ha^{-1} was recorded from I_1.On the other hand, the lowest straw yield 3.402 t ha^{-1} was observed from I_3. Straw yield became maximum when irrigation applied upto field capacity (I_1) rather than $1/4^{th}$ of field capacity (I_3). Razi-us-Shams (1996) observed that irrigation increased the straw yields over the control.

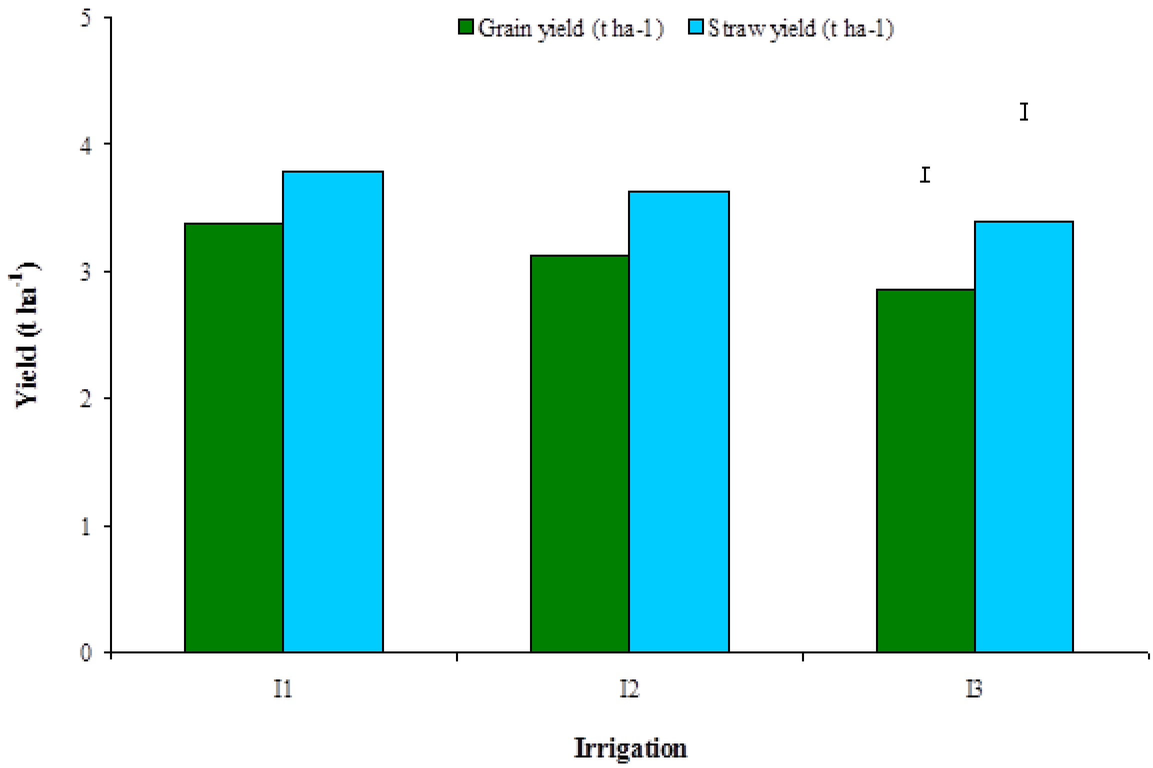

Fig.7 Effect of amount of irrigation on grain and straw yield

Here,

I_1 = Irrigation upto field capacity

I_2 = Irrigation upto 1/2 of the field capacity

I_3 = Irrigation upto1/4th of the field capacity

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

Grain yield of wheat showed statistically significant variation due to different sowing date (Fig. 8). The highest grain yield (3.607 t ha-^{1}) was observed from the treatment of S_2 and the lowest grain yield 2.567 t ha-^{1} observed from S_1 was statistically similar to 3.07 t ha-^{1} recorded from S_2. Maximum grain yield was obtained from S_2 (20 November) compared to S_1 (10 November).Hossain*et al.* (2011) observed that highest yield was obtained wheat sown in November 22 to December 20 compared to November 08, 15 and December 27.

Significant variation was recorded for straw yield of wheat due to different sowing date under the present trial (Fig. 8). The highest straw yield as 4.027 t ha-^{1} was observed from S_2 and the lowest straw yield 3.079 t ha-^{1} was recorded from S_1. S_3 produced 3.834 t ha^{-1} and S_4produced 3.480 t ha-^{1}. Lowest straw yield was obtained from early sowing, S_1 (10 November) compared to late sowing, S_4 (10 December). Ahmed *et al*. (2006) found that the highest straw yield (4.28 t/ha) produced due to early sowing (30 November), whereas the lowest straw yield (3.21 t/ha) was obtained from delay sowing.

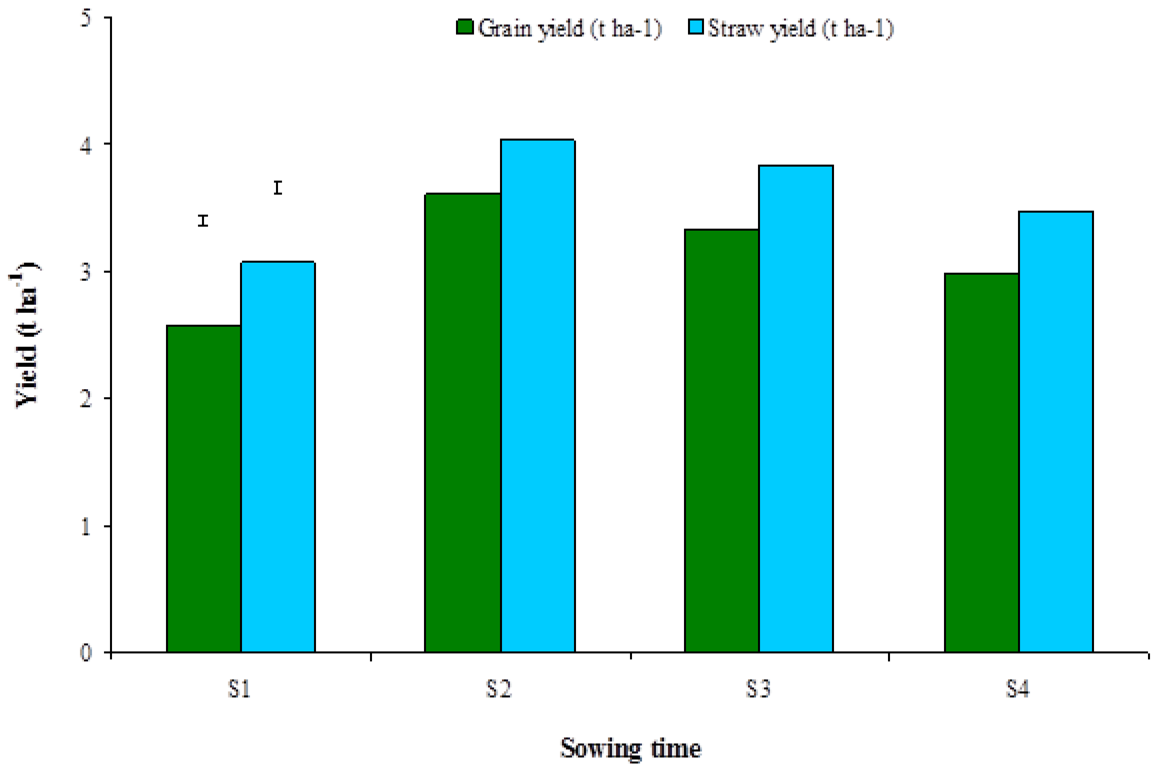

Fig.8 Effect of sowing time on grain and straw yield

Here,

S1= 10 November

S2 = 20 November

S3 = 30 November

S4 = 10 December

4.3.3 Effect of amount of irrigation and sowing time on biological yield and harvest index of wheat

Biological yield

It was revealed from the experiment that biological yield of wheat showed statistically significant variation due to different levels of irrigation under the present trial (Table 9). The highest biological yield (7.168 t ha^{-1}) was recorded from I_1. 6.753 t ha^{-1} recorded from I_2. On the other hand, the lowest biological yield 6.259 t ha^{-1} was observed from I_3.

Statistically significant variation was recorded for biological yield of wheat due to varying sowing times (Table 9). The highest biological yield (7.633 t $ha-^{1}$) was obtained from S_2, while the lowest biological yield (5.646 t ha-1) was recorded from S_1. S_3 produced 7.161 t $ha-^{1}$ and S_4 produced 6.467 t $ha-^{1}$.Atikulla (2013) observed that the highest biological yield (8.94 t ha^{-1}) obtained from November 19, 2012 (S_1), while the lowest biological yield (8.25 t ha^{-1}) was recorded from December 9 sowing date (S_3).

Harvest index (%)

Harvest index of wheat showed statistically non significant variation due to different amount of irrigation under the present trial (Table 11). Numerically, the highest harvest index (47.09%) was recorded from I_1 and the lowest harvest index was 45.56% was observed from I_3 which was statistically similar to I_2(46.25%). Ngwako*et al*. (2013) showed thatirrigation throughout the growth stages increased harvest index by 16.71% over no irrigation.

Data revealed that there was significant variation for harvest index of wheat due to varying sowing times (Table 11). The highest harvest index (47.21%) was observed from S_2 and the lowest 45.42% was from S_1. Harvest index (46.43%) was observed from S_3 which was statistically similar to S_4 (46.15%).Ehdaie*et al*. (2001) stated that harvest index was reduced by early sowing.

Table 11. Effect of amount of irrigation and sowing time on biological yield and harvest index of wheat

Treatment	Biological yield (t ha^{-1})	Harvest index (%)
Irrigation level		
I_1	7.168 a	47.09 a
I_2	6.753 b	46.25 b
I_3	6.259 c	45.56 b
SE	0.049	0.181
Level of significance	**	**
Sowing time		
S_1	5.646 d	45.42 c
S_2	7.633 a	47.21 a
S_3	7.16 b	46.43 b
S_4	6.467 c	46.15 b
SE	0.051	0.244
Level of significance	**	**
CV (%)	2.24	1.58

** = Significant at 1% level of probability

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% level of probability

Here,

I_1 =Irrigation upto field capacity, I_2 = Irrigation upto1/2 of the field capacity, I_3 = Irrigation upto1/4thof the field capacity
S_1= 10 November, S_2 = 20 November, S_3 = 30 November, S_4 = 10 December

4.3.4. Interaction of amount of irrigation and sowing time on yield characters of wheat

Data revealed that interaction effect of different amount of irrigation and sowing times showed significant differences on grain yield ha^{-1} of wheat (Table 12). The highest grain yield ha^{-1} of wheat (3.970 t ha^{-1}) was obtained from the treatment combination of irrigation upto field capacity with 20 November, 2014 sowing time (I_1S_2) and the lowest grain yield of wheat ha^{-1} (2.3 t ha^{-1}) was obtained from the treatment combination of irrigation upto 1/4th of field capacity with 10 November, 2014 (I_3S_1).

Interaction effect of amount of irrigation and sowing time showed significant differences on straw yield of wheat (Table 12). The highest straw yield (4.310 t ha^{-1}) was observed from I_1S_2, while the lowest straw yield (2.867 t ha-1) was recorded from I_3S_1.

Amount of irrigation and sowing date showed significant differences on biological yield of wheat due to interaction effect (Table 12). The highest biological yield (8.280 t ha^{-1}) was observed from I_1S_2, while the lowest biological yield (5.167 t ha^{-1}) was recorded from I_3S_1.

There were no significant differences on interaction effect of different amount of irrigation and sowing time on harvest index of wheat (Table 12). Numerically, the highest harvest index (47.93%) was observed from I_1S_2, while the lowest harvest index (44.66%) was recorded from I_3S_1.

Table 12. Interaction effects of amount of irrigation and sowing time on yield characters of wheat

Irrigation x Sowing time	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_1S_1	2.750 e	3.170 g	5.920 f	46.42
I_1S_2	3.970 a	4.310 a	8.280 a	47.93
I_1S_3	3.550 b	4.000 b	7.550 b	47.02
I_1S_4	3.250 c	3.670 e	6.920 cd	46.97
I_2S_1	2.650 e	3.200 g	5.850 f	45.30
I_2S_2	3.530 b	3.970 bc	7.500 b	47.07
I_2S_3	3.330 c	3.833 cd	7.163 c	46.38
I_2S_4	3.00 d	3.500 f	6.500 e	46.15
I_3S_1	2.30 f	2.867 h	5.167 g	44.66
I_3S_2	3.320 c	3.800 de	7.120 c	46.63
I_3S_3	3.100 d	3.670 e	6.770 d	45.79
I_3S_4	2.710 e	3.270 g	5.980 f	45.32
SE	0.041	0.048	0.088	0.422
Level of significance	*	*	*	NS
CV (%)	2.36	2.30	2.24	1.58

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 1% and 5% level of probability

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November 2014 to March 2015 to determine the influence of amount of irrigation and sowing time on growth and yield of wheat. The experiment comprised two factors; Factors A: Irrigation (3 levels): I_1: Irrigation upto field capacity; I_2: Irrigation upto 1/2 of field capacity and I_3: Irrigation upto1/4th of field capacity (at CRI, initiation of flowering and grain filling stage); 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 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 upto field capacity) produced the tallest plant height (41.71cm,81.10cm,81.44cm and 83.35cm) respectively at 40, 65,90 DAS and at harvest and the corresponding lowest plant height was found to be recorded under the treatment I_3 (irrigation upto 1/4th field capacity). In respect of the effect of irrigation on number of tillers hill^{-1},it was revealed from the collected data that irrigation upto field capacity (I_1) obtained the highest value in each data recording day from 40 DAS to 90 DAS and at harvest while I_3 (irrigation upto 1/4th of field capacity) obtained the respective lowest values. In respect of the effect of irrigation, the highest dry weight plant^{-1} at 40 days obtained from irrigation upto 1/4th of field capacity (I_3) and lowest observed in irrigation upto field capacity (I_1).The highest dry weight plant^{-1} at 65 days obtained from irrigation upto field capacity (I_1) and lowest observed in irrigation upto 1/4th of field capacity (I_3).The highest dry weight plant^{-1} at 90 days obtained from irrigation upto field capacity (I_1) and lowest observed in irrigation upto 1/2 of field capacity (I_2).The highest dry weight plant^{-1} at harvest obtained from irrigation uptofield capacity (I_1) and lowest observed in irrigationupto1/4th of field capacity (I_3).

Maturity of wheat was found to vary with irrigation and results indicate that irrigation(I_3)upto 1/4th of field capacity in wheat field accelerated its maturity which is contrary to irrigation(I_1) upto field capacity as such the highest maturity period (105.70 days) was found in I_1 while the shortest maturity (100.60 days) was found in I_3.

Data on yield contributing characters of wheat as plant height (cm), spike length (cm),no. of spikelets per spike, no. of grains spike^{-1} and 1000 grain weight (g) were recorded at 40 DAS, 65 DAS, 90 DAS and harvest. Results revealed that irrigation had significant effect on each of these parameters. As a result, I_1 (Irrigation upto field capacity) recorded the highest values in each of the above parameters. The highest values which were 80.96, 30.20,16.93, 49.92 and 49.65 respectively. On the other hand, I_3 i.e. irrigation upto 1/4th of field capacity had significantly the lowest corresponding values of 74.71, 15.14,16.25,42.78 and 45.81.The effect of irrigation may be summed up in this way that irrigation enhanced the yield of wheat and irrigation upto field capacity performed better than that of other irrigation levels.

Yield parameters as grain yield, straw yield and biological yield varied significantly on the influence of irrigation. Consequently, all yield parameters responded significantly to higher amount of irrigation. The highest grain yield ha^{-1} (3.380 t) and highest straw yield ha^{-1} (3.787 t) were obtained by the treatment I_1 and the respective lowest grain yield ha^{-1} (2.858 t) and straw yield ha^{-1} (3.402t) were obtained by the treatment I_3. In case of biological yield I_1 obtained the highest value of 7.168 t ha^{-1} which was significantly higher than each of the respective values obtained by the rest irrigation treatments and highest harvest index (47.09%) was obtained from I_1 compared to other irrigation treatments.

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(44.99cm,83.85cm and 85.07cm) was observed in S_1 at 40,65 DAS and harvest respectively. Lowest (38.22cm)was observed in S_4 at 40 DAS,76.01 cm was observed in S_3 at 65 DAS and at harvest 76.42cm from S_3.Highest number of tillers plant^{-1}was observed in S_2 at40,65, 90 DAS and harvest. Lowest was recoded from S_1.Highest dry weight plant^{-1} were recorded under the treatment S_3 (November 30, 2014 sowing time) at 40 DAS while the lowest values were observed under the treatment S_1 (November 10, 2014 sowing time).Highest dry weight plant^{-1} was observed in S_2 at 65 DAS and lowest in S_1. At harvest, highest was found in S_4 andlowest wasfound in S_1.The crop maturity also varied significantly with sowing time and S_1 had the highest maturity of 111.8 days, while S_4 had the lowest maturity period of 96.22 days. Yield contributing characters of wheat varied significantly on the effect of sowing time and S_2 obtained the highest values of 80.51,22.67,17.20,51and 53.30 respectively for plant height(cm), spike length (cm), number of spikelets spike^{-1} , number of grains spike^{-1}and 1000-grain weight whereas the lowest values which were 73.44,14.57,15.60,38.29 respectively and 42.96 were obtained from $S_{1.}$ As the yield contributing characters recorded the highest values in November 20, sowing (S_2) so, the highest grain yield (3.607 t ha^{-1}), straw yield (4.027 t ha^{-1}) and biological yield (7.633 t ah^{-1}) and harvest index (47.21%) were also recorded in November 20 sowing (S_2) and all the lowest values of all these parameters were recorded on November 10 sowing (S_1).

Interaction effect was also found to vary significantly. Irrigation upto field capacity(I_1) in combination with November 20 sowing (I_1S_2) recorded the highest values in each of the yield contributing characters of wheat studied and as such this treatment combination also obtained the highest grain yield (3.97 t ha^{-1}), straw yield (4.310 t ha^{-1}) and biological yield (8.280 t ha^{-1}) and harvest index(47.93%) respectively. The respective lowest yield 2.300 t ha^{-1}, 2.867 t ha^{-1}, 5.167 t ha,$^{-1}$ 44.66% were obtained in the treatment combination of I_3S_1.

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

i) Growth, yield attributes and yield of wheat were significantly affected with irrigation and time of sowing.

ii) Adequate amount of irrigation (field capacity) produced the highest seed yield.

iii) Optimum sowing time of wheat was found to be November 20.

Recommendation:

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

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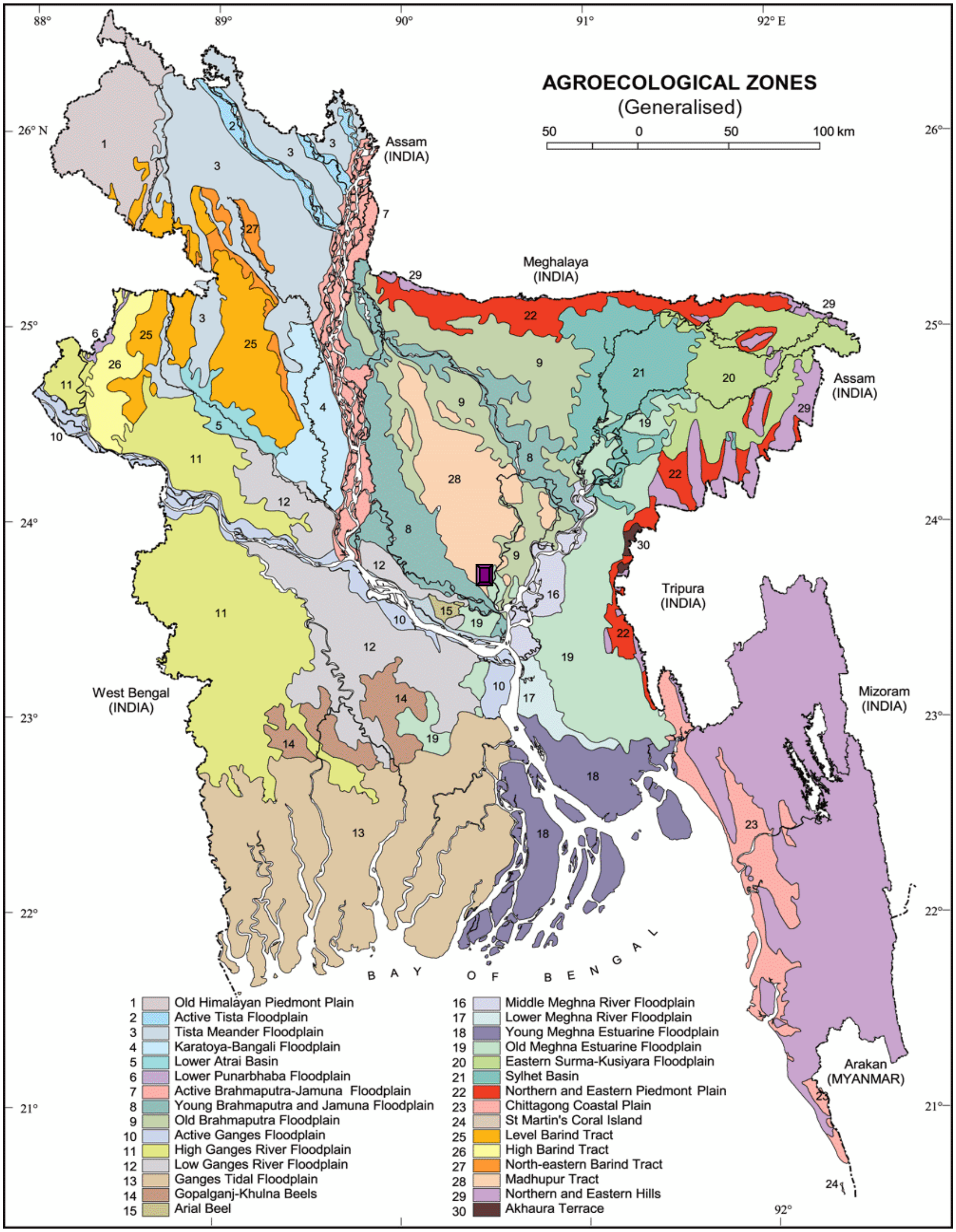
APPENDICES

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



Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

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 III. Monthly record of 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 (%)	Rainfall (mm) (total)
	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: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka

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

Source of variation	df	Plant height (cm) at DAS			
		40	**65**	**90**	**At harvest**
Replication	2	1.090	4.113	2.118	1.553
Irrigation (A)	2	39.395**	25.009*	51.442*	111.355*
Error	4	0.647	3.153	3.632	9.393
Sowing (B)	3	116.572**	100.690**	6.679NS	141.843**
A x B	6	9.178**	2.617NS	10.550*	1.141NS
Error	18	0.395	3.473	3.127	5.213

** = Significant at 1% level of probability, * = Significant at 5% level of probability

NS = Not significant

AppendixV. Analysis of variance (mean square) of the data for number of tillers/hill at days after sowing

Source of variation	df	Number of tillers/hill at DAS			
		40	**65**	**90**	**At harvest**
Replication	2	0.017	0.025	0.036	0.018
Irrigation (A)	2	3.809**	3.768**	3.190**	1.208**
Error	4	0.038	0.026	0.049	0.015
Sowing (B)	3	3.044**	2.082**	1.397**	1.820**
A x B	6	0.143**	0.105**	0.388**	0.062**
Error	18	0.032	0.026	0.040	0.013

** = Significant at 1% level of probability

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

Source of variation	df	Dry weight/plant (g) at DAS			
		40	65	90	At harvest
Replication	2	0.003	0.557	0.037	1.000
Irrigation (A)	2	0.159**	20.182**	4.684**	20.874**
Error	4	0.008	0.489	0.296	0.118
Sowing (B)	3	0.786**	10.370**	30.941**	51.115**
A x B	6	0.188**	4.048**	7.517**	4.097**
Error	18	0.006	0.434	0.210	0.413

** = Significant at 1% level of probability

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

Source of variation	df	Days to flowering	Days to maturity
Replication	2	0.529	4.005
Irrigation (A)	2	88.055**	77.482**
Error	4	0.584	4.127
Sowing (B)	3	195.137**	471.682**
A x B	6	1.580*	0.734NS
Error	18	0.564	4.087

** = Significant at 1% level of probability, * = Significant at 5% level of probability NS =Non significant

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

Source of variation	df	Plant height (cm)	Spike length (cm)	No. of spikelet/ spike	No. of grains/ spike	1000 grain wt/plot
Replication	2	3.36	1.44	0.005	3.21	0.483
Irrigation (A)	2	126.00**	892.12**	1.410**	153.25**	44.672**
Error	4	3.72	1.35	0.009	3.15	0.541
Sowing (B)	3	104.99**	131.96**	4.633**	283.47**	166.557**
A x B	6	13.34**	96.56**	0.043**	9.78*	1.460*
Error	18	3.50	1.32	0.007	2.94	0.538

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Appendix IX. 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	0.009	0.007	0.031	0.714
Irrigation (A)	2	0.819**	0.451**	2.482**	7.015**
Error	4	0.006	0.010	0.029	0.395
Sowing (B)	3	1.810**	1.569**	6.742**	4.967**
A x B	6	0.016*	0.019*	0.070*	0.095NS
Error	18	0.005	0.007	0.023	0.534

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

PLATE

Plate.1: Initiation of fowering stage

Plate.2: Application of irrigation

Plate.3: Flowering Stage

Plate.4 Maturity Stage