EFFECT OF SINGLE IRRIGATION AND SOWING DATE ON GROWTH AND YIELD OF WHEAT

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Single Irrigation and Sowing Date on Growth and Yield of Wheat"** 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 **Md. Nizam Atikulla**, Registration number: **06-01899** 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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ABSTRACT

The experiment was conducted during the period from November 2012 to March 2013 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of single irrigation and sowing date on growth and yield of wheat. The experiment comprised two factors; Factors A: Irrigation (4 levels): I_0: No irrigation i.e. control; I_1: Irrigation at 20 DAS (Crown root initiation stage); I_2: Irrigation at 55 DAS (Flowering stage) and I_3: Irrigation at 75 DAS (Grain filling stage); Factor B: Sowing date (3 levels at 10 days interval): S_1: Sowing at 19 November, 2012; S_2: Sowing at 29 November, 2012 and S_3: Sowing at 09 December, 2012. The experiment was laid out in Split Plot Design with three replications. Irrigation was assigned in the main plot and sowing date was in the sub-plot. It was evident from the results that morpho-physiological and yield contributing characters of wheat were significantly influenced by irrigation, sowing date and their interaction. In respect of the effect of irrigation results revealed 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 I_2 (irrigation at flowering) and I_3 (irrigation at grain filling stage of wheat). 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. 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). Due to cumulative action of irrigation at crown root initiation stage (I_1) and November 19 sowing (S_1) the combination effect (I_1S_1) recorded the highest results in number of tillers hill^{-1} (5.17), number of spikes hill^{-1} (4.50), filled grains spike^{-1} (34.33) and 1000 seed weight (47.09 g) of wheat and that resulted to get ultimately the highest seed yield (3.82 t ha^{-1}), straw yield (5.96 t ha^{-1}) and biological yield (9.78 t ha^{-1}) of the same. Due to poor performance of individual treatment of non-irrigation (I_0) and December 9 sowing date (S_3) the combination I_0S_3 recorded statistically the lowest grain yield (2.44 t ha^{-1}), straw yield (4.74 t ha^{-1}) and biological yield (7.38). Harvest index was found 40.16% for I_1S_1 and 32.94% for I_0S_3.

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CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is primarily grown across the exceptionally diverse range of environments. It is an important protein containing cereal with high amount of carbohydrate and is a staple food for two third of the total population of the world (Majumder, 1991). Saari (1998) reported that wheat is cultivated throughout the world and is grown under different environmental conditions ranging from humid to arid, subtropical to temperate zone. But the largest area of wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh, India and Nepal (Dubin and Ginkel, 1991). It contributes to the national economy by reducing the volume of import of cereals for fulfilling the food requirements of the country (Razzaque *et al.*, 1992). Generally wheat supplies carbohydrate (69.60%) and reasonable amount of protein (12%), fat (1.72%), and also minerals (16.20%) and other necessary nutrients (BARI, 1997). In Bangladesh, wheat is the second most important cereal crop (FAO, 1997).

In the environmental condition of Bangladesh wheat is a well adapted cereal crop for its vegetative growth and development. Though the crop was introduced in Bangladesh during the period of former East Pakistan in 1967, its reputation increased after 1975. Now the popularity of wheat as staple food is increasing day by day in our country. Wheat cultivation has been increased manifolds to meet up the food shortage in the country. But, in spite of its importance, the yield of the crop in the context of our country is low (2.2 t ha^{-1}) in comparison to other countries of the world (FAO, 1997). The area, production and yield of wheat have been increasing dramatically based on the demand of over increasing population of Bangladesh during the last two decades, but its present yield is too low in comparison to some developed countries like Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 tha^{-1}, respectively (FAO, 2000). At present about 706.33 thousand hectares of land in Bangladesh is covered by wheat with the annual production of 1,592 thousand tons (BBS, 2011).

Yield and quality of seeds of wheat are very low in Bangladesh. The low yield of wheat in Bangladesh however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors, irrigation facilities with sowing time of wheat are the major reasons of yield reduction in Bangladesh. In Bangladesh, wheat is grown during Rabi (winter) season and it is dry and as such, the inadequate soil moisture in this season limits the use of fertilizers, and consequently results in decreased grain yield. About 42.78% of the total wheat area in the country is irrigated and the rest of the area is cultivated under rainfed condition (BBS, 2008).

Irrigation plays a vital role in terms of bringing good growth and development of wheat. Insufficient soil moisture affects both the germination of seed and uptake of nutrients from the soil. Irrigation frequency also has a significant influence on growth and yield of wheat (Khajanij and Swivedi, 1988). But in Bangladesh most of the farmers are not in a position to provide irrigation in different critical stages of wheat production because of the inadequate facility of irrigation devices and irrigation sources. These suggest that irrigation water should be supplied precisely at the peak period of crop growth, which may provide good yield of wheat. 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 imposition of water stress 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). From a survey Ahmed and Elias (1986) reported that in Bangladesh, lack of irrigation facilities was found to be a major constraint for 38% wheat growers, and 25% of the farmers of Bangladesh could not grow wheat due to this problem.

Generally, wheat is sown in November to ensure optimal crop growth and avoid high temperature. After that if wheat is sown in the field it faces high range of temperature for its growth and development as well as yield potential. Among different factor late sowing of wheat is one of the major reasons of yield reduction, because about 60% of the wheat is cultivated at late sowing conditions after harvesting of the transplanted aman rice (Badaruddin *et al*., 1994). Temperature is one of the major environmental factors that governs grain yields in wheat significantly. Photosynthesis in wheat is maximum between 22 and 25^0C (Kobza and Edwards, 1987) and decreases sharply above 35^0C (Al-Khatib and Paulsen, 1990). But major wheat area under rice-wheat cropping system is late planted (Badruddin *et al*., 1994) including Bangladesh. Late planted wheat plants face a period of high temperature stress during reproductive stages causing reduced kernel number spike^{-1} (Bhatta *et al*., 1994; Islam *et al*., 1993) and reduced kernel weight (Acevedo *et al*., 1991) as well as the reduction of seed yield (Islam *et al*., 1993).

Information on the precise time of application of irrigation as well as the proper sowing time of wheat to optimize the wheat production within the farmers limited resources is inadequate in Bangladesh. So in the context of the above mentioned situation in respect of wheat cultivation in Bangladesh, the present peace of work was undertaken with the following objectives-

- To determine the precise time of application of one irrigation in wheat production to maximize its yield
- To determine the optimum sowing time of wheat in this agro-climatic zone and
- To investigate the interaction effect of irrigation and sowing time on the growth and yield of wheat.

CHAPTER II

REVIEW OF LITERATURE

One of the major reasons of yield reduction of wheat is that about 60% of the crop is cultivated at late sowing condition after harvesting the transplanted aman rice and in dry condition in dry season. So irrigation and subsequently sowing time are the most important factors need to be considered in wheat cultivation. Very limited research works related to growth, yield and development of wheat due to irrigation levels and sowing date have been carried out and the research work also so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the irrigation and sowing date of wheat done at home and abroad have been reviewed under the following headings:

2.1. Influence of irrigation on the growth and yield of wheat

In Bangladesh generally, wheat is grown during Rabi (winter) season and it is dry and as such, the inadequate soil moisture in this season limits the use of fertilizers, and consequently results in decreased grain yield. So, Irrigation is the most important agronomic factor that affects the growth and development of plants. Research works done at home and abroad showed that irrigation at optimum time greatly influences yields of wheat. The yield and yield parameters of wheat varied due to the prevailing moisture condition during pre-antesis and post-anthesis development. Some of the pertinent literatures regarding effect of irrigation level in home and abroad have been presented below-

Plant height

Islam (1997) reported 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.

Gupta *et al.* (2001) reported that plant height 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 plant height. Among the yield attributes plant height were positively correlated with grain and biological yield irrigation at the anthesis stage.

Wang *et al.* (2002) conducted a pot experiment in a green house to study the effects of water deficit and irrigation at different growing stages of winter wheat and observed that water deficiency retarded plant growth.

Wang *et al*. (2009) to investigate the effects of different irrigation and N supply levels on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farmlands with an accurate management system with irrigation regimes [0.6, 0.8 and 1.0 estimated wheat evapotranspiration (ET)] and N fertilizer application rates as the main-plot and split-plot respectively. Under the experimental conditions, irrigation and N has relative low effects on plant height.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al*. (2011) 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^3/ha at the elongation stage and of 450 m^3/ha at the booting stage or separate irrigation of 900 m^3/ha at the two stage were the highest.

Tillering pattern

Gupta *et al.* (2001) reported 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.

Zhai *et al*. (2003) conducted a pot experiment with 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.

Field trials were conducted by Malik *et al*. (2010) to estimate the effect of number of irrigations on yield of wheat crop in the semi arid area of Pakistan. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T_2), while number of tillers m^{-2} were not affected significantly.

Spike, grains and 1000-grains weight

This study was carried out by Baser *et al*. (2004) to determine 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.

Twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in a field experiment conducted by Zarea and Ghodsi (2004) 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.

The study was carried out by Mangan *et al*. (2008) to evaluate the performance of yield and yield components traits of wheat genotypes under water stress conditions. Four wheat varieties were screened under water stress conditions at Nuclear Institute of Agriculture (NIA) Tandojam. Different irrigation treatments

(1, 2, 3 and 4) were applied during various crop growth stages. Yield contributing traits of wheat varieties were significantly affected under water stress conditions. Except spike yield, Sarsabz had significantly more 1000-grain weight, main spike yield and grains spike^{-1} as compared to other varieties over all irrigation treatments; hence more tolerant to drought. 1000-grain weight ranged between 28.1-41.8 g in four treatments.

Two field experiments with winter wheat were made by Zhao *et al*. (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Irrigation frequency and N application rate had considerable influences on total number of culms, which was significantly higher in W_1, W_2 and W_3 than in W_0, while no significant difference existed among W_1, W_2 and W_3. The effects of irrigation frequency on spike number per ha and 1000-grain-weight were statically significant, and the effects of N rate on spike number per ha and grain number per spike were significant.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during Rabi seasons. The I_2 treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. Progressive increase in number of irrigations from 1 to 4 increased various yield contributing characters viz., effective tillers m^{-2}, ear length, no. of grains ear^{-1} and test weight while three and four irrigations were found statistically at par with each other.

Field trials were conducted by Malik *et al*. (2010) to estimate the effect of number of irrigations on yield of wheat crop in the semi arid area of Pakistan. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T_2), while 1000-grains weights were not affected significantly.

Using semi-winter wheat Yumai 49-198 as experiment material, a field experiment was conducted by Li *et al*. (2010) to investigate the leaf area index, dry matter accumulation, photosynthetic characteristics and yield of winter wheat under different irrigation stages and amounts. The results showed that, before the jointing stage, the leaf area index and spike length increased with the increase of irrigation amount. After jointing stage, all the indexes were good when the field water capacity maintained at 65%, while too much irrigation amount was unfavourable to the dry matter accumulation, especially to the photosynthetic rate of flag leaf and yield formation after anthesis.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al*. (2011) and found that the soil was obviously short of moisture when the irrigation was managed in the former stage, and the layer of 20-40 cm was the lowest one in all of the layers. The group dynamics, the volume of spikes per hectare and the tiller volume of single plant were improved under national compensative irrigation. The spike volume per ha, the tillers and spikes per plant were increased by 16,500-699,000, 0.12-1.16 and 0.01-0.11, respectively. For the effect of irrigation on spike length and spike grains, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better.

Grain and straw yield

Sah *et al*. (1990) found the maximum grain yield of wheat with two irrigations but the maximum grain protein content was obtained with three irrigations. Sharma (1993) obtained higher yield with three irrigations given at CRI, tillering and milking stages of wheat than other treatments with three irrigations. They also found maximum water use efficiency with three irrigations given at CRI, tillering and milking stages.

Upadhyaya and Dubey (1991) conducted an experiment in India with 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) reported that maximum grain and straw yields were recorded with the application of three irrigations, applied at CRI, maximum tillering and grain filling stages. Irrigation given at CRI+ Maximum tillering (MT), CRI + Booting (BT) and CRI + Grain filling (GR) were at per in respect of number of spikes/m^2 and grains/spikes, but had higher spikes and grains over CRI + MT stages.

Yadav *et al*. (1995) reported that two irrigations scheduled at CRI (Crown Root Initiation) and milk stages gave the maximum plant height (1.026 m), maximum number of grain/ear (65), straw weight (4500 kg/ha) and grain yield (3158 kg/ha) of wheat.

Islam (1996) observed that irrigation significantly influenced the plant heights, number of effective tillers per plant, grain and straw yields but it had no influence of grains per ear and 1000-grain weight. The highest grain yield (3.71 t/ha) was obtained with three irrigations (25, 45 and 60 DAS) and the lowest with no irrigations (2.61 t/ha) was obtained.

Naser (1996) reported that the effect of different irrigations on yield and yield attributing characters were statistically significant. Two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. The highest grain and straw yields, the maximum number of tillers per plant, the highest spike length, and the maximum number of grains per spike were recorded when two irrigations were applied. The control treatment showed the lowest result in all plant parameters.

Razi-us-Shams (1996) observed 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.

Meena *et al.* (1998) conducted a field experiment during 1993-95 at New Delhi on bread wheat (cv. HD 2265) with no irrigation or irrigation at flowering and/or crown root initiation stages and reported that wheat grain yield was the highest with 2 irrigations (2.57 t/ha in 1993 and 2.64 t/ha).

A field experiment was conducted by Ghodpage and Gawande (2001) in Akola, Maharashtra, India, during rabi to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations) at various physiological growth stages of late-sown wheat in Morna command area. The maximum grain yield of 2488 kg/ha was obtained in 6 irrigations treatment and it was significantly superior over all other treatments. In general, there was consistent reduction in grain yield due to missing irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, missing irrigation at tillering and milking stages resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, milking and dough stages, recording 29.30% yield reduction. Approximately 50% loss in grain was observed when irrigation was missed at tillering, flowering, milking and dough stages.

Debelo *et al.* (2001) conducted a field experiment in Ethiopia on bread wheat and 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.

Gupta *et al.* (2001) reported 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.

Wang *et al*. (2002) conducted a pot experiment in a green house to study the effects of water deficit and irrigation at different growing stages of winter wheat and observed that irrigation increased yield of wheat significantly than under control condition.

Zhai *et al*. (2003) conducted a pot experiment with 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 yield of winter wheat.

Twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in a field experiment conducted by Zarea and Ghodsi (2004) in Iran and found that grain yield decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied grain yield were higher in cultivars C-75-14 and C-75-9.

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The study was carried out by Mangan *et al*. (2008) to evaluate the performance of yield and yield components traits of wheat genotypes under water stress conditions. Four wheat varieties were screened under water stress conditions at Nuclear Institute of Agriculture (NIA) Tandojam. Different irrigation treatments (1, 2, 3 and 4) were applied during various crop growth stages. Grain yield of wheat varieties were significantly affected under water stress conditions. Grain yield ranged between 373 kg ha^{-1} in single irrigation treatment to 3931 kg ha^{-1} in four irrigations.

Gao *et al*. (2009) conducted a field experiment to determine the reasonable and effective water-saving irrigation schemes in wheat production, the commercial wheat cvs Shannong 15 and Yannong 21 were grown in in China and subjected to 3 water irrigation treatments: W_0 (with a relative water content of 60% in the 0-140 cm soil layer at the jointing stage and 55% at anthesis), W_1 (75% at the jointing stage and 65% at anthesis) and W_2 (75% at the jointing stage and 75% at anthesis). The highest irrigation water use efficiency was recorded in W_1 and the highest grain yield and water use efficiency (WUE) were achieved in W_2 for both cultivars. Under the conditions of this experiment, W_2 was the optimum water management treatment, which was beneficial to both of grain yield and WUE.

Two field experiments with winter wheat were made by Zhao *et al*. (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Irrigation frequency and N application rate had considerable influences on total number of culms, which was significantly higher in W_1, W_2 and W_3 than in W_0, while no significant difference existed among W_1, W_2 and W_3. The effects of irrigation frequency on spike number per ha and 1000-grain-weight were statically significant, and the effects of N rate on spike number per ha and grain number per spike were significant. Grain yield was the highest in W_3 and the lowest in W_0, and the highest in N_1 and the lowest in N_0.

Two field experiments with winter wheat were made by Zhao *et al*. (2009) in Hebei, China. Four irrigation treatments (W_0, no irrigation; W_1, irrigation at the elongation stage; W_2, irrigations at the elongation and the heading-anthesis stages; and W_3, irrigations at thawing, the elongation stage and the heading-anthesis stage) were combined with 3 nitrogen (N) application treatments. Irrigation frequency and N application rate had considerable influences on total number of culms, which was significantly higher in W_1, W_2 and W_3 than in W_0, while no significant difference existed among W_1, W_2 and W_3. Grain yield was the highest in W_3 and the lowest in W_0.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during Rabi seasons. The I_2 treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. The highest grain yield (40.65 q ha^{-1}) was credited to I_4 that was significantly superior over I_1 and I_2 but non-significant with I_3.

Field trials were conducted by Malik *et al*. (2010) to estimate the effect of number of irrigations on yield of wheat crop in the semi arid area of Pakistan. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the grain yield were significantly higher when crop was irrigated with five irrigations (T_2). The highest grain yield was recorded with five irrigations at different critical growth stages of wheat crop. The possible reason might be availability of more moisture. The results revealed that the application of irrigation at tillering stage played a vital role to increase wheat yield and contrarily the application of irrigation at maturity caused decrease in wheat yield.

In view of the importance of wheat, less available and costly P fertilizer and shortage of water a field study was conducted by Rahim *et al*. (2010) under farmer's field conditions to see the effect of phosphorus application and irrigation scheduling on wheat yield. Four irrigations i.e. 0, 2, 3, 4 were applied at critical stages of wheat. Basal N:K=130:65 kg ha^{-1} were applied. Band placement of P proved better over broadcast, whilst three irrigations at crown roots, booting, and grain development stages were sufficient to get maximum yield.

Naeem *et al*. (2010) conducted a field study pertaining to the effect of different levels of irrigation on yield and yield components of wheat cultivars at Agronomic Research Area, University of Agriculture, Faisalabad. Treatments were three cultivars and five irrigation levels I_1 (irrigation at crown root stage), I_2 (irrigation at crown root + tillering), I_3 (irrigation at crown root + tillering + booting), I_4 (irrigation at crown root + tillering + booting + anthesis), and I_5 (irrigation at crown root + tillering + booting + anthesis + milking). Wheat crop supplied with five irrigations at crown root + tillering + booting + earing + milking recorded the highest grain yield (5696.8 kg ha^{-1}) which was significantly higher than all the other irrigation levels.

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

Harvest index and economic return

Boogaard *et al*. (1996) carried out an experiment in a Mediterranean environment in North Syria with wheat under rainfed and irrigated conditions and reported that under rainfed conditions harvest index was increased.

Twenty bread wheat cultivars were subjected to irrigation at 10, 20 and 30-day intervals in a field experiment conducted by Zarea and Ghodsi (2004) in Iran and found that harvest index decreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied, harvest index were higher in cultivars C-75-14 and C-75-9.

Wang *et al*. (2009) to investigate the effects of different irrigation and N supply levels on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farmlands with an accurate management system with irrigation regimes [0.6, 0.8 and 1.0 estimated wheat evapotranspiration (ET)] and N fertilizer application. Water consumption was increased with irrigation, water consumption in high irrigation treatment was increased by 16.68% and 36.88% compared with intermediate irrigation treatment and low irrigation treatment, respectively. The low irrigation (378 mm), accompanied by 221 kg N/hm^2 was the best management system for the relative high economic yield and high WUE in this region.

The field experiment was conducted by Vinod *et al*. (2011) during winter seasons to study the effect of irrigation and fertilizer management on yield and economics of simultaneous planting of winter sugarcane + wheat. The experiment was carried out in split plot design, keeping four irrigation options in main plot, viz. irrigation scheduled at 0.8 (I_1), 1.0 (I_2), 1.2 (I_3) IW/CPE ratio and critical stages i.e. crown root initiation, tillering, late jointing, flowering, milk and dough stages of wheat (I_4), and four nutrient levels, with four replications. The maximum gain of gross return (Rs 126,992.0/ha), net return (Rs 75,882.5/ha) and B:C ratio (1.49) was obtained with irrigation at physiological stages of wheat.

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. The lowest value corresponded to the treatment with irrigation during grain filling and that under rainfed conditions.

2.2. Influence 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 done at home and abroad showed that delay in 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 influence 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 have been presented below-

Plant height

In a trial with cultivar Balaka in Joydepur and Jessore, BARI (1984) reported that the tallest plant (76.83 cm) was obtained at Jessore when sowing was done on 20 November and shortest with 30 December sowing. Similar results have also been observed by Farid *et al.* (1993).

The plant height of barely was significantly influenced by date of sowing. In an experiment carried out by Moula (1999) to study the effect of sowing time on growth and development of barley varieties and reported that the tallest plant was recorded by November 25 sowing (111.8 cm) and the shortest plant was recorded by December 25 sowing (73.8 cm).

Chowdhury (2002) conducted an experiment with four sowing dates and reported that delay in sowing decreased plant height. At the final harvest highest plant height was observed in November 1 sown plant. But at 60 DAS highest plant height was recorded in December in 15 sown plants.

Haider (2002) reported that November 15 sown plants of all cultivars of wheat under each irrigation regimes were found to be taller than December 5 sown wheat plants.

Tillering pattern

In a trial with wheat in Joydebpur and Jessore, BARI (1984) reported that the highest number of effective tillers plant^{-1} was obtained by 20 November sowing similar finding were reported by Sarker *et al*. (1999).

The associations of yield and effective tiller were also reported by many scientists. Shrivastava *et al.* (1998) studied relationship between various traits in wheat. They reported that yield had significant positive correlation with effective tillers per plant.

Chowdhury (2002) conducted an experiment with four sowing dates and reported that the highest number of average tillers plant^{-1} were produced by November 15 sown wheat plants and the second highest number were produced by November 30 sown plants which was at par with November 1 sown plants. The lowest number of tillers plant^{-1} were produced by December 15 sown plants.

A field experiment was conducted by Ahmed *et al.* (2006) at Farming System Research and Development (FSRD) site, Chabbishnagar, Godari, Rajshahi under rainfed condition during rabi seasons to find out the suitable variety and sowing time (30 November, 15 December and 30 December). They concluded that number of tiller increased significantly with early sowing (30 November) in all varieties in both the years.

Spike, grains and 1000-grain weight

Zhao *et al.* (1985) conducted experiments on barley in Chinaunder two different sowing dates, viz., October 28 and November 17 in 1982-83 and November 7 and November 27 in 1983-84. They found that with delay in sowing tiller and ear number/10 plants decreased from 64 to 41 in 1982-83 and from 49 to 18 in 1983-84. The full growth period was shortened with delay in sowing.

Sekhon *et al.* (1991) reported that early sowing decreased the number of spikelets spike^{-1}, grains spike^{-1} but increased 1000-grain weight and yield of wheat. They also reported that late sowing decreased 1000 grain weight and yield.

Ryu *et al.* (1992) concluded that the highest grain weight of barley was reached at 40 days after heading in early and intermediated sowing and 35 days in late sowing.

Eissa *et al.* (1994) observed that spikes m^{-2} and grains $spike^{-1}$ were significantly increased while grain weight non-significantly decreased as sowing date was delayed from November to December. Chowdhury (2002) conducted an experiment with four sowing dates and reported 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 in December 15 sown plants.

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.

Zende *et al.* (2005) conducted an experiment during the 2002/03 rabi season in Akola, Maharashtra, India, to evaluate the effects of sowing time (15 November, 1 December and 15 December) on the growth and yield of durum wheat (*Triticum durum)* and concluded that the growth, yield and yield attributes, except for the spike length, showed significant increases when durum wheat crops were sown on 15 November compared with those sown on 1 December and 15 December.

Grain and straw yield

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.

Farid *et al.* (1993) conducted an experiment on sowing dates having five sowing times started from November with 15 day intervals with three cultivars. They observed that November 5 was found to be the optimum time for AP-1-20 and November 5 to December 5 for Centinella and AP-1-20, respectively. In general, all the cultivars performed better when sown on November 5. In all cases yield was reduced significantly with delayed sowing beyond December 20.

Comy (1995) concluded from two years study in Ireland on malting barley cv. Blenhiem sown on March, early April and late April that the earliest sown spring barley generally gave the highest yield and the best quality grain .

BARI (1997) reported from the study in Jamalpur during the rabi season that among the five sowing dates viz. November 5, November 20, December5, December 20 and January 5, the grain yield was statistically different among those sowings. The crop sown on December 20 produced the lowest grain yield which was closely followed by that of January 5 sowing. Adrastic reduction in grain yield was observed when the crop was sown on December 5 or later.

A field experiment was conducted by Chowdhury (2002) at four sowing dates viz. sown at November 1, November 15, November 30 and December 15 and reported that the highest grain yield was recorded in November 15 sown plants and the next highest value was recorded in November 30 sown plants and the lowest yield was recorded in December 15 sown plants.

Haider (2002) conducted experiment with two sowing dates and reported that November 15 sown plants produced significantly higher grain yield in both the years for all the irrigation regimes and varieties of wheat and the lowest yield was recorded in December 5 sown plants.

A field experiment was conducted by Ahmed *et al.* (2006) at Farming System Research and Development (FSRD) site, Chabbishnagar, Godari, Rajshahi under rainfed condition during rabi seasons to find out the suitable variety and sowing time (30 November, 15 December and 30 December). They concluded that grain and straw yields increased significantly with early sowing (30 November) in all varieties. The results show that early sowing (30 November) gave the highest grain (2.55 t/ha) and straw yield (4.28 t/ha), whereas the lowest grain yield (1.23 t/ha) and straw yield (3.21 t/ha) was obtained from delay sowing.

Harvest index and economic return

Harvest index (HI) is the ratio of economic yield to biological yield and is a useful index of assessing the extent of phytomass converted into useful economic yield. The economic yield of barley is its grain and biological yield of a crop is the TDM at final harvest (Donald and Hamblim, 1976).

Sharma (1993) conducted an experiment with eight spring wheat (*Triticum aestivum)* cultivars and 2 advanced breeding lines in Nepal and showed that due to delayed sowing harvest index was reduced and maximum harvest index of 41.1% occurred with the November 25 sowing.

Samuel *et al.* (2000) reported that late sowing condition (6 January 1997) reduce the harvest index (36.1%) from (41.5%) of normal sowing condition (29 November 1996) in wheat. Ehdaie *et al.* (2001) reported that early sowing decreased harvest index. They reported that greater N supply increased shoot biomass by 29%, grain yield by 16% and protein by 5% but decrease harvest index by 10%.

From the above review of literature it is evident that sowing time has a significant influence on yield and yield components of wheat. The literature suggests that early or delay sowing other than optimum time reduces the grain yield of wheat which is directly related with the temperature of the growing period of the crop. Reduction in grain yield is mainly attributed by the reduced number of spike plant^{-1}, grains spike^{-1} and thousand grain weight due to curtailment of period for development of these parameters.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to March 2013 to find out the effect of single irrigation and sowing date on growth and yield of wheat. The details of the materials and methods i.e. location of experimental site, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis has been presented below under the following headings:

3.1. Description of the experimental site

3.1.1. Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

3.1.2. Soil characteristics of the experimental plot

The soil belonged to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix I.

3.1.2. Climate condition

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

3.2. Experimental details

The experiment comprised of two factors

Factors A: Irrigation (4 levels)

i) I_0: No irrigation i.e. control

ii) I_1: Irrigation at 20 DAS (Crown root initiation stage)

iii) I_2: Irrigation at 55 DAS (Flowering stage)

iv) I_3: Irrigation at 75 DAS (Grain filling stage)

Factor B: Sowing date (3 levels at 10 days interval)

i) S_1: Sowing at 19 November, 2012

ii) S_2: Sowing at 29 November, 2012

iii) S_3: Sowing at 09 December, 2012

There were in total 12 (4×3) treatment combinations such as I_0S_1, I_0S_2, I_0S_3, I_1S_1, I_1S_2, I_1S_3, I_2S_1, I_2S_2, I_2S_3, I_3S_1, I_3S_2 and I_3S_3.

3.2.2. Experimental design and layout

The experiment was laid out in Split Plot Design with three replications. There were 36 plots having the size of 2 m × 1.5 m and 12 treatment combinations were randomly distributed in these plots. Irrigation was assigned in the main plot and sowing date was in the sub-plot.

3.3. Growing of crops

3.3.1. Seed collection

BARI Gom-26 was used as a test crop of this study. The seeds were collected from Agronomy Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

3.3.2. Preparation of the main field

The piece of land selected for the experiment was opened in the 1st week of November 2012 with a power tiller, and was exposed to the sun for a week after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally a desirable tilth of soil was obtained for sowing of seeds.

3.3.3. Seeds sowing

Furrows were made for sowing the wheat seeds when the land was in proper joe condition and seeds were sown at 19 November, 2012, 29 November, 2012 and 09 December, 2012 as per treatment. Seeds were sown continuous with maintaining 20 cm line to line distance and plant to plant 5 cm. After sowing, seeds were covered with soil and slightly pressed by hand.

3.3.4. Application of fertilizers and manure

The fertilizers N, P, K and S in the form of Urea, TSP, MP and Gypsum, respectively were applied. The entire amount of TSP, MP and Gypsum, 2/3rd of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation (BARI, 2006). The dose and method of application of fertilizer are presented below-

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: Krishi Projukti Hatboi, BARI, Joydebpur, Gazipur, 2006

3.3.5. After care

After the germination of seeds, various intercultural operations such as irrigation and drainage, weeding, top dressing of fertilizer and plant protection measures were accomplished for better growth and development of the wheat seedlings as per the recommendation of BARI.

3.3.5.1. Irrigation and drainage

Irrigation was applied as per treatment. For I_0 leveled plot no irrigation was provided, for I_1 leveled plot one irrigation was provided at 20 DAS (crown root initiation-CRI) stage), for I_2 leveled plot one irrigation provided at 55 DAS (flowering stage) and for I_3 leveled plot one irrigation was provided at 75 DAS (grain filling stage). Proper drainage system was also developed for draining out excess water.

3.3.5.2. Weeding

Weedings were done to keep the plots free from weeds which ultimately ensured better growth and development of wheat seedlings. The newly emerged weeds were uprooted carefully. The rotary weeder was used starting from 30 DAS, four times, an interval of 15 days. One manual weeding was taken up once at peak tillering stage to remove weeds around the clumps.

3.3.5.3. Plant protection

The crop was attacked by different kinds of insects during the growing period. Triel-20 ml was applied on 12 January and sumithion-40 ml/20 litre of water was applied on 30 January as plant protection measure. During the entire growing period the crop was observed carefully as protection measures.

3.4. Harvesting, threshing and cleaning

The crop was harvested manually depending upon the maturity of plant from each plot starting from the 14 of March, 2012 and total crop was harvested for 3 consecutive dates. Crop was harvested in different days as they attain mature stage which also varied as per sowing time of this study. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of wheat grain. Fresh weight of wheat grain and straw were recorded plot wise from 1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of wheat grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.5. Data collection

3.5.1. Crop Growth Characters

Plant height

The height of plant was recorded in centimeter (cm) at 25, 45, 65 and 85 DAS (Days after sowing) and at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot that were tagged earlier. The height was measured from the ground level to the tip of the plant with the help of a meter scale.

Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 25, 45, 65 and 85 DAS. Data were recorded by counting tillers from each plant and as the average of 10 plants selected at random from the inner rows of each plot.

Dry matter content plant^{-1}

Data from five sample plants from each plot were collected and gently washed with tap water, thereafter soaked with paper towel. Then fresh weight was taken immediately after soaking by paper towel. After taking fresh weight, the sample was oven dried at 70^{0}C for 72 hours. Then oven-dried samples were transferred into a desiccator and allowed to cool down to room temperature, thereafter dry weight of plant was taken and expressed in gram. Dry matter content plant^{-1} was recorded at 25, 45, 65 and 85 DAS.

Estimated growth parameter

Using the data on the leaf area and dry matter from each specific treatment, the following growth parameters were derived with the following mentioned calculation (Hunt, 1978):

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula:

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \quad g\ m^{-2} day^{-1}$$

Where,

GA = Ground area (m^2)

W_1 = Total dry weight at previous sampling date (T_1)

W_2 = Total dry weight at current sampling date (T_2)

T_1 = Date of previous sampling

T_2 = Date of current sampling

Relative Growth Rate (RGR)

Relative growth rate was calculated using the following formula:

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \quad (g\ g^{-1} day^{-1})$$

Where,

W_1 = Total dry weight at previous sampling date (time T_1)

W_2 = Total dry weight at current sampling date (time T_2)

T_1 = Date of previous sampling

T_2 = Date of current sampling

Ln = Natural logarithm

3.5.2. Yield contributing Characters

Days required from sowing to flowering

Days required from sowing to starting of flowering was recorded by calculating the number of days from sowing to starting of flowering by keen observation of the experimental plots during the experimental period.

Days required from sowing to maturity

Days required from sowing to starting of maturity was recorded by calculating the number of days from sowing to starting of maturity as spikes become brown color by keen observation of the experimental plot.

Number of spike hill^{-1}

The total number of spike hill^{-1} was estimated by counting the number of spike from 10 hill and then averaged to have number of spike hill^{-1}.

Number of spikelets spike^{-1}

The total number of spikelets spike^{-1} was counted as the number of spikelets from 10 randomly selected spikes from each plot and average value was recorded.

Spike length (cm)

The length of spike was measured with a meter scale from 10 selected spike and the average value was recorded.

Number of filled grains spike^{-1}

The total number of filled grains spike^{-1} was counted as the number of filled grains from 10 randomly selected spikes from each plot and average value was recorded.

Number of unfilled grains spike^{-1}

The total number of unfilled grains spike^{-1} was counted as the number of unfilled grains from 10 randomly selected spikes from each plot and average value was recorded.

Number of total grains spike^{-1}

The total number of grains spike^{-1} was counted by adding the number of filled and unfilled grains from 10 randomly selected spike from each plot and average value was recorded.

Weight of 1000-grain (g)

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.

3.5.3. Yield

Grain yield (t ha^{-1})

Grains obtained from 1 m^{-2} from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area used to record grain yield m^{-2} and converted this into t ha^{-1}.

Straw yield (t ha^{-1})

Straw obtained from m^{-2} from each unit plot were sun-dried and weighed carefully. The dry weight of straws of central 1 m^2 area was used to record straw yield m^{-2} and was converted this into t ha^{-1}. Straw obtained from m^{-2} were converted into t ha^{-1}straw weight.

Biological yield (t ha^{-1})

Grain yield and straw yield together were regarded as biological yield of wheat. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

Harvest index (%)

Harvest index was calculated from per hectare grain and straw yield that were obtained from each unit plot and expressed in percentage using the following formula-

$$\text{HI (\%)} = \frac{\text{Economic yield (Grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.6. Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the different level of irrigations and sowing date and also their interaction. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

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 III-X. 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

Plant height of wheat showed statistically significant variation due to different levels of irrigation at 25, 45, 65, 85 DAS and at harvest under the present trial (Figure 1). At 25 DAS, the tallest plant (25.80 cm) was recorded from I_1 (Irrigation at 20 DAS), while the shortest plant (19.04 cm) was observed from I_0 (no irrigation i.e. control) which was statistically similar to 19.39 cm and 19.56 cm obtained in I_3 (Irrigation at 75 DAS) and I_2 (Irrigation at 55 DAS) treatment, respectively. At 45 DAS, the tallest plant (49.22 cm) was found from I_1, while the shortest plant (41.41 cm) was observed from I_2 which was statistically similar to 41.49 cm and 41.54 cm obtained in I_3 and I_0 treatment, respectively. At 65 DAS, the tallest plant (69.02 cm) was recorded from I_1, while the shortest plant (59.63 cm) was obtained from I_0 which was statistically similar to 60.60 cm and 63.29 cm obtained in I_3 and I_2 treatment, respectively. At 85 DAS, the tallest plant (80.72 cm) was recorded from I_1, while the shortest plant (68.35 cm) was observed from I_0 which was closely followed by 75.88 cm and 73.85 cm obtained in I_2 and I_3 and they were statistically similar. At harvest, the tallest plant (85.12 cm) was observed from I_1, while the shortest plant (66.39 cm) from I_0 which was statistically similar to 80.16 cm obtained in I_2 and was closely followed by 78.94 cm obtained in I_3. Islam (1997) reported that plant height increased with increasing number of irrigations.

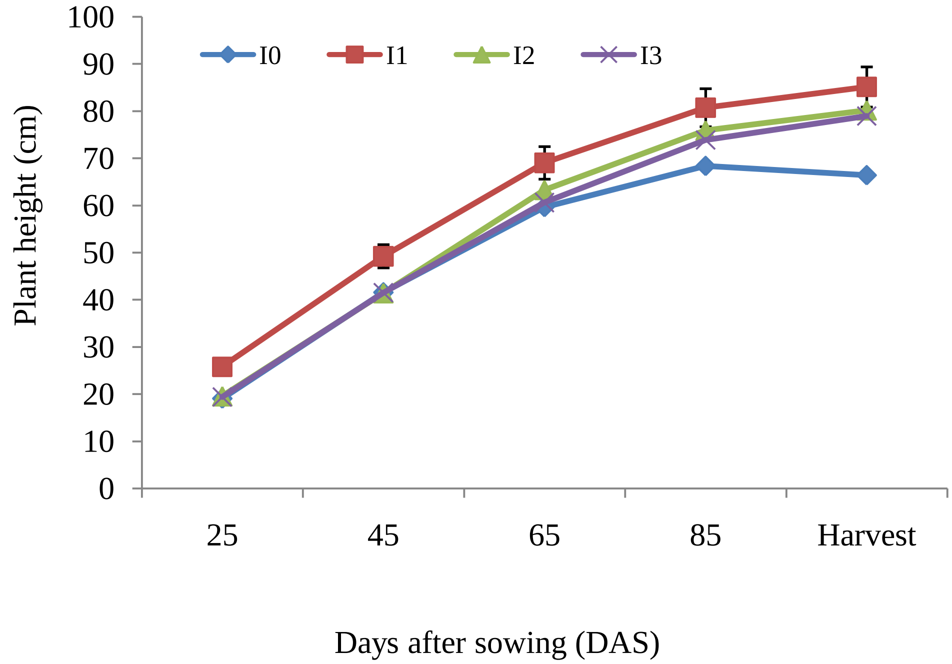

Figure 1. Effect of irrigation level on plant height of wheat

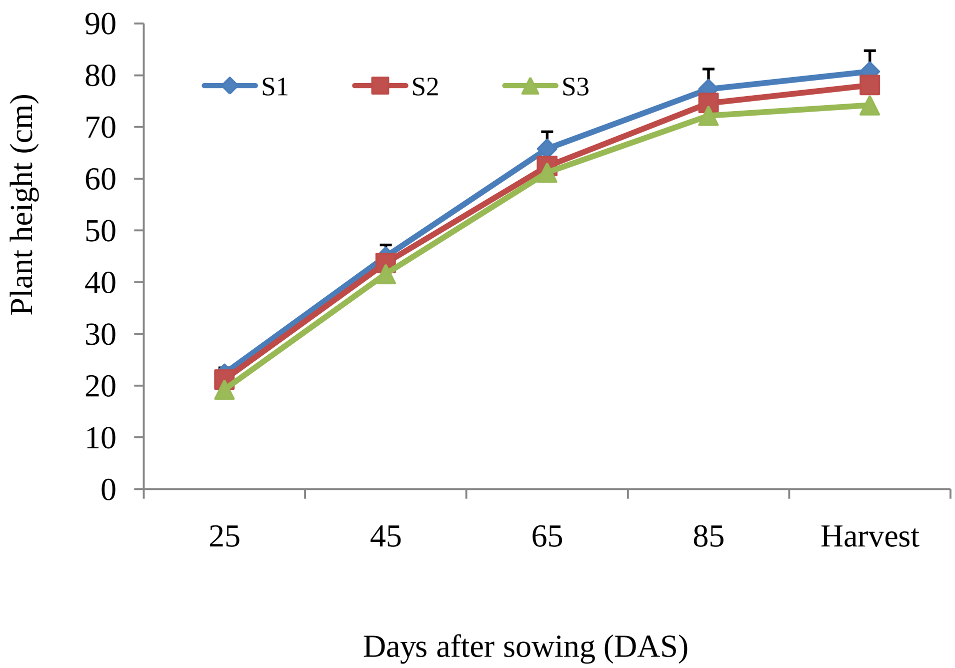

Figure 2. Effect of sowing date on plant height of wheat

Statistically significant variation for plant height of wheat at 25, 45, 65, 85 DAS and at harvest was due to different sowing date (Figure 2). At 25, 45, 65, 85 DAS and at harvest, the tallest plant as 22.34 cm, 44.95 cm, 65.78 cm, 77.32 cm and 80.70 cm were observed from S_1 treatment (Sowing at 19 November, 2012), which were statistically similar to corresponding plant height viz., 21.20 cm, 43.70 cm, 62.44 cm, 74.60 cm and 78.07 cm obtained in S_2 (Sowing at 29 November, 2012) and the corresponding shortest plant 19.30 cm, 41.60 cm, 61.19 cm, 72.18 cm and 74.19 cm were recorded from S_3 (Sowing at 09 December, 2012). Seeds sowing at November 19 ensure the tallest plant than early and delay sowing of seeds. BARI (1984) reported that the tallest plant (76.83 cm) when sowing was done on 20 November and shortest with 30 December sowing.

Interaction effect of different levels of irrigation and sowing date showed significant differences on plant height of wheat at 25, 45, 65, 85 DAS and at harvest (Table 2). At 25, 45, 65, 85 DAS and at harvest, the tallest plants as 28.19 cm, 52.42 cm, 73.51 cm, 85.58 cm and 92.80 cm, respectively were observed from I_1S_1 (Irrigation at 20 DAS and sowing date 29 November, 2012), while the shortest corresponding plants as 17.26 cm, 39.16 cm, 57.90 cm, 66.73 cm and 67.09 cm respectively were recorded from I_0S_0 (no irrigation and sowing at 09 December, 2012).

4.1.2. Number of tillers hill^{-1}

Different levels of irrigation varied significantly in terms of number of tillers hill^{-1} of wheat at 25, 45, 65 and 85 DAS under the present trial (Figure 3). At 25, 45, 65 and 85 DAS, the highest number of tillers hill^{-1} viz. 1.79 cm, 3.38, 6.70 and 4.87 respectively were recorded from I_1, while the corresponding lowest number of tillers hill^{-1} were observed with I_0 which was statistically similar to I_2 and I_3. Application of 2 irrigations at crown root initiation stage and pre flowering stage ensured the optimum vegetative growth of the wheat with highest number of tillers hill^{-1} as referred by Meena *et al*, (1998). Gupta *et al.* (2001) reported that when water stress was imposed at the booting stage caused a greater reduction in number of tillers.

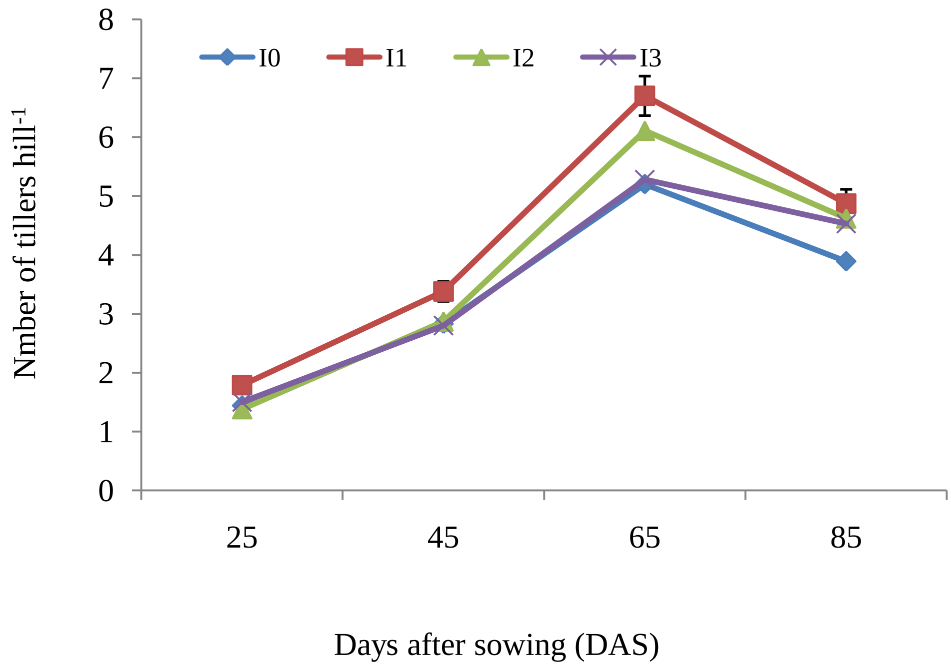

Figure 3. Effect of irrigation level on number of tillers hill^{-1} of wheat

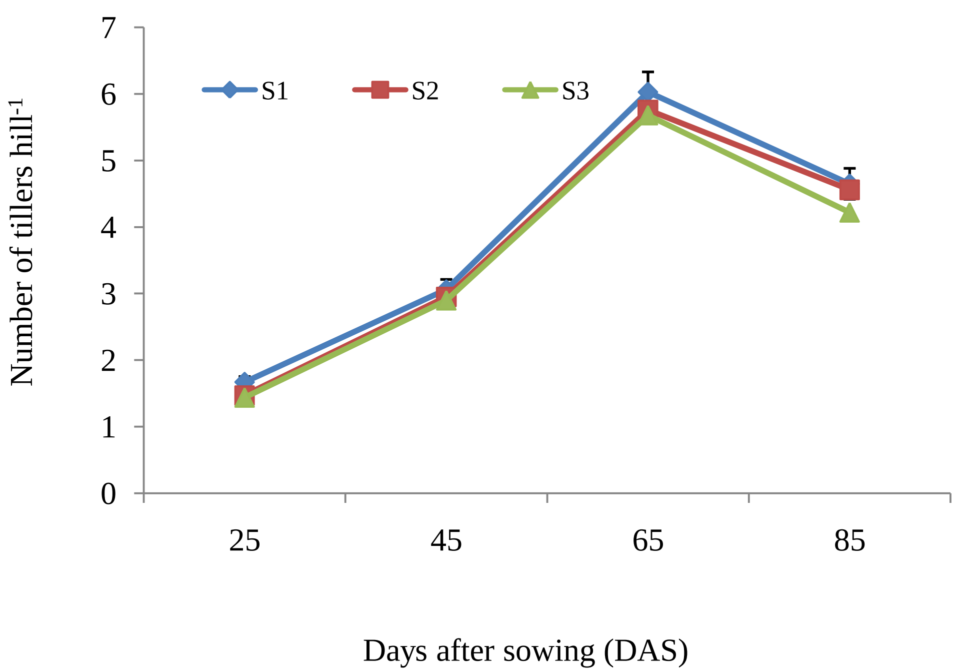

Figure 4. Effect of sowing date on number of tillers hill^{-1} of wheat

Table 2. Interaction effect of irrigation level and sowing date on plant height of wheat

Treatment combination of irrigation and sowing date	Plant height (cm) at				
	25 DAS	45 DAS	65 DAS	85 DAS	Harvest
I_0S_1	18.46 bc	40.67 b	59.03 de	68.74 de	66.46 e
I_0S_2	19.39 bc	42.33 b	58.36 de	69.58 de	67.33 e
I_0S_3	19.29 bc	41.62 b	61.51 de	71.22 c-e	76.92 cd
I_1S_1	28.19 a	52.42 a	73.51 a	85.58 a	92.80 a
I_1S_2	27.81 a	51.41 a	69.72 ab	82.01 ab	90.10 ab
I_1S_3	21.41 b	43.84 b	63.82 cd	74.58 cd	72.45 de
I_2S_1	21.40 b	43.67 b	67.42 bc	80.71 ab	83.38 bc
I_2S_2	18.03 bc	38.80 b	60.95 de	73.60 cd	77.02 cd
I_2S_3	19.25 bc	41.77 b	61.52 de	73.34 cd	80.07 cd
I_3S_1	21.34 b	43.06 b	63.15 c-e	76.27 bc	80.15 cd
I_3S_2	19.57 bc	42.27 b	60.74 de	74.06 cd	79.77 cd
I_3S_3	17.26 c	39.16 b	57.90 e	66.73 e	67.09 e
SE	1.168	1.388	1.727	1.920	2.554
Level of significance	0.05	0.01	0.05	0.05	0.05
CV(%)	9.66	5.54	4.74	4.45	5.70

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Number of tillers hill^{-1} of wheat showed statistically significant variation at 25, 45, 65 and 85 DAS due to different sowing date (Figure 4). At 25, 45, 65 and 85 DAS, the highest number of tillers hill^{-1} as 1.67, 3.06, 6.03 and 4.65 were found respectively from S_1 and the corresponding lowest number such as 1.44, 2.90, 5.68 and 4.22 were recorded from S_3 which were statistically similar to 1.47, 2.95, 5.76 and 4.56 obtained from S_2. Seeds sowing at November 19 ensured the maximum tiller than early and delay sowing of seeds. BARI (19984) reported that 20 November sowing produced the highest number of effective tillers plant^{-1}.

Different levels of irrigation and sowing date showed significant differences on number of tillers hill^{-1} of wheat due to interaction effect at 25, 45, 65 and 85 DAS (Table 3). At 25, 45, 65 and 85 DAS, the highest number of tillers hill^{-1} viz., 1.90, 3.50, 7.00 and 5.17 respectively were observed from I_1S_1, while the corresponding lowest number of tillers hill^{-1} such as1.23, 2.70, 5.07 and 3.70 were recorded from I_3S_3 treatment combination. From the results of interaction effect it reveals that irrigation at crown root initiation stage with the combination of sowing in November 19 2012 showed better performance than all other combination of irrigation timing and sowing dates.

4.1.3. Dry matter content plant^{-1}

Dry matter content plant^{-1} of wheat showed statistically significant variation due to different levels of irrigation at 25, 45, 65 and 85 DAS (Figure 5). At 25, 45, 65 and 85 DAS, the highest dry matter content plant^{-1} viz., 2.48 g, 6.53 g, 12.24 g and 18.75 g were attained from I_1, while the corresponding lowest quantity of 2.22 g, 5.56 g, 10.84 g and 15.79 g dry matter content plant^{-1} were found in I_0 which was followed by the other levels of irrigation under the present trial.

Significant variation for dry matter content plant^{-1} of wheat at 25, 45, 65 and 85 DAS were due to different sowing date (Figure 6). At 25, 45, 65 and 85 DAS, the highest dry matter content plant^{-1} as 2.41 g, 6.30 g, 12.06 g and 18.24 g were observed from S_1, which were statistically similar to corresponding value of 2.29 g, 5.84 g, 11.59 g and 17.91 g obtained from S_2 and the corresponding lowest viz., 2.20 g, 5.42 g, 11.00 and 16.95 g were recorded from S_3.

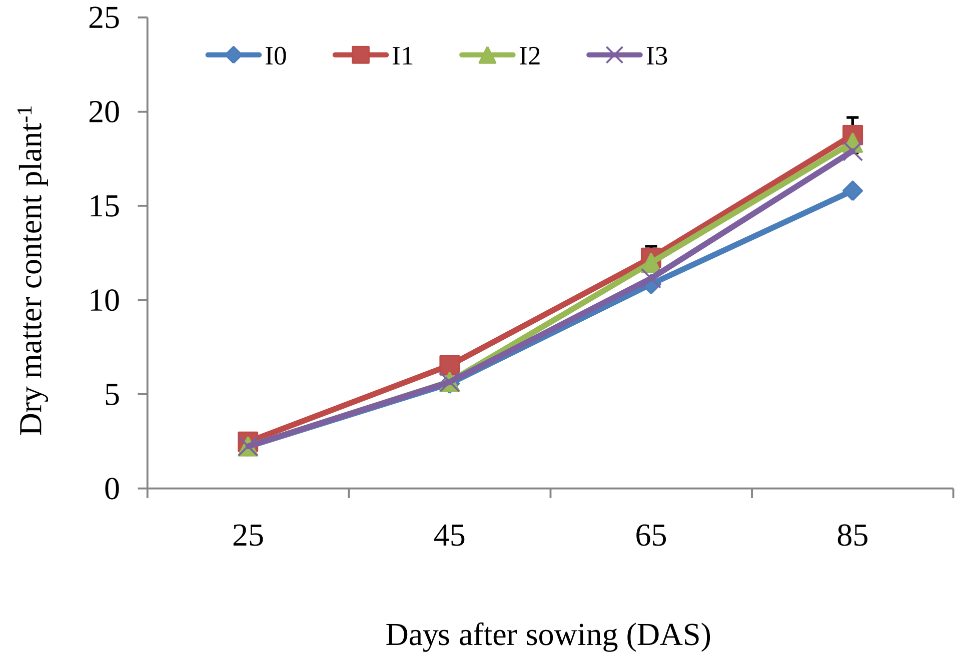

Figure 5. Effect of irrigation level on dry matter content plant^{-1} of wheat

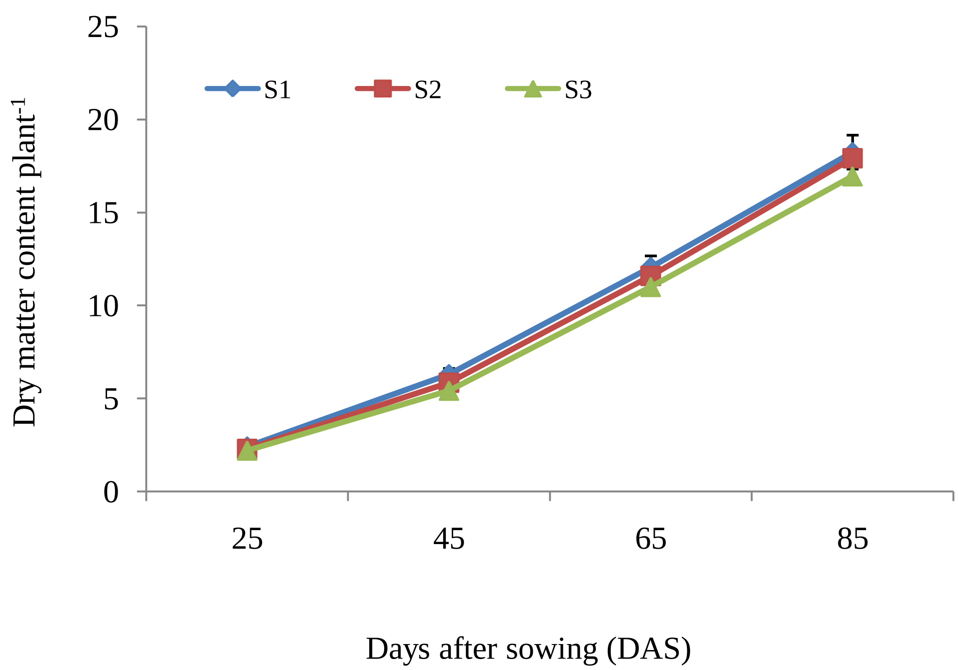

Figure 6. Effect of sowing date on dry matter content plant^{-1}of wheat

Table 3. Interaction effect of irrigation level and sowing date on number of tillers hill^{-1} of wheat

Treatment combination of irrigation and sowing date	Number of total tillers hill^{-1}			
	25 DAS	45 DAS	65 DAS	85 DAS
I_0S_1	1.53 cd	2.73 f	5.23 e	3.93 ef
I_0S_2	1.40 ef	2.90 d-f	5.20 e	4.03 ef
I_0S_3	1.40 ef	2.87 ef	5.33 e	4.27 de
I_1S_1	1.90 a	3.50 a	7.00 a	5.17 a
I_1S_2	1.80 a	3.40 ab	6.80 ab	4.90 ab
I_1S_3	1.67 b	3.23 bc	6.30 bc	4.53 b-d
I_2S_1	1.60 bc	3.07 cd	6.60 ab	4.90 ab
I_2S_2	1.30 fg	2.77 ef	5.87 cd	4.57 b-d
I_2S_3	1.67 b	2.77 ef	5.87 cd	4.40 cd
I_3S_1	1.43 de	2.93 de	5.43 de	4.60 b-d
I_3S_2	1.40 ef	2.73 f	5.17 e	4.73 bc
I_3S_3	1.23 g	2.70 f	5.07 e	3.70 f
SE	0.035	0.057	0.163	0.111
Level of significance	0.01	0.01	0.01	0.05
CV(%)	4.01	5.34	4.86	4.28

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Interaction effect of different levels of irrigation and sowing date showed significant differences on dry matter content plant^{-1} of wheat at 25, 45, 65 and 85 DAS (Table 4). At 25, 45, 65 and 85 DAS, respectively the highest dry matter content plant^{-1} 2.72 g, 7.28 g, 13.14 g and 19.60 g which were observed from I_1S_1, while the corresponding lowest dry matter content plant^{-1} were 2.11 g, 5.11 g, 10.33 g and 15.69 g, respectively found in I_3S_3.

4.1.4. Crop Growth Rate (CGR)

Crop growth rate (CGR) of wheat showed statistically significant variation due to different levels of irrigation for 25-45 DAS but non significant for 45-65 DAS and 65-85 DAS (Table 5). At 25-45 DAS I_1, irrigation at crown root initiation stage produced significantly the highest CGR gm^{-2}day^{-1} of 4.05 while the other 3 irrigation levels such as I_0, I_2 and I_3 produced statistically similar CGR gm^{-2}day^{-1} of 3.34 (I_0), 3.42 (I_2) and 3.41 (I_3), respectively. From 45-65 DAS and 65-85 DAS where the effect of irrigation was non-significant numerically, the highest CGR gm^{-2}day^{-1} were 6.32 and 13.05 obtained from I_1 and the corresponding lowest value 5.29 and 9.89 respectively obtained from I_0. Naser (1996) reported the highest crop growth rate were recorded when two irrigations were applied.

Statistically significant variation was observed on CGR of wheat for 25-45 DAS but non significant for 45-65 DAS and 65-85 DAS due to different sowing date (Table 5). In recording CGR of 45-65 DAS sowing on S_1 and S_2 recorded that CGR gm^{-2}day^{-1} as 3.89 and 3.55 which were significantly higher than that of 3.22 obtained in S_3. From 45-65 DAS and from 65-85 DAS S_1 sowing produced numerically, the highest CGR gm^{-2}day^{-1} of 5.76 and 12.62 while S_3 sowing produced the lowest CGR gm^{-2}day^{-1} of 5.58 and 11.90, respectively.

Interaction effect of different levels of irrigation and sowing date showed significant differences on CGR of wheat for 25-45 DAS but non significant for 45-65 DAS and 65-85 DAS (Table 6). At 25-45 DAS, 45-65 DAS and 65-85 DAS, the highest CGR as 4.57, 6.76 and 14.51 gm^{-2}day^{-1} were respectively observed from I_1S_1, while the corresponding lowest CGR as 3.02, 4.97 and 8.92 gm^{-2}day^{-1} were respectively recorded from I_3S_3.

Table 4. Effect of irrigation level and sowing date on dry matter content plant^{-1} of wheat

Treatment combination of irrigation and sowing date	Dry matter content plant^{-1} (g) at			
	25 DAS	45 DAS	65 DAS	85 DAS
I_0S_1	2.13 cd	5.36 c-e	10.67 c	16.57 c-e
I_0S_2	2.24 b-d	5.32 de	11.06 c	16.07 de
I_0S_3	2.29 b-d	5.99 b-e	11.14 c	15.60 e
I_1S_1	2.72 a	7.28 a	13.14 a	19.60 a
I_1S_2	2.51 ab	6.92 ab	12.55 ab	19.32 a
I_1S_3	2.21 cd	5.39 c-e	11.02 c	17.33 b-d
I_2S_1	2.42 bc	6.31 bc	13.07 a	18.70 ab
I_2S_2	2.13 cd	5.57 c-e	11.70 bc	18.07 a-c
I_2S_3	2.18 cd	5.19 e	11.17 c	18.30 ab
I_3S_1	2.37 b-d	6.25 b-d	11.70 bc	18.96 ab
I_3S_2	2.28 b-d	5.55 c-e	11.06 c	18.16 a-c
I_3S_3	2.11 d	5.11 e	10.33 c	15.69 e
SE	0.086	0.286	0.410	0.501
Level of significance	0.05	0.01	0.05	0.05
CV(%)	6.46	8.46	6.14	4.90

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Table 5. Effect of irrigation level and sowing date on Crop Growth Rate (CGR) of wheat of wheat

Treatment	CGR: Crop Growth Rate (g $m^{-2}day^{-1}$) at		
	25-45 DAS	45-65 DAS	65-85 DAS
Irrigation levels			
I_0	3.34 b	5.29	9.89
I_1	4.05 a	6.32	13.50
I_2	3.42 b	5.71	12.75
I_3	3.41 b	5.49	13.02
SE			
Level of significance	0.05	NS	NS
Sowing date			
S_1	3.89 a	5.76	12.62
S_2	3.55 ab	5.76	12.35
S_3	3.22 b	5.58	11.90
SE			
Level of significance	0.05	NS	NS
CV(%)	14.46	11.93	20.20

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Table 6. Interaction effect of irrigation level and sowing date on Crop Growth Rate (CGR) of wheat of wheat

Treatment combination of irrigation and sowing date	CGR: Crop Growth Rate (g $m^{-2}day^{-1}$) at		
	25-45 DAS	45-65 DAS	65-85 DAS
I_0S_1	3.23 c	5.48	10.71
I_0S_2	3.08 c	5.74	10.03
I_0S_3	3.70 a-c	5.15	11.79
I_1S_1	4.57 a	6.76	14.51
I_1S_2	4.41 ab	5.64	13.54
I_1S_3	3.18 c	5.63	12.62
I_2S_1	3.89 a-c	5.86	11.26
I_2S_2	3.44 bc	6.13	12.73
I_2S_3	2.93 c	6.05	14.25
I_3S_1	3.88 a-c	5.46	12.91
I_3S_2	3.26 c	5.52	14.20
I_3S_3	3.02 c	4.97	8.92
SE			
Level of significance	0.05	NS	NS
CV(%)	14.46	11.93	20.20

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

4.1.5. Relative Growth Rate (RGR)

Relative growth rate (RGR) of wheat showed statistically non significant variation due to different levels of irrigation at 25-45 DAS, 45-65 DAS and 65-85 DAS under the present trial (Table 7). At 25-45 DAS, 45-65 DAS and 65-85 DAS, numerically, the highest RGR 0.048, 0.038 and 0.024 g g^{-1} day^{-1} were respectively recorded from I_1, while numerically, the lowest RGR 0.045, 0.034 and 0.019 g g^{-1} day^{-1} were respectively observed from I_0.

Statistically non significant variation for RGR of wheat at 25-45 DAS, 45-65 DAS and 65-85 DAS was due to different sowing date (Table 7). At 25-45 DAS, 45-65 DAS and 65-85 DAS, numerically, the highest RGR 0.048, 0.035 and 0.022 g g^{-1} day^{-1} were observed from S_1 and the corresponding lowest RGR 0.045, 0.032 and 0.020 g g^{-1} day^{-1} were recorded from S_3.

Interaction effect of different levels of irrigation and sowing date showed no significant differences on RGR of wheat at 25-45 DAS, 45-65 DAS and 65-85 DAS (Table 8). At 25-45 DAS, 45-65 DAS and 65-85 DAS, numerically, the highest RGR 0.051, 0.039 and 0.026 g g^{-1} day^{-1} were observed from I_1S_1, while the corresponding lowest RGR 0.042, 0.029 and 0.017g g^{-1} day^{-1} were recorded from I_3S_3.

4.2. Yield contributing characters

4.2.1. Days required from sowing to flowering

Days required from sowing to flowering of wheat showed statistically significant variation due to different levels of irrigation under the present trial (Table 9). The highest days required from sowing to flowering (70.67) was recorded from I_0, which was statistically similar (69.44) with I_3 and closely followed (68.44) by I_2 and the lowest days required from sowing to flowering (65.56) was observed from I_1.

Table 7. Effect of irrigation level and sowing date on Relative Growth Rate (RGR) of wheat of wheat

Treatment	RGR: Relative growth rate (g g^{-1} day^{-1}) at		
	25-45 DAS	45-65 DAS	65-85 DAS
Irrigation levels			
I_0	0.045	0.034	0.019
I_1	0.048	0.038	0.024
I_2	0.046	0.032	0.021
I_3	0.046	0.034	0.021
SE			
Level of significance	NS	NS	NS
Sowing date			
S_1	0.048	0.035	0.022
S_2	0.046	0.033	0.021
S_3	0.045	0.032	0.020
SE			
Level of significance	NS	NS	NS
CV(%)	11.48	12.11	20.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Table 8. Interaction effect of irrigation level and sowing date on Relative Growth Rate (RGR) of wheat of wheat

Treatment combination of irrigation and sowing date	RGR: Relative growth rate (g g^{-1} day^{-1}) at		
	25-45 DAS	45-65 DAS	65-85 DAS
I_0S_1	0.046	0.033	0.021
I_0S_2	0.043	0.037	0.019
I_0S_3	0.048	0.031	0.022
I_1S_1	0.051	0.039	0.026
I_1S_2	0.049	0.030	0.022
I_1S_3	0.045	0.036	0.022
I_2S_1	0.048	0.036	0.018
I_2S_2	0.048	0.037	0.022
I_2S_3	0.043	0.030	0.020
I_3S_1	0.048	0.031	0.024
I_3S_2	0.044	0.035	0.025
I_3S_3	0.042	0.029	0.017
SE			
Level of significance	NS	NS	NS
CV(%)	11.48	12.11	20.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Table 9. Effect of irrigation level and sowing date on yield contributing characters of wheat

Treatment	Days required from sowing to flowering	Days required from sowing to maturity	Number of spikes $hill^{-1}$	Number of spikelets $spike^{-1}$
Irrigation levels				
I_0	70.67 a	121.56 a	3.60 b	14.41 b
I_1	65.56 c	115.33 b	4.37 a	18.47 a
I_2	68.44 b	118.89 ab	4.19 a	17.37 a
I_3	69.44 ab	118.22 ab	4.18 a	16.97 a
SE	0.508	1.132	0.061	0.663
Level of significance	0.01	0.05	0.05	0.01
Sowing date				
S_1	66.75 b	118.17 ab	4.18 a	17.85 a
S_2	70.17 a	117.33 b	4.11 ab	16.76 ab
S_3	68.67 a	120.00 a	3.96 b	15.80 b
SE	0.556	0.621	0.056	0.414
Level of significance	0.01	0.05	0.05	0.01
CV(%)	5.81	4.81	4.72	8.53

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Statistically significant variation from days required from sowing to flowering of wheat was due to different sowing date (Table 9). The highest days required from sowing to flowering (70.17) was observed from S_2 which was statistically similar (68.67) with S_3, while the lowest days required from sowing to flowering (66.75) was recorded from S_1.

Interaction effect of different levels of irrigation and sowing date showed significant differences on days required from sowing to flowering of wheat (Table 10). The highest days required from sowing to flowering (75.00) was observed from I_0S_3 which was statistically similar with I_3S_3 (74.33) and I_2S_2 (73.67), while the lowest days required from sowing to flowering (59.00) was recorded from I_1S_3.

4.2.2. Days required from sowing to maturity

Statistically significant variation was recorded in terms of days required from sowing to maturity of wheat due to different levels of irrigation (Table 9). The highest days required from sowing to maturity (121.56) was recorded from I_0, which was closely followed by I_2 (118.89) and I_3 (118.22),while the two later were statistically similar. On the other hand, the lowest days required from sowing to maturity (115.33) was observed from I_1.

Different sowing dates showed statistically significant variation for days required from sowing to maturity of wheat (Table 9). The highest days (120.00) required from sowing to maturity was observed from the treatment S_3, which was statistically similar to S_1 (118.17) but was statistically higher than S_2 (117.33).

Days required from sowing to maturity of wheat showed significant differences due to the interaction effect of different levels of irrigation and sowing date (Table 10). The highest days required from sowing to maturity (125.33) was observed from I_0S_3, while the lowest days required from sowing to maturity (114.67) was recorded from I_1S_3.

Table 10. Interaction effect of irrigation level and sowing date on yield contributing characters of wheat

Treatment combination of irrigation and sowing date	Days required from sowing to flowering	Days required from sowing to maturity	Number of spikes hill^{-1}	Number of spikelets spike^{-1}
I_0S_1	65.00 f	119.33 bc	3.67 d	11.90 d
I_0S_2	72.00 a-c	120.00 b	3.57 d	15.53 c
I_0S_3	75.00 a	125.33 a	3.57 d	15.80 c
I_1S_1	67.33 d-f	115.67 cd	4.50 a	20.60 a
I_1S_2	70.33 b-d	115.67 cd	4.43 ab	19.00 ab
I_1S_3	59.00 g	114.67 d	4.17 a-c	15.80 c
I_2S_1	65.33 f	119.00 bc	4.27 ab	19.90 a
I_2S_2	73.67 ab	118.33 b-d	4.10 bc	15.80 c
I_2S_3	66.33 ef	119.33 bc	4.20 a-c	16.40 bc
I_3S_1	69.33 c-e	118.67 b-d	4.30 ab	19.00 ab
I_3S_2	64.67 f	115.33 cd	4.33 ab	16.70 bc
I_3S_3	74.33 a	120.67 b	3.90 cd	15.20 c
SE	1.112	1.242	0.111	0.828
Level of significance	0.01	0.05	0.05	0.05
CV(%)	5.81	4.81	4.72	8.53

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

4.2.3. Number of spikes $hill^{-1}$

Number of spikes $hill^{-1}$ of wheat showed statistically significant variation due to different levels of irrigation under the present trial (Table 9). The highest number of spikes $hill^{-1}$ (4.37) was recorded from I_1, which was statistically similar with I_2 (4.19) and I_3 (4.18), whereas the lowest number of spikes $hill^{-1}$ (3.60) was observed from I_0.

Statistically significant variation was observed in number of spikes $hill^{-1}$ of wheat due to different sowing date (Table 9). The highest number of spikes $hill^{-1}$ (4.18) was observed from S_1, which was statistically similar with S_2 (4.11) and the lowest number of spikes $hill^{-1}$ (3.96) was recorded from S_3.

Interaction effect of different levels of irrigation and sowing date showed significant differences on number of spikes $hill^{-1}$ of wheat (Table 10). The highest Number of spikes $hill^{-1}$ (4.50) was observed from I_1S_1 which was statistically similar with I_1S_2 (4.43), I_3S_2 (4.33), I_3S_1 (4.30), I_2S_1 (4.27), I_2S_3 (4.20), I_1S_3 (4.17) but was significantly higher than I_2S_2 (4.10), I_3S_3 (3.90), I_1S_1 (3.67), I_2S_2 (3.57) and I_0S_2 (3.57), while the lowest number of spikes $hill^{-1}$ (3.57) was recorded from I_0S_2 and I_0S_3.

4.2.4. Number of spikelets $spike^{-1}$

Different levels 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 $spike^{-1}$ (18.47) was recorded from I_1, which was statistically similar with I_2 (17.37) and I_3 (16.97), while the lowest number of spikelets $spike^{-1}$ (14.41) was observed from I_0. Naser (1996) reported that the highest number of grains per spike were recorded when two irrigations were applied.

Significant variation was found for number of spikelets $spike^{-1}$ of wheat due to different sowing date (Table 9). The highest number of spikelets $spike^{-1}$ (17.85) was observed from S_1, which was statistically similar with S_2 (16.76) and the lowest number of spikelets $spike^{-1}$ (15.80) was recorded from S_3.

Interaction effect of different levels of irrigation and sowing date showed significant differences on number of spikelets spike^{-1} of wheat (Table 10). The highest Number of spikelets spike^{-1} (20.60) was observed from I_1S_1, while the lowest Number of spikelets spike^{-1} (11.90) was recorded from I_0S_1.

4.2.5. Spike length (cm)

Statistically significant variation was recorded for spike length of wheat due to different levels of irrigation (Table 11). The highest spike length (19.19 cm) was recorded from I_1, which was statistically similar (18.74 cm and 18.60 cm) with I_2 and I_3, while the lowest spike length (16.90 cm) was observed from I_0. Naser (1996) reported the highest spike length when two irrigations were applied.

Spike length of wheat showed statistically significant variation due to different sowing date (Table 11). The highest spike length (18.63 cm) was observed from S_1, which was statistically similar to 18.41 cm obtained from S_2 and the lowest spike length (18.03 cm) was recorded from S_3. 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.

Different levels of irrigation and sowing date showed significant differences on spike length of wheat due to interaction effect (Table 12). The highest spike length (19.60 cm) was observed from I_1S_1, while the lowest spike length (16.77 cm) was recorded from I_0S_2.

4.2.6. Number of filled grains spike^{-1}

Number of filled grains spike^{-1} of wheat showed significant variation due to different levels of irrigation (Table 11). The highest number of filled grains spike^{-1} (29.33) was recorded from I_1, which was statistically similar to 27.61 obtained in with I_2 and closely followed by 26.94 found in I_3 and the lowest number (23.22) was observed from I_0. Gupta *et al.* (2001) reported that number of grains decreased to a greater extent when water stress was imposed at the anthesis stage.

Table 11. Effect of irrigation level and sowing date on yield contributing characters of wheat

Treatment	Spike length (cm)	Filled grains $spike^{-1}$	Unfilled grains $spike^{-1}$	Total grains $spike^{-1}$	Weight of 1000 grains (g)
Irrigation levels					
I_0	16.90 b	23.22 c	3.62 a	26.84 b	39.01 b
I_1	19.19 a	29.33 a	1.99 d	31.32 a	44.43 a
I_2	18.74 a	27.61 ab	2.94 b	30.56 a	42.12 ab
I_3	18.60 a	26.94 b	2.61 c	29.56 a	41.50 ab
SE	0.220	0.630	0.078	0.680	0.870
Level of significance	0.01	0.01	0.01	0.01	0.05
Sowing date					
S_1	18.63 a	30.17 a	2.45 c	32.62 a	43.43 a
S_2	18.41 ab	25.83 b	2.70 b	28.53 b	41.46 b
S_3	18.03 b	24.33 b	3.22 a	27.56 b	40.40 b
SE	0.128	0.558	0.061	0.578	0.579
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.41	7.21	7.62	6.77	4.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Statistically significant variation was recorded for number of filled grains spike^{-1} of wheat due to different sowing date (Table 11). The highest number of filled grains spike^{-1} (30.17) was observed from S_1, whereas the lowest number of filled grains spike^{-1} (24.33) was recorded from S_3 which was statistically similar to 25.83 observed in S_2.

Interaction effect of different levels of irrigation and sowing date showed significant differences on number of filled grains spike^{-1} of wheat (Table 12). In the interaction effect of different irrigation levels and sowing dates, the sowing dates of 19 November 2012 (S_1) in combination with each of the 4 irrigation levels except I_0 performed better than those of all other treatment combination of irrigation and sowing dates. Out of the 3 combinations of S_1 with irrigation level I_1S_1 obtained the highest number of filled grains spike^{-1} (34.33). Treatment combination of I_2S_1 and I_3S_1 produced the filled grain spike^{-1} 33.17 and 31.67 which were statistically similar to 34.33. The lowest number of filled grains spike^{-1} (21.50) was recorded from I_0S_3.

4.2.7. Number of unfilled grains spike^{-1}

Data revealed that unfilled grains spike-^{1} of wheat showed statistically significant variation due to different levels of irrigation under (Table 11). The highest unfilled grains spike^{-1} (3.62) was recorded from I_0, which was closely followed by I_2 (2.94) and the lowest unfilled grains spike^{-1} (1.99) was observed from I_1.

Different sowing date varied significantly for unfilled grains spike^{-1} of wheat (Table 11). The highest unfilled grains spike^{-1} (3.22) was observed from S_3 and the lowest unfilled grains spike^{-1} (2.45) was recorded from S_1 which was closely followed by (2.70) found in S_2.

Statistically significant variation was observed due to that interaction effect of different levels of irrigation and sowing date on unfilled grains spike^{-1} of wheat (Table 12). The highest unfilled grains spike^{-1} (4.03) was observed from I_0S_3, while the lowest unfilled grains spike^{-1} (1.50) was recorded from I_1S_1.

Table 12. Interaction effect of irrigation level and sowing date on yield contributing characters of wheat

Treatment combination of irrigation and sowing date	Spike length (cm)	Filled grains $spike^{-1}$	Unfilled grains $spike^{-1}$	Total grains $spike^{-1}$	Weight of 1000 grains (g)
I_0S_1	17.13 ef	24.33 cd	3.07 c	27.40 cd	41.02 c-f
I_0S_2	16.77 f	23.83 cd	3.77 ab	27.87 cd	38.70 d-f
I_0S_3	16.80 f	21.50 d	4.03 a	25.27 d	37.33 f
I_1S_1	19.60 a	34.33 a	1.50 f	35.83 a	47.09 a
I_1S_2	19.40 ab	29.33 b	1.77 f	31.10 bc	45.05 ab
I_1S_3	18.57 b-d	24.33 cd	2.70 cd	27.03 d	41.14 c-f
I_2S_1	18.83 a-c	33.17 a	2.40 de	35.57 a	42.03 b-e
I_2S_2	18.43 cd	24.33 cd	2.83 c	27.17 d	39.66 d-f
I_2S_3	18.97 a-c	25.33 c	3.60 b	28.93 cd	44.65a-c
I_3S_1	18.97 a-c	31.67 ab	2.13 e	33.80 ab	43.57 a-c
I_3S_2	19.03 a-c	25.83 c	2.17 e	28.00 cd	42.44 b-d
I_3S_3	17.80 de	23.33 cd	3.53 b	26.87 d	38.48 ef
SE	0.255	1.115	0.123	1.155	1.158
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.41	7.21	7.62	6.77	4.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

4.2.8. Number of total grains spike^{-1}

Number of total grains spike^{-1} of wheat showed statistically significant variation due to different levels of irrigation under the present trial (Table 11). The highest number of total grains spike^{-1}, 31.32 was recorded from I_1, which was statistically similar to 30.56 and 29.56 observed in I_2 and I_3, while the lowest number of total grains spike^{-1} 26.84 was observed from I_0. Islam (1996) observed that irrigation had no influence of grains per spike.

Statistically significant variation for number of total grains spike^{-1} of wheat was due to different sowing date (Table 11). The highest number of total grains spike^{-1} 32.62 was observed from S_1 and the lowest number of total grains spike^{-1} (27.56) was recorded from S_3, which was statistically similar to 28.53 observed in S_2. Chowdhury (2002) conducted an experiment with four sowing dates and reported that grains spike^{-1} decreased with delay in sowing date from November 15 and the lowest grains spike^{-1} were recorded in December 15 sown plants.

Different levels of irrigation and sowing date showed significant differences on number of total grains spike^{-1} of wheat due to their interaction effect (Table 12). The highest number of total grains spike^{-1} (35.83) was observed from I_1S_1, while the lowest number of total grains spike^{-1} (25.27) was recorded from I_0S_3.

4.2.9. Weight of 1000-grain (g)

It was found that weight of 1000-grain of wheat varied significantly due to different levels of irrigation under the present trial (Table 11). The treatment I_1 produced the highest 1000-grain weight of 44.43 g which was statistically similar to 42.12 g and 41.50 g obtained from the treatment I_2 and I_3, respectively, while the treatment I_0 produced the lowest 1000-grain weight of 39.01 g. Islam (1996) observed that irrigation had no influence of 1000-grain weight.

Statistically significant variation was recorded for weight of 1000-grain of wheat due to different sowing date (Table 11). The treatment S_1 produced significantly the highest 1000 grain weight of 43.43 g while S_3 produced significantly the lowest 1000-grain weight of 40.40 g which was statistically similar to 41.46 g which was found in S_3 treatment. Chowdhury (2002) conducted an experiment with four sowing dates and reported that 1000-grain weight decreased with delay in sowing date from November 15 and the lowest 1000-grain weight were recorded in December 15 sown plants.

Interaction effect of different levels of irrigation and sowing date varied significantly on weight of 1000-grain of wheat (Table 12). The highest weight of 1000-wheat grain (47.09 g) was observed from I_1S_1, while the lowest weight of 1000-grain (37.33 g) was recorded from I_0S_3.

4.3. Yield

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

Grain yield of wheat ha^{-1} significantly differed from irrigated to non-irrigated condition but virtually no significant difference was observed among the 3 irrigation treatments studied. Hence it indicated that given one irrigation at any growth stage of the wheat, bears more or less equal weight. Among the 3 different studied irrigation stages of wheat crown root initiation stage obtained numerically the highest grain yield of wheat ha^{-1} (3.43 t) while flowering and grain filling stage obtained 3.22 t and 3.26 t, respectively. Baser *et al*. (2004) reported that grain yield under non-irrigated conditions was reduced by approximately 40%. Bazza *et al.* (1999) reported that one water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations but Meena *et al.* (1998) reported that wheat grain yield was the highest with 2 irrigations (2.57 ton/ha in 1993 and 2.64 ton/ha) at flowering and/or crown root initiation stages. Wheat is sown in November to ensure optimal crop growth and avoid high temperature and after that if wheat is sown in the field it faces high range of temperature for its growth and development as well as yield potential. Islam *et al*., (1993) reported that late planted wheat plants faced a period of high temperature stress during reproductive stages causing reduced kernel number spike^{-1} as well as the reduction of seed yield.

Table 13. Effect of irrigation level and sowing date on yield of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Irrigation levels				
I_0	2.61b	5.00 b	7.61 c	34.25
I_1	3.43 a	5.66 a	9.09 a	37.68
I_2	3.22 a	5.44 a	8.66 b	37.20
I_3	3.26 a	5.47 a	8.73 b	37.29
SE	0.125	0.084	0.077	1.249
Level of significance	0.01	0.01	0.01	NS
Sowing date				
S_1	3.33 a	5.62 a	8.94 a	37.09
S_2	3.07 b	5.30 b	8.38 b	36.52
S_3	2.99 b	5.26 b	8.25 b	36.21
SE	0.062	0.096	0.117	0.619
Level of significance	0.01	0.05	0.01	NS
CV(%)	6.84	6.15	4.76	5.86

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Grain yield of wheat showed statistically significant variation due to different sowing date (Table 13). The highest grain yield (3.33 t ha^{-1}) was observed from the treatment of S_1 and the lowest grain yield 2.99 t ha^{-1} observed from S_3 was statistically similar to 3.07 t ha^{-1} recorded from S_2.

Data revealed that interaction effect of different levels of irrigation and sowing date showed significant differences on grain yield ha^{-1} of wheat (Table 14). It reveals from the results that non-irrigated condition of wheat crop irrespective of any sowing date studied performed worse while irrigation at crown root initiation stage in combination with November sowing performed better. The highest grain yield ha^{-1} of wheat (3.82 t ha^{-1}) was obtained from the treatment combination of irrigation at crown root initiation stage with 19 November 2012 sowing date (I_1S_1) and the lowest grain yield of wheat ha^{-1} (2.44 t ha^{-1}) was obtained from the treatment combination of non irrigated condition with 09 December 2012 sowing date (I_0S_3).

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

Straw yield of wheat showed statistically significant variation due to different levels of irrigation (Table 13). The highest straw yield of 5.66 t ha^{-1} was recorded from I_1, which was statistically similar to 5.47 t ha^{-1} and 5.44 t ha^{-1}, respectively obtained from I_3 and I_2. On the other hand, the lowest straw yield 5.00 t ha^{-1} was observed from I_0.

Significant variation was recorded for straw yield of wheat due to different sowing date under the present trial (Table 13). The highest straw yield as 5.62 t ha^{-1} was observed from S_1 and the lowest straw yield 5.26 t ha^{-1} was recorded from S_3 which was statistically similar to 5.30 t ha^{-1} obtained from S_2.

Table 14. Interaction effect of irrigation level and sowing date on yield of wheat

Treatment combination of irrigation and sowing date	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0S_1	2.64 ef	4.97 e	7.61 d	34.69 b-d
I_0S_2	2.74 ef	5.31 b-e	8.05 cd	34.07 cd
I_0S_3	2.44 f	4.74 e	7.18 d	33.98 d
I_1S_1	3.82 a	5.96 a	9.78 a	40.16 a
I_1S_2	3.59 ab	5.68 a-d	9.27 ab	38.79 ab
I_1S_3	2.89 de	5.33 a-e	8.22 c	35.11 b-d
I_2S_1	3.26 b-d	5.92 ab	9.18 ab	35.47 b-d
I_2S_2	2.97 c-e	5.27 c-e	8.24 c	35.97 b-d
I_2S_3	3.44 ab	5.13 de	8.57 bc	39.12 ab
I_3S_1	3.59 ab	5.84 a-c	9.43 a	38.01 a-c
I_3S_2	3.30 bc	5.30 b-e	8.60 bc	38.38 ab
I_3S_3	2.90 c-e	5.27 c-e	8.17 c	35.50 b-d
SE	0.124	0.192	0.234	1.238
Level of significance	0.01	0.05	0.01	0.05
CV(%)	6.84	6.15	4.76	5.86

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

I_0: No irrigation i.e. control

I_1: Irrigation at 20 DAS (crown root initiation stage)

I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 75 DAS (grain filling stage)

S_1: Sowing at 19 November, 2012

S_2: Sowing at 29 November, 2012

S_3: Sowing at 09 December, 2012

Interaction effect of different levels of irrigation and sowing date showed significant differences on straw yield of wheat (Table 14). The highest straw yield (5.96 t ha^{-1}) was observed from I_1S_1, while the lowest straw yield (4.74 t ha^{-1}) was recorded from I_0S_3.

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

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 13). The highest biological yield (9.09 t ha^{-1}) was recorded from I_1, which was closely followed by 8.73 t ha^{-1} and 8.66 t ha^{-1} recorded respectively from I_2 and I_3 while the later two were statistically similar. On the other hand, the lowest biological yield 7.61 t ha^{-1} was observed from I_0. Gupta *et al.* (2001) reported that biological yield decreased to a greater extent when water stress was imposed at the anthesis stage.

Statistically significant variation was recorded for biological yield of wheat due to different sowing date (Table 13). 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}).

Different levels of irrigation and sowing date showed significant differences on biological yield of wheat due to interaction effect (Table 14). The highest biological yield (9.78 t ha^{-1}) was observed from I_1S_1, while the lowest biological yield (7.18 t ha^{-1}) was recorded from I_0S_3.

4.3.4. Harvest index (%)

Harvest index of wheat showed statistically non significant variation due to different levels of irrigation under the present trial (Table 13). Numerically, the highest harvest index (37.68%) was recorded from I_1 and, the lowest harvest index (34.25%) was observed from I_0. Gupta *et al.* (2001) reported that harvest index decreased to a greater extent when water stress was imposed at the anthesis stage.

Data revealed that there was no significant variation for harvest index of wheat due to different sowing date (Table 13). Numerically, the highest harvest index (37.09%) was observed from S_1 and the lowest 36.21% was from S_3. Samuel *et al.* (2000) reported that late sowing condition (6 January 1997) reduce the harvest index (36.1%) from (41.5%) of normal sowing condition (29 November 1996) in wheat.

Interaction effect of different levels of irrigation and sowing date showed significant differences on harvest index of wheat (Table 14). The highest harvest index (40.16%) was observed from I_1S_1, while the lowest harvest index (32.98%) was recorded from I_0S_3.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November 2012 to March 2013 to find out the effect of single irrigation and sowing date on growth and yield of wheat. The experiment comprised two factors; Factors A: Irrigation (4 levels): I_0: No irrigation i.e. control; I_1: Irrigation at 20 DAS (Crown root initiation stage); I_2: Irrigation at 55 DAS (Flowering stage) and I_3: Irrigation at 75 DAS (Grain filling stage); Factor B: Sowing date (3 levels at 10 days interval): S_1: Sowing at 19 November, 2012; S_2: Sowing at 29 November, 2012 and S_3: Sowing at 09 December, 2012. The experiment was laid out in Split Plot Design with three replications. Irrigation was assigned in the main plot and sowing date 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 matter content hill^{-1}, crop growth rate (CGR) and relative growth rate (RGR) were measured at 15 days interval starting from 25 DAS onwards to 85 DAS except plant height where data was recorded at harvest also. In each parameter except RGR the data recorded was found to vary significantly due to the effect of irrigation, sowing date and their interaction.

From the data recorded for plant height, it was revealed that the treatment I_1 (irrigation at crown root initiation stage) produced the tallest plant (in each plant height recording day) which was significantly higher than the corresponding plant height recorded in the rest 3 irrigation treatments. The corresponding lowest plant height was found to be recorded under the treatment I_0. The corresponding plant height recorded in I_2, I_3 and I_0 were found to be similar with each other. The highest plant height (85.12 cm) was recorded at harvest under the treatment I_1, while the corresponding lowest plant height (66.39 cm) was recorded under the treatment I_0.

In respect of the effect of irrigation on number of tillers hill^{-1}, dry matter content plant^{-1} and crop growth rate it was revealed from the collected data that irrigation at crown root initiation stage (I_1) obtained the highest value in each data recording day from 25 DAS to 85 DAS in each of the above mentioned parameters while I_0 (no irrigation) obtained the respective lowest values. The range of the highest values recorded for the above parameters from 25 DAS to 85 DAS were 1.79 to 4.87, 2.48 to 18.75 g, 4.05 gm^{-2}day^{-1} to 13.50 gm^{-2}day^{-1} while that of the lowest values were 1.2 to 4.1, 2.22 g to 15.79 g and 3.34 gm^{-2}day^{-1} to 9.89 gm^{-2}day^{-1}, respectively. Relative growth rate was not found to vary significantly on irrigation.

Maturity of wheat was found to vary with irrigation and results indicate that irrigation in wheat field hastened its maturity and as such the highest maturity period (121.56 days) was found in I_0 while the shortest maturity (115.33 days) was found in I_1.

Data on yield contributing characters of wheat as number of spikes hill^{-1}, filled grains spike^{-1}, total grains spike^{-1} and 1000 grain weight were recorded at harvest and results revealed that irrigation had significant effect on each of these parameters. As a result, I_1 (irrigation at crown root initiation) recorded the highest values in each of the above parameters. The highest values which were 4.37, 29.33, 31.32 and 44.43 respectively for the above parameters were statistically similar to their corresponding values obtained in I_2 and I_3 except the parameter filled grains spike^{-1} where I_3 had statistically the lower value than I_1 and I_2. On the other hand, I_0 i.e. the non-irrigated plots had significantly the lowest corresponding values of 3.60, 23.22, 26.84 and 39.01. The effect of irrigation may be sum up in this way that irrigation enhanced the yield of wheat and irrigation at crown root initiation stage performed better than that of other irrigation stages.

Yield parameters as grain yield, straw yield and biological yield varied significantly on the effect of irrigation. Keeping consistence in effect with yield contributing parameters, those yield parameters also responded positively with the irrigation treatment. Consequently each of the irrigated plots resulted statistically the higher value than that of non-irrigated plots and the values obtained by the irrigated plots were similar to each other. The highest grain yield ha^{-1} (3.43 t) and highest straw yield ha^{-1} (5.66 t) were obtained by the treatment I_1 and the respective lowest grain yield ha^{-1} (2.61 t) and straw yield ha^{-1} (5.00 t) were obtained by the treatment I_0. In case of biological yield I_1 obtained the highest value of 9.09 t ha^{-1} which was significantly higher than each of the respective values obtained by the rest irrigation treatments.

Regarding the effect of sowing date on the growth habit of wheat under study it was observed that the treatment had significant effect on the growth parameters of wheat and the highest values of the growth parameters as plant height, number of tillers $plant^{-1}$, dry matter $plant^{-1}$ CGR and RGR were recorded under the treatment S_1 (November 19, 2012 sowing date) while the lowest values were observed under the treatment S_3 (December 9, 2012 sowing date). The crop maturity also varied significantly with sowing time and S_3 had the highest maturity of 120 days, while S_1 had the lowest maturity period of 117.33 days. Yield contributing characters of wheat varied significantly on the effect of sowing date and S_1 obtained the highest values of 4.18, 30.17, 32.62 and 43.43, respectively for number of spikes $hill^{-1}$, filled grains $spike^{-1}$, total grains $spike^{-1}$ and 1000-grain weight and the corresponding lowest values which were respectively 3.96, 24.33, 27.56 and 40.40 were obtained from S_3 As the yield contributing characters recorded the highest values in November 19, sowing (S_1) so, the highest grain yield (3.33 t ha^{-1}), straw yield (5.62 t ha^{-1}) and biological yield (8.94 t ah^{-1}) were also recorded in November 19 sowing (S_1) and all the lowest values of all these parameters were recorded in December 9 sowing (S_3).

Interaction effect was also found to vary significantly. Irrigation at crown root stage in combination with November 19 sowing (I_1S_1) 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 (3.82 t ha^{-1}), straw yield (5.96 t ha^{-1}) and biological yield (9.78 t ha^{-1}), respectively. The respective lowest yield 2.41 t ha^{-1}, 4.74 t ha^{-1} and 7.38 t ha^{-1} were obtained in the treatment combination of I_0S_3.

Based on the experimental results, it may be concluded here that

i) Morphological growth, yield attributes and yield of wheat are positively co-related with irrigation and time of sowing.

ii) When one irrigation is to be applied in wheat field, irrigation should be given at crown root initiation stage.

iii) November sowing of wheat is found better than December sowing in relation to the crop performance.

However, these findings need to be further investigated and evaluated on different agro-ecological zones before final recommendation to the farmers.

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APPENDICES

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

A. 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

B. Physical and chemical properties of the soil before experimentation

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2012 to March 2013

Month	*Air temperature (^{0}C)		*Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
November, 2012	25.82	16.04	78	00
December, 2012	22.4	13.5	74	00
January, 2013	24.5	12.4	68	00
February, 2013	27.1	16.7	67	30
March, 2013	31.4	19.6	54	11

* Monthly average

* Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka

Apendix III. Analysis of variance of the data on plant height at different days after sowing (DAS) of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		50 DAS	60 DAS	70 DAS	80 DAS	Harvest
Replication	2	1.277	0.502	1.466	1.748	0.538
Levels of irrigation (A)	3	94.671**	184.74**	257.82**	300.56**	316.82**
Error	6	3.321	2.825	12.304	11.463	13.912
Sowing date (B)	2	28.304**	261.82**	399.64**	389.99**	375.32**
Interaction (A×B)	6	12.400**	59.708**	98.073**	93.459**	73.852**
Error	16	4.092	14.414	15.191	19.621	16.662

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix IV. Analysis of variance of the data on number of tillers hill^{-1} at different days after sowing (DAS) of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square			
		Number of tillers hill^{-1} at			
		50 DAS	60 DAS	70 DAS	80 DAS
Replication	2	0.001	0.004	0.013	0.021
Levels of irrigation (A)	3	0.754**	1.689**	1.287**	2.134**
Error	6	0.009	0.049	0.015	0.097
Sowing date (B)	2	1.874**	1.551**	1.363**	1.604**
Interaction (A×B)	6	0.104*	0.060*	0.084**	0.160*
Error	16	0.037	0.031	0.043	0.053

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix V. Analysis of variance of the data on dry matter content plant^{-1} (g) at different days after sowing (DAS) of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square			
		Dry matter content plant^{-1} (g) at			
		50 DAS	60 DAS	70 DAS	80 DAS
Replication	2	0.097	0.170	0.089	0.163
Levels of irrigation (A)	3	6.782**	29.292**	26.423**	133.615**
Error	6	0.107	0.347	1.473	1.369
Sowing date (B)	2	1.463**	8.820**	7.449**	10.871**
Interaction (A×B)	6	0.415**	0.729**	2.266**	2.464**
Error	16	0.152	0.247	1.066	0.846

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix VI. Analysis of variance of the data on Crop Growth Rate (CGR) at different days after sowing (DAS) of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square		
		Crop Growth Rate (g $m^{-2}day^{-1}$) at		
		50-60 DAS	60-70 DAS	70-80 DAS
Replication	2	0.446	0.184	0.487
Levels of irrigation (A)	3	7.895	0.359	42.374
Error	6	0.505	1.856	1.568
Sowing date (B)	2	3.472	0.278	0.468
Interaction (A×B)	6	0.165	1.570	0.614
Error	16	0.332	1.282	2.408

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix VII. Analysis of variance of the data on Relative Growth Rate (RGR) and days required from sowing to flowering and maturity of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square				
		Relative growth rate (g g^{-1} day^{-1}) at			Days required for flowering	Days required for maturity
		50-60 DAS	60-70 DAS	70-80 DAS		
Replication	2	0.0001	0.0001	0.0001	0.778	1.768
Levels of irrigation (A)	3	0.0001	0.0001	0.001	22.769*	77.902**
Error	6	0.0001	0.0001	0.0001	4.630	8.483
Sowing date (B)	2	0.0001	0.0001	0.0001	47.444**	184.48**
Interaction (A×B)	6	0.0001	0.0001	0.0001	9.296*	21.184*
Error	16	0.0001	0.0001	0.0001	3.083	9.010

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix VIII. Analysis of variance of the data on number of spikes $hill^{-1}$, number of spikelets $spike^{-1}$ and spike length of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square		
		Number of spikes $hill^{-1}$	Number of spikelets $spike^{-1}$	Spike length (cm)
Replication	2	0.030	0.655	0.167
Levels of irrigation (A)	3	2.987**	26.405**	33.780**
Error	6	0.048	1.136	2.718
Sowing date (B)	2	0.910**	31.959**	24.385**
Interaction (A×B)	6	0.119*	5.939**	7.769**
Error	16	0.085	1.772	1.570

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix IX. Analysis of variance of the data on filled, unfilled and total grains spike^{-1} and weight of 1000-grain of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square			
		Filled grains spike^{-1}	Unfilled grains spike^{-1}	Total grains spike^{-1}	Weight of 1000-grain (g)
Replication	2	1.609	0.004	1.523	0.529
Levels of irrigation (A)	3	71.439**	0.201**	64.627**	258.037**
Error	6	4.302	0.010	4.484	1.940
Sowing date (B)	2	59.708**	0.448**	50.042**	107.772**
Interaction (A×B)	6	14.483**	0.103*	16.759**	6.242*
Error	16	3.314	0.031	3.298	3.928

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Apendix X. Analysis of variance of the data on yield of wheat influenced by irrigation levels and sowing date

Source of variation	Degrees of freedom	Mean square			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.006	0.074	0.083	2.587
Levels of irrigation (A)	3	1.811**	1.997**	7.456**	8.612**
Error	6	0.128	0.137	0.491	1.279
Sowing date (B)	2	2.107**	0.498**	4.651**	38.509**
Interaction (A×B)	6	0.249**	0.416**	1.244**	2.508**
Error	16	0.049	0.088	0.195	2.872

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability