YIELD RESPONSE OF WHEAT AS AFFECTED BY IRRIGATION AND POTASSIUM FERTILIZER

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TO

MY BELOVED PARENTS

DEPARTMENT OF AGRONOMY

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CERTIFICATE

This is to certify that the thesis entitled **'Yield Response of Wheat as Affected by Irrigation and Potassium Fertilizer'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Md. Samsujjoha Chowdhury**, Registration number: **07-02469** 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:
Dhaka, Bangladesh

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YIELD RESPONSE OF WHEAT AS AFFECTED BY IRRIGATION AND POTASSIUM FERTILIZER

ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during from November 2012 to March 2013 to find out the yield response of wheat as affected by irrigation and potassium fertilizer. BARI Gom-24 was used as a test crop of this study. The experiment comprised of two factors- Factors A: Irrigation, 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 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage) and Factor B: Level of potassium fertilizer, K_0: 0 kg MOP ha^{-1}, K_1: 50 kg MOP ha^{-1} and K_2: 100 kg MOP ha^{-1}. The experiment was laid out in split plot design where irrigation in main plot and potassium fertilizer in sub-plot with three replications. Data on growth, yield and yield parameter recorded and variation was observed for different treatment. In case of different levels of irrigation, the longest spike (18.19 cm) was observed from I_3, while the shortest spike (15.90) was observed from I_0. The maximum number of filled grains $spike^{-1}$ (31.17) was observed from I_3, whereas the minimum number (26.22) was observed from I_0. The highest grain yield (3.28 t ha^{-1}) was observed from I_3, while the lowest grain yield (2.23 t ha^{-1}) was observed from I_0. The highest straw yield (5.45 t ha^{-1}) was observed from I_3, whereas the lowest straw yield (3.87 t ha^{-1}) was observed from I_0. For different levels of potassium fertilizer, the longest spike (18.63 cm) was observed from K_3 treatment, while the shortest spike (15.03 cm) was observed in K_0. The maximum number of filled grains $spike^{-1}$ (31.54) was observed from K_3 treatment, while the minimum number of filled grains $spike^{-1}$ (24.33) was found in K_0. The highest grain yield (3.25 t ha^{-1}) was observed from K_3 treatment, while the lowest grain yield (2.38 t ha^{-1}) was found in K_0. The highest straw yield (5.45 t ha^{-1}) was observed from K_3 treatment, again the lowest straw yield (4.14 t ha^{-1}) was found in K_0. Due to interaction effect of different levels of irrigation and potassium fertilizer, the longest spike (19.60 cm) was observed from I_3K_2, while the shortest spike (13.80 cm) was recorded from I_0K_0. The maximum number of filled grains $spike^{-1}$ (34.83) was observed from I_3K_2 and the minimum number of filled grains $spike^{-1}$ (23.33) was recorded from I_2K_0. The highest grain yield (3.79 t ha^{-1}) was observed from I_3K_2, while the lowest grain yield (2.04 t ha^{-1}) was recorded from I_0K_0. The highest straw yield (6.09 t ha^{-1}) was observed from I_3K_2, while the lowest straw yield (3.77 t ha^{-1}) was recorded from I_0K_0. Irrigation at 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage) and 100 kg K_2O ha^{-1} gave the better performance in terms of growth and yield of wheat.

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CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important food crop and primarily grown acrossthe exceptionally diverse range of environments (WRC, 2009). Importance of wheat cropmay be understood from the fact that it covers about 42% of total cropped area in rice-wheat system in South Asia (Iqbal*et al.*, 2002).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). In Bangladesh, wheat is the second most important cereal crop (FAO, 1997). It occupies above 4% of the total cropped area and 11% of the area cropped in rabi and contributes 7% to the total output of food cereals (Anon., 2008).Generally wheat supplies carbohydrate (69.60%), protein (12%), fat (1.72%), and also minerals (16.20%) and also other necessary nutrients in trace amount (BARI, 1997).

Bangladesh had become highly dependent on wheat imports while dietary preferences were changing such that wheat was becoming a highly desirable food supplement to rice. Domestic wheat production rose to more than 1 million tons per year, but still only 7-9% of total food grain production (BARI, 2010).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 wheat growing 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 metric tons (BBS, 2011).

Yield and quality of wheat are very low in Bangladesh and the low yield 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 of wheat are the major reason of yield reduction. 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). Major constraints to wheat grain yield in this region are inadequate rainfall and high temperatures during grain filling at the end of the season (Radmehr*et al*., 2003; Andarzian*et al*., 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.

There are 17 essential elements, among them some elements required in relatively high amounts, are called macronutrients and some in trace amounts are called micronutrients.Potassium (K) is an essential nutrient involved in regulating water balance and enhancing water uptake. Potassium is involved in nearly all processes needed to sustain plant life besides its role in conferring pest and disease resistance. Potassium fertilization can be either applied to soil or as foliar spray to plants. Soil application is the standard form of application and has its own advantages unless soil pH and other factors affect the movement and uptake from soil to the plants. The conventional way to apply K to the soil is before planting (pre-planting), and larger quantity may improve soil fertility for subsequent crops (Fernandez, 2012). Although soil application of K fertilizers have been used to maintain optimum level of nutrients in crop. Potassium has significant effect on dry matter accumulation and productivity of wheat under water stress condition (Baque*et al.*, 2006). Potassium is reported to improve water relations as well as productivity of different crops under water stress condition (Johnson, 1983, Islam *et al.*, 2004).

Information on the precise time of application of irrigation as well as the proper level of potassium 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 research work was undertaken with the following objectives-

- To study the effect of different levels of potassium and irrigation on growth and yield of wheat and
- To examine the combined effect of different levels of potassium and irrigation frequency on yield and yield contributing characters 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 nutrient especially potassium arethe 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 potassium fertilizerhave 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 potassium fertilizer 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 a) 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 b) 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 yielddecreased with increasing irrigation intervals. When a 20 and 30-day irrigation interval were applied grain yieldwere higher in cultivars C-75-14 and C-75-9.

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The study was carried out by Manganet *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.

Gaoet *al.* (2009) conducted a field experiment to determine the reasonable and effective water-saving irrigation schemes in wheat production, the commercial wheat cvsShannong 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 andirrigation 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 potassium on growth and yield of wheat

There are 16 essential nutrient elements among them potassium is one of the major and primary element for the growth, development and better yield of wheat. Potassium play pivotal role is different growth stages and yield of wheat.

Saren and Jana (2008) conducted a field experiment in West Bengal, India, in winter to study the effects of irrigation depth (4.5, 6.0, 9.0 and 12.0 cm), with the half rate of N (urea) and full rate of P (50 kg single super phosphate/ha) and K (50 kg muriate of potash/ha) were applied as basal. The application of 50 kg K/ha as top dressing after irrigation gave the longest plant, highest length of spike, number of effective tillers, grains and straw yields and N, P, K uptake by grain and straw.

Malek*et al.* (2013)conducted an experiment to find out the effect of potassium sulfate and zinc fertilizers on wheat drought resistance under water stress conditions. In this test, a split factorial in a randomized complete block design with three replications. Factors examined include the normal irrigation and supplemental irrigation in main plots were performed and potassium fertilizers concentrations of zero, 60, 120 and 180 kg ha potassium sulfate source and zinc concentrations zero and 25 kg ha of zinc sulfate source factorial subplots were performed. At the end of the experiment seed yield, number of grains per spike, number of spikelets per spike, 1000 seed weight and the amount of protein, potassium, zinc and nitrogen on grain measured. The results showed that potash fertilizer had a positive effect on most traits.

Patel and Upadhaya (1993) found that plant height of wheat increased significantly with increasing rates of N up to 150 kg Nha^{-1}. Plant height was significantly increased with 0-200 kg N ha^{-1} (Meneses and Ivan-Marcelo, 1992) Highest plant height of wheat was found when nitrogen was applied at the rate of 120 kg N ha^{-1} (Ellen, 1987; Dhuka*et al.*,1991). Ahmed and Hossain (1992) observed that plant height of wheat were 79.9, 82.3 and84.4 cm with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height increased with increasing nitrogen fertilizer doses. Gami*et al.* (1986) reported that plant height of wheat increased up to 160 kg N ha^{-1} which was at par with that of 120 kg N ha^{-1}. Chandra *et al.* (1992) carried out an experiment during 1979-80 at Varanast, Uttar Pradesh (India) and reported that plant height and dry matter increased with increasing the rate of N up to 120 kg N ha^{-1}. Further increment of 3 kg N ha^{-1} decreased this parameter.

Bellido*et al.* (2000) evaluated a field experiment with 4 level of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and reported that the amount of total dry matter was significantly greater at the N fertilizer rates of 100 and 150 kg N ha^{-1}. Kumar and Sharma (1999) conducted a field experiment with 4 levels of N (0, 40, 80 and 120 kg N ha^{-1}) and observed that dry matter accumulation in wheat increased from 0-40 kg N ha^{-1} at 40 DAS, 0-120 kg N ha^{-1} at 60 DAS, 0-80 kg N ha^{-1} at 80 DAS. Verma and Achraya (1996) observed that LAI increased significantly at maximum tillering and flowering stages with increasing levels of nitrogen. Tanaka (1983) observed that the LAI above a certain limit causes decrease in NAR. Kumar *et al.* (1995) reported that increasing levels of N tended to show higher meristematic activities, formation and functioning of protoplasm, which consequently increased the plant growth.

Frederick and Camberato (1995) observed that increase in N rate resulted in higher LAI and maximum LAI values were found at 90 kg N ha^{-1}. Plant height of wheat remarkably influenced with different levels of N application (Behera, 1995). Patel *et al.* (1995) observed that plant height of wheat increased with increasing rates of N up to 120 kg N ha^{-1}. Singh *et al.* (1996) evaluated 3 levels of N (40, 80 and 120 kg N/ha) and found the growth parameters were significantly improved by nitrogen application. Plant height, number of tillers and ear length were significantly increased with nitrogen application up to 80 kg N ha^{-1}, grain and straw yields were significantly increased up to 120 kg N ha^{-1}.

Kumar *et al.* (1995) carried out field experiment with 4 levels of nitrogen (0, 60, 120 and 180 kg N/ha) and reported that productive tillers increased significantly with the increase of N doses from 0 to 120 kg ha^{-1}, but differences in productive tillers between 120 and 180 kg N ha^{-1} were not significant.

Effective tillers m^{-2} responded significantly to the applications of N-fertilizer (Behera, 1995). Effective tillers increased significantly with increase the level of N up to 80 kg N ha^{-1} (Singh and Singh, 1991). Patel and Upadhyay (1993) conducted an experiment with 3 levels of N (90, 120 and 150 kg N ha^{-1}) and reported that total and effective tillers m^{-2} increased significantly with increasing rates of N up to 120 kg N ha^{-1}.

Upadhyay and Tiwari (1996) conducted a field experiment on two wheat varieties (Sonalika and Lok 1) with three levels of N (90, 120 and 150 kg ha^{-1}) and observed that nitrogen application up to 120 kg ha^{-1} increased the number of fertile spikelets $spike^{-1}$ with lower dose (90 kg N ha^{-1}). Application of N beyond 120 kg N did not increase the value of this character.

Johnson *et al.* (1990) stated that higher leaf number of short and narrow leaved had high LAI that gave high yield by producing more tillers.

Geethadevi*et al.* (2000) found that 120 kg nitrogen ha^{-1} in the form of urea, 50% nitrogen was applied in four splits resulted in higher number of tillers, grains $spike^{-1}$, and higher grain weight $plant^{-1}$. They also observed that dry matter $hill^{-1}$ increased almost linearly with the increase in N level, but its effect was more conspicuous after the heading stage. Tillers $plant^{-1}$ increased linearly with the increase in N fertilizer levels. Grain yield and most of the yield attributes varied significantly. The highest grain yield (3804 kg ha^{-1}) obtained from 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3810 kg ha^{-1}).

Bayan and Kandasamy (2002) noticed that the application of recommended doses of N in four spilts at 10 days after sowing, active tillering, panicle initiation and at heading stages recorded significantly lower dry weight of weeds and increased crop growth viz., effective tillers m^{-2}.

Maurya and Verma (1990) conducted an experiment with 3 levels of N (0, 60, 90 kg N ha^{-1}) and observed that application of N significantly increased the spike length of wheat, 90 kg N ha^{-1} gave the maximum spike length. Dhuka*et al.* (1991) conducted a field experiment on "GW 120" wheat with 3 level of N (40, 80 and 120 kg ha^{-1}) and observed that spike length of whet was significantly increased by N application. Maximum spike length was obtained at 120 kg N ha^{-1}. Patel and Upadhyay (1993) conducted an experiment with levels of N (90, 120 and 150 kg ha^{-1}) and the result showed that spike length of wheat increased significantly with increasing rates of N upto 120 kg N ha^{-1}. Singh *et al.* (1996) carried out a field experiment with three level of nitrogen (40, 80 and 120 kg ha^{-1}) and found that the growth parameters were significantly improved by nitrogen application. Plant height, number of tillers m^{-2} and ear length were significantly increased owing to nitrogen application up to 120 kg ha^{-1}.

The number of spikelets $spike^{-1}$ may be changed with different levels of nitrogen. Nitrogen had a significant impact on number of spikelets $spike^{-1}$. Number of spikelets $spike^{-1}$increaed with increasing of N rate up to 120 kg N ha^{-1} (Malik *et al.*, 1987 and Singh *et al.*, 1992).

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

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

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

Zhang *et al.* (2000) measured various crop response to a mixed municipal solid waste (refuse) bio-soilds co-compost (named Nutrin Plus) and examined the fate of certain metals associate with Nutri Plus compost. There were six treatments: check 50, 100 and 200 t compost ha^{-1}, NPKS (75 kg N ha^{-1}, 20 kg P ha^{-1}, 45 kg K ha^{-1} and 18 kg S ha^{-1}), PK (2 kg P, 45 kg K ha^{-1}), and three crops: rape, wheat and barley. The research results showed that the compost slightly increased heavy metal concentrations in the soil but did not cause and photo-toxicity to crops. Yield from 100 and 200 t ha^{-1} compost application was higher than with NPKS treatment. However, the yield of 50 t ha^{-1} compost application was similar to that of NPKS treatment. The compost apparently was more beneficial in the year of application. The results suggested that Nutri Plus compost application generated positive yield responses in all three crops. Crop yield increased as the application rate increased.

Singh and Singh (2000) reported that the effect of sewage sludge-based compost on the growth attributes and yield of wheat during 1997, in Allahabad, Uttar Pradesh, India. The treatment were control, Jamuna compost at 2520 g ha^{-1} + rear at 986.60 g ha^{-1}, Jamuna compost at 5040 g ha^{-1} + urea at 657.33 g ha^{-1}, Jamuna compost at 7560 g ha^{-1} + urea at 328.60 g ha^{-1}, Jamuna compost at 10083 g ha^{-1}, and urea at 1315 g ha^{-1}. All the treatments equally received P at 2268.75 g ha^{-1} and potash at 403.33 g ha^{-1}. The plant height was maximum at 100% urea application compared to 76.7 cm in Jamuna compost at 105 days after sowing. Similar effect was observed is the number of tillers m^{-2} row length. The fresh and dry weight of wheat samples from 100% urea application was 102.8 g and 22.1 g, respectively, in sludge-based Jamuna compost at 75 DAS. The highest grain yield of 44.58 q ha^{-1} was observed in 100% urea application, and it was the least in Jamuna compost (13.74 q ha^{-1}). However, application of Jamuna compost, along with urea at 25 and 50%, showed an increase in the growth and yield parameters of wheat, which was on par with 100% urea application.

From the above review of literature it is evident that potassium fertilizer has a significant influence on yield and yield components of wheat. 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 from November 15, 2012 to 20, March 2013 to find out theyield response of wheat as affected by irrigation and potassium fertilizer. 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).The AEZ map shows the specific location of the experimental site presented in Appendix I.

3.1.2. Climatic 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 experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

3.1.3. 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 III.

3.2. Experimental details

3.2.1 Treatment of the experiment

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 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage)

Factor B: Level of potassium fertilizer (3 levels)

i) K_0: 0 kg MoP (as a source of K_2O) ha^{-1}

ii) K_1: 50 kgMoP (as a source of K_2O) ha^{-1}

iii) K_2: 100 kg MoP (as a source of K_2O) ha^{-1}

There were in total 12 (4×3) treatment combinations such as I_0K_0,I_0K_1, I_0K_2, I_1K_0, I_1K_1, I_1K_2, I_2K_0, I_2K_1, I_2K_2, I_3K_0, I_3K_1 and I_3K_2.

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 2.0 m × 3.0 m and 12 treatment combinations were randomly distributed in these plots. Irrigation was assigned in the main plot and potassium fertilizer was in the sub-plot. Layout of the experimental plot presented in Appendix IV.

3.3. Growing of crops

3.3.1. Seed collection

BARI Gom-24 was used as a test crop of this study. The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.3.2. Preparation of the main field

The piece of land selected for the experiment was opened in the 1st week of November2012 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 15 November, 2012. 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, MoP 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	--
MoP	As per treatment	100	--
Gypsum	120 kg	100	--
Cowdung	10 ton	100	--

Source: KrishiProjuktiHatboi, BARI, Joydebpur, Gazipur, 2011

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 three irrigation was provided at 20, 55 and 75 DAS (crown root initiation stage, flowering stage and 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 treatment 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 wheatgrain. 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 30, 45, 60 and75 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 plantwith the help of a meter scale.

Number of tillers $hill^{-1}$

The number of tillers $hill^{-1}$ was recorded at 30, 45, 60 and 75 DAS. Data were recorded by counting tillers from each plant and as the average of 10plants selected at random from the inner rows of each plot.

3.5.2. Yield contributing Characters

Days required from sowing to flowering

Days required from sowingto 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 sowingto 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 10randomly 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 10randomly 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 10randomly 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 recordedwhich 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-

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

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 potassium fertilizerand 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

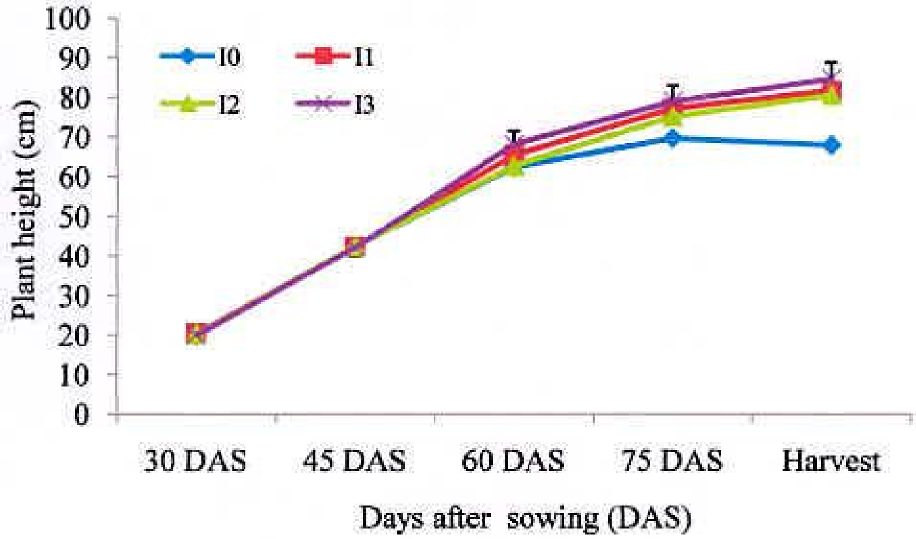
RESULTS AND DISCUSSION

The experiment was conducted during from November 2012 to March 2013 to find out the yield response of wheat as affected by irrigation and potassium fertilizer. 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 V-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following headings:

4.1. Crop Growth Characters

4.1.1. Plant height

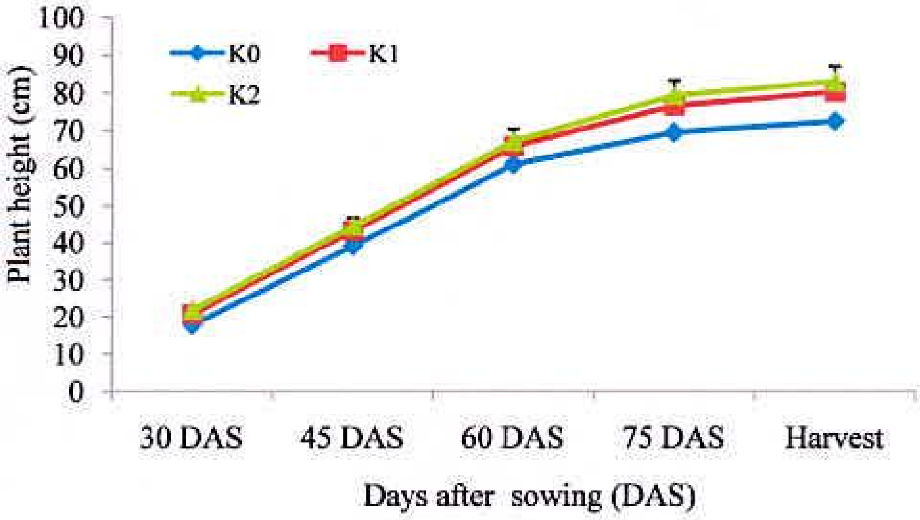
Plant height of wheat showed statistically non-significant variation due to different levels of irrigation at 30, 45 DAS but significant for 60, 75 DAS and at harvest (Figure 1). At 30 DAS, the tallest plant (20.46 cm) was recorded from I_1 (irrigation at 20 DAS: crown root initiation stage), while the shortest plant (19.94 cm) was observed from I_0 (no irrigation i.e. control). At 45 DAS, the tallest plant (42.49 cm) was found from I_1, while the shortest plant (42.18 cm) was observed from I_3 (irrigation at 20, 55 and 75 DAS: crown root initiation stage, flowering stage and grain filling stage). At 60 DAS, the tallest plant (68.15 cm) was recorded from I_3 which was statistically similar (65.42 cm) to I_1, while the shortest plant (62.43 cm) was obtained from I_0 which was statistically similar (62.73 cm) to I_2 (irrigation at 55 DAS: flowering stage) treatment, respectively. At 75 DAS, the tallest plant (78.95 cm) was recorded from I_3 which was statistically similar (77.11) to I_1 and followed (75.08 cm) by I_2, while the shortest plant (69.58 cm) was observed from I_0. At harvest, the tallest plant (84.56 cm) was observed from I_3 which was statistically similar (81.60 cm and 80.39 cm) with I_1 and I_2, while the shortest plant (67.84 cm) from I_0. Islam (1997) reported that plant height increased with increasing number of irrigations.



I_0: No irrigation i.e. control I_1: Irrigation at 20 DAS

I_2: Irrigation at 55 DAS I_{3-}: Irrigation at 20, 55 and 75 DAS

Figure 1. Effect of irrigation on plant height of wheat. Vertical bars represnt LSD value.



K_0: 0 kg MOP ha^{-1} K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Figure 2. Effect of different levels of potassium on plant height of wheat. Vertical bars represnt LSD value.

Statistically significant variation was observed in terms of plant height of wheat at 30, 45, 60, 75 DAS and at harvest was due to different levels of potassium fertilizer (Figure 2). At 30, 45, 60, 75 DAS and at harvest, the tallest plant (21.92, 44.57, 67.16, 79.38 and 82.98 cm, respectively) were observed from K_2 treatment (100 kg MOP ha^{-1}), which were statistically similar (20.78, 43.32, 65.82, 76.66 and 80.35 cm, respectively) to K_1 (50 kg MOP ha^{-1}), while the shortest plant (17.88, 39.22, 61.07, 69.49 and 72.47 cm) was observed in K_0 (0 kg MOP ha^{-1} i.e. control condition). Saren and Jana (2008) found that application of 50 kg K/ha as top dressing after irrigation gave the longest plant.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on plant height of wheat at 30, 45, 60, 75 DAS and at harvest (Table 2). At 30, 45, 60, 75 DAS and at harvest, the tallest plants (22.82, 46.04, 72.64, 86.14 and 93.58 cm, respectively) were observed from I_3K_2, while the shortest plants as 15.04, 35.46, 60.95, 68.14 and 69.11 cm respectively were recorded from I_0K_0 (no irrigation and 0 kg MOP).

4.1.2. Number of tillers $hill^{-1}$

Number of tillers $hill^{-1}$ of wheat showed statistically non-significant variation due to different levels of irrigation at 30, 45 DAS but significant for 60, 75 DAS and at harvest (Figure 3). At 30 DAS, the maximum number of tiller $hill^{-1}$ (2.37) was recorded from I_2, while the minimum number (2.28 cm) was observed from I_2. At 45 DAS, the maximum number of tillers $hill^{-1}$ (3.67) was found from I_1, while the minimum number (3.60) was observed from I_2. At 60 DAS, the maximum number of tillers $hill^{-1}$ (5.37) was recorded from I_3 which was closely followed (4.78 and 4.74) by I_1 and I_2 and they were statistically similar, while the minimum number (3.87) was obtained from I_0. At 75 DAS, the maximum number of tillers $hill^{-1}$ (5.53) was recorded from I_3 which was closely followed (5.29 and 5.20) by I_1 and I_2, while the minimum number (4.70) was observed from I_0. Application of 2 irrigations at crown root initiation stage and pre flowering stage ensured the optimum vegetative growth of the wheat as referred by Meena *et al*, (1998).

Table 2. Interaction effect of irrigation and potassium fertilizer on plant height at different days after sowing (DAS) of wheat

Treatments	Plant height (cm) at				
	30 DAS	45 DAS	60 DAS	75 DAS	Harvest
I_0K_0	15.04 c	35.46 e	58.03 d	68.14 e	69.11 f
I_0K_1	20.62 ab	43.95 a-c	62.49 cd	71.30 de	68.17 ef
I_0K_2	19.69 ab	42.29 a-d	61.16 cd	69.29 e	69.24 ef
I_1K_0	19.48 ab	41.39 a-d	61.65 cd	71.90 de	78.85 cd
I_1K_1	19.26 ab	40.42 cd	65.08 bc	76.16 cd	79.80 cd
I_1K_2	22.63 a	45.29 ab	69.55 ab	83.27 ab	86.16 a-c
I_2K_0	17.49 bc	38.78 de	63.64 cd	69.78 e	75.70 de
I_2K_1	20.80 ab	43.89 a-c	64.87 bc	76.62 cd	82.55 cd
I_2K_2	22.57 a	44.68 a-c	65.28 bc	78.83 bc	82.93 b-d
I_3K_0	19.52 ab	41.24 b-d	60.95 cd	68.19 e	69.23 ef
I_3K_1	22.44 a	45.03 a-c	70.85 a	82.57 ab	90.88 ab
I_3K_2	22.82 a	46.04 a	72.64 a	86.14 a	93.58 a
$LSD_{(0.05)}$	3.501	4.161	5.177	5.543	7.655
Level of significance	0.05	0.01	0.01	0.01	0.01
CV(%)	10.02	5.67	4.62	4.26	5.63

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)

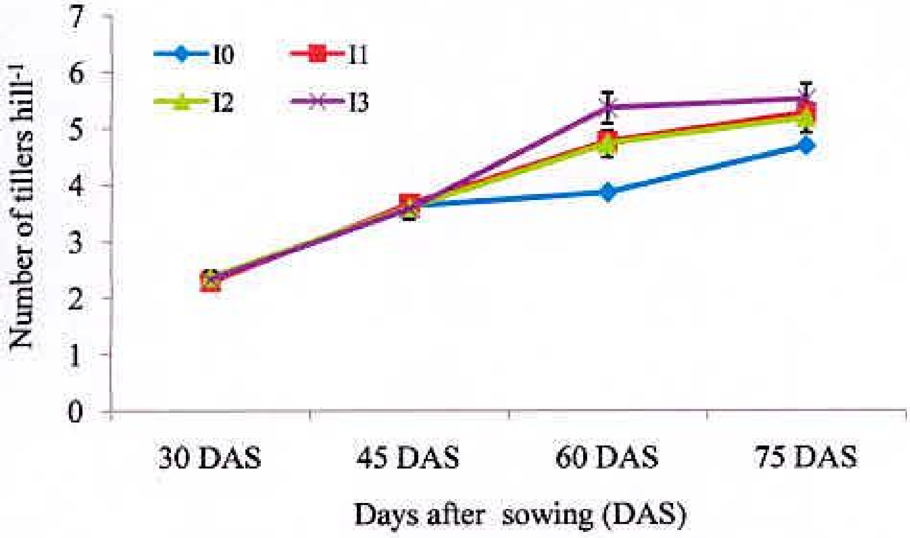
I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

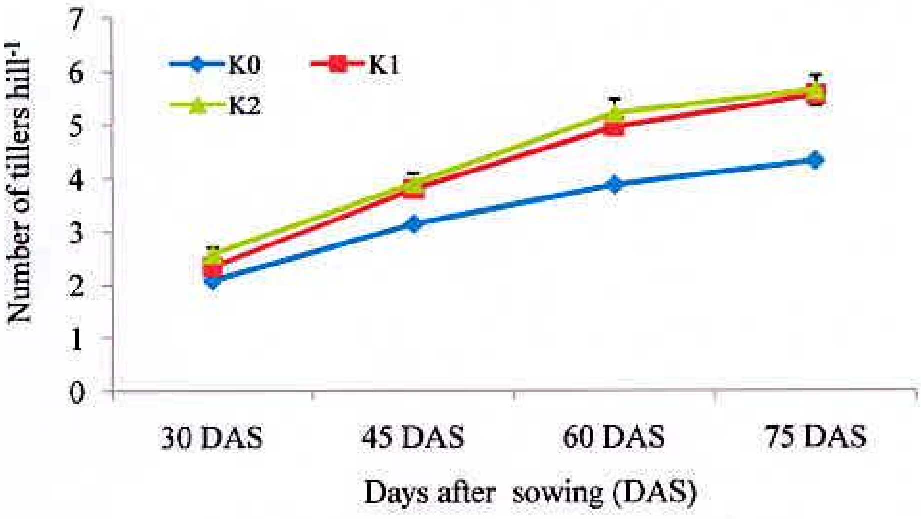
K_2: 100 kg MOP ha^{-1}



I_0: No irrigation i.e. control I_1: Irrigation at 20 DAS

I_2: Irrigation at 55 DAS I_3: Irrigation at 20, 55 and 75 DAS

Figure 3. Effect of irrigation on number of tillers hill^{-1} of wheat. Vertical bars represnt LSD value.



K_0: 0 kg MOP ha^{-1} K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Figure 4. Effect of different levels of potassium on number of tillers hill^{-1} of wheat. Vertical bars represnt LSD value.

Different levels of potassium fertilizer showed statistically significant variation in terms of number of tillers $hill^{-1}$ of wheat at 30, 45, 60 and 75 DAS due to (Figure 4). At 30, 45, 60 and 75 DAS, the maximum number of tillers $hill^{-1}$ (2.58, 3.91, 5.22 and 5.65, respectively) were observed from K_2 treatment, which was followed (2.34, 3.80, 4.96 and 5.56, respectively) by K_1, while the minimum number (2.08, 3.15, 3.88 and 4.33, respectively) was observed in K_0.

Statistically significant variation was recorded due to the interaction effect of different levels of irrigation and potassium fertilizer in terms of number of tillers $hill^{-1}$ of wheat at 30, 45, 60 and 75 DAS (Table 3). At 30, 45, 60 and 75 DAS, the maximum number of tillers $hill^{-1}$ (2.67, 4.07, 6.00 and 6.17, respectively) were observed from I_3K_2, while the shortest corresponding number of tillers $hill^{-1}$ as 2.00, 3.03, 3.33 and 4.13, respectively were recorded from I_0K_0.

4.2. Phenology and 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 (Table 4). The maximum days required from sowing to flowering (69.00) was observed from I_0 which was statistically similar (68.00) with I_2 and closely followed (66.78) by I_1, while the minimum days required from sowing to flowering (63.89) was observed from I_0.

Statistically significant variation was recorded in terms of days required from sowing to flowering of wheat due to different levels of potassium fertilizer (Table 4). The maximum days required from sowing to flowering (68.67) were observed from K_0 treatment, whereas the minimum days required from sowing to flowering (65.33) was observed in K_1 which was statistically similar (66.75) with K_2.

Table 3. Interaction effect of irrigation and potassium fertilizer on number of tillers hill^{-1} at different days after sowing (DAS) of wheat

Treatments	Number of tillers hill^{-1}			
	30 DAS	45 DAS	60 DAS	75 DAS
I_0K_0	2.00 f	3.03 e	3.33 e	4.13 e
I_0K_1	2.40 b-d	3.90 a-c	4.20 d	5.03 c
I_0K_2	2.53 a-c	3.73 c	4.07 d	4.93 c
I_1K_0	2.10 ef	3.17 de	3.87 d	4.40 de
I_1K_1	2.23 de	3.77 bc	4.87 c	5.57 b
I_1K_2	2.60 ab	3.90 a-c	5.60 ab	5.90 ab
I_2K_0	2.10 ef	3.13 de	4.03 d	4.27 de
I_2K_1	2.33 cd	3.73 c	4.97 c	5.73 b
I_2K_2	2.50 a-c	3.93 ab	5.23 bc	5.60 b
I_3K_0	2.10 ef	3.27 d	4.30 d	4.53 d
I_3K_1	2.40 b-d	3.80 bc	5.80 a	5.90 ab
I_3K_2	2.67 a	4.07 a	6.00 a	6.17 a
$LSD_{(0.05)}$	0.190	0.173	0.490	0.324
Level of significance	0.01	0.01	0.05	0.01
CV(%)	4.66	5.74	6.04	3.60

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Table 4. Effect of irrigation and potassium fertilizer on phenology and yield contributing characters of wheat

Treatments	Days required from sowing to flowering	Days required from sowing to maturity	Number of spikes hill^{-1}	Number of spikelets spike^{-1}
I_0	69.00 a	121.56 a	3.14 b	13.63 b
I_1	66.78 b	118.89 ab	3.99 a	16.70 a
I_2	68.00 ab	118.22 ab	3.98 a	16.30 a
I_3	63.89 c	115.33 b	4.17 a	17.80 a
$LSD_{(0.05)}$	1.605	3.916	0.203	2.238
Level of significance	0.01	0.05	0.01	0.05
K_0	68.67 a	120.00 a	3.37 b	13.72 b
K_1	65.33 b	117.33 b	4.01 a	16.76 a
K_2	66.75 b	118.17 ab	4.08 a	17.85 a
$LSD_{(0.05)}$	1.697	1.861	0.169	1.237
Level of significance	0.01	0.05	0.01	0.01
CV(%)	6.34	5.93	4.81	5.10

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on days required from sowing to flowering (Table 5). The maximum days required from sowing to flowering (75.00) were observed from I_0K_0 and the minimum days required from sowing to flowering (59.00) was recorded from I_3K_0.

4.2.2. Days required from sowing to maturity

Different levels of irrigation showed statistically significant variation in terms of days required from sowing to maturity of wheat (Table 4). The maximum days required from sowing to maturity (121.56) was observed from I_0 which was statistically similar (118.89 and 118.22) with I_1 and I_2, whereas the minimum days required from sowing to maturity (115.33) was observed from I_3.

Days required from sowing to maturity varied significantly terms of wheat due to different levels of potassium fertilizer (Table 4). The maximum days required from sowing to maturity (120.00) were observed from K_0 treatment, which was statistically similar (118.17) with K_2, again the minimum days required from sowing to maturity (117.33) was observed in K_1.

Different levels of irrigation and potassium fertilizer showed significant differences on days required from sowing to maturity due to Interaction effect (Table 5). The maximum days required from sowing to maturity (125.33) were observed from I_0K_0, whereas the minimum days required from sowing to maturity (114.67) was recorded from I_3K_0.

4.2.3. Number of spikes hill^{-1}

There was a significant variation in terms f number of spikes hill^{-1} of wheat due to different levels of irrigation (Table 4). The maximum number of spikes hill^{-1} (4.17) was observed from I_3 which was statistically similar (3.99 and 3.98) with I_1 and I_2, while the minimum number of spikes hill^{-1} (3.14) was observed from I_0.

Table 5. Interaction effect of irrigation and potassium fertilizer on phenology and yield contributing characters of wheat

Treatments	Days required from sowing to flowering	Days required from sowing to maturity	Number of spikes $hill^{-1}$	Number of spikelets $spike^{-1}$
I_0K_0	75.00 a	125.33 a	3.00 d	13.47 de
I_0K_1	67.00 bc	120.00 b	3.17 d	15.53 cd
I_0K_2	65.00 c	119.33 bc	3.27 cd	11.90 e
I_1K_0	66.33 bc	119.33 bc	3.60 c	14.40 c-e
I_1K_1	68.67 bc	118.33 b-d	4.10 b	15.80 cd
I_1K_2	65.33 c	119.00 bc	4.27 ab	19.90 a
I_2K_0	74.33 a	120.67 b	3.30 cd	13.20 de
I_2K_1	60.33 d	115.33 cd	4.33 ab	16.70 bc
I_2K_2	69.33 b	118.67 b-d	4.30 ab	19.00 ab
I_3K_0	59.00 d	114.67 d	3.57 c	13.80 de
I_3K_1	65.33 c	115.67 cd	4.43 ab	19.00 ab
I_3K_2	67.33 bc	115.67 cd	4.50 a	20.60 a
$LSD_{(0.05)}$	3.395	3.722	0.337	2.475
Level of significance	0.01	0.05	0.05	0.01
CV(%)	6.34	5.93	4.81	5.10

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Statistically significant variation was observed in terms of number of spikes hill^{-1} of wheat due to different levels of potassium fertilizer (Table 4). The maximum number of spikes hill^{-1} (4.08) was observed from K_3 treatment, which was statistically similar (4.01) with K_1, while the minimum number of spikes hill^{-1} (3.37) was observed in K_0.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on number of spikes hill^{-1} (Table 5). The maximum number of spikes hill^{-1} (4.50) were observed from I_3K_2, while the minimum number of spikes hill^{-1} (3.00) was recorded from I_0K_0.

4.2.4. Number of spikelets spike^{-1}

Number of spikelets spike^{-1} of wheat showed statistically significant variation due to different levels of irrigation (Table 4). The maximum number of spikelets spike^{-1} (17.80) was observed from I_3 which was statistically similar (16.70 and 16.30) with I_1 and I_2, whereas the minimum number of spikelets spike^{-1} (13.63) was observed from I_0. Naser (1996) reported that the highest number of grains per spike were recorded when two irrigations were applied.

There was a statistically significant variation was observed in terms of number of spikelets spike^{-1} of wheat due to different levels of potassium fertilizer (Table 4). The maximum number of spikelets spike^{-1} (17.85) was observed from K_3 treatment, which was statistically similar (16.76) with K_1, again the minimum number of spikelets spike^{-1} (13.72) was observed in K_0.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on number of spikelets spike^{-1} (Table 5). The maximum number of spikelets spike^{-1} (20.60) was observed from I_3K_2, whereas the minimum number of spikelets spike^{-1} (11.90) was recorded from I_0K_2.

4.2.5. Spike length

Spike length of wheat showed statistically significant variation due to different levels of irrigation (Table 6). The longest spike (18.19 cm) was observed from I_3 which was statistically similar (17.74 cm and 17.60 cm) with I_1 and I_2, while the shortest spike (15.90) was observed from I_0. Naser (1996) reported the highest spike length when two irrigations were applied.

Statistically significant variation was recorded in terms of spike length of wheat due to different levels of potassium fertilizer (Table 6). The longest spike (18.63 cm) was observed from K_3 treatment, which was statistically similar (18.41 cm) with K_1, while the shortest spike (15.03 cm) was observed in K_0. Saren and Jana (2008) found that application of 50 kg K/ha as top dressing after irrigation gave the highest length of spike.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on spike length (Table 7). The longest spike (19.60 cm) were found from I_3K_2, while the shortest spike (13.80 cm) from I_0K_0.

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

Number of filled grains spike^{-1} of wheat showed statistically significant variation due to different levels of irrigation (Table 6). The maximum number of filled grains spike^{-1} (31.17) was observed from I_3 which was statistically similar (29.44) with I_1 and closely followed (28.87) by I_2, whereas the minimum number (26.22) 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.

Statistically significant variation was observed in terms of number of filled grains spike^{-1} of wheat due to different levels of potassium fertilizer (Table 6). The maximum number of filled grains spike^{-1} (31.54) was observed from K_3 treatment, which was statistically similar (30.83) with K_1, while the minimum number of filled grains spike^{-1} (24.33) was found in K_0.

Table 6. Effect of irrigation and potassium fertilizer on yield contributing characters of wheat

Treatments	Spike length (cm)	Filled grains spike^{-1}	Unfilled grains spike^{-1}	Weight of 1000 grains (g)
I_0	15.90 b	26.22 c	3.62 a	39.51 b
I_1	17.74 a	29.44 ab	2.94 b	42.67 a
I_2	17.60 a	28.78 b	2.61 c	42.05 ab
I_3	18.19 a	31.17 a	1.99 d	44.46 a
$LSD_{(0.05)}$	0.762	2.179	0.271	2.699
Level of significance	0.01	0.01	0.01	0.05
K_0	15.03 b	24.33 b	3.22 a	40.40 b
K_1	18.41 a	30.83 a	2.70 b	42.72 a
K_2	18.63 a	31.54 a	2.45 c	43.41 a
$LSD_{(0.05)}$	0.383	1.671	0.184	1.673
Level of significance	0.01	0.01	0.01	0.01
CV(%)	8.88	4.55	6.68	6.31

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on number of filled grains spike^{-1} (Table 7). The maximum number of filled grains spike^{-1} (34.83) was observed from I_3K_2 and the minimum number of filled grains spike^{-1} (23.33) was recorded from I_2K_0.

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

Number of unfilled grains spike^{-1} of wheat showed statistically significant variation due to different levels of irrigation (Table 6). The maximum number of unfilled grains spike^{-1} (3.62) was observed from I_0 which was closely followed (2.94) with I_1, while the minimum number of unfilled grains spike^{-1} (1.99) was observed from I_3 which was closely followed (2.61) by I_2.

Statistically significant variation was observed in terms of number of unfilled grains spike^{-1} of wheat due to different levels of potassium fertilizer (Table 6). The maximum number of unfilled grains spike^{-1} (3.22) was observed from K_0 treatment, which was followed (2.70) by K_1, while the minimum number of unfilled grains spike^{-1} (2.45) was found in K_3.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on number of unfilled grains spike^{-1} (Table 7). The maximum number of unfilled grains spike^{-1} (4.03) was observed from I_0K_1, while the minimum number of unfilled grains spike^{-1} (1.50) was recorded from I_3K_2.

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 (Figure 5). The maximum number of total grains spike^{-1} (33.16) was observed from I_3 which was statistically similar (32.39 and 31.39) with I_1 and I_2, while the minimum number of total grains spike^{-1} (29.84) was observed from I_0. Islam (1996) observed that irrigation had no influence of grains per spike.

Table 7. Interaction effect of irrigation and potassium fertilizer on yield contributing characters of wheat

Treatments	Spike length (cm)	Filled grains spike^{-1}	Unfilled grains spike^{-1}	Weight of 1000 grains (g)
I_0K_0	13.80 f	24.33 e	3.07 c	37.33 f
I_0K_1	16.77 c	28.83 cd	4.03 a	40.70 c-f
I_0K_2	17.13 c	25.50 de	3.77 ab	40.52 d-f
I_1K_0	15.97 d	25.33 de	3.60 b	44.65 b
I_1K_1	18.43 b	29.33 c	2.83 c	41.66 b-e
I_1K_2	18.83 ab	33.67 ab	2.40 de	41.70 b-e
I_2K_0	14.80 e	23.33 e	3.53 b	38.48 ef
I_2K_1	19.03 ab	30.83 bc	2.17 e	44.44 bc
I_2K_2	18.97 ab	32.17 a-c	2.13 e	43.23 b-d
I_3K_0	15.57 d	24.33 e	2.70 cd	41.14 b-e
I_3K_1	19.40 a	34.33 ab	1.77 f	44.05 b-d
I_3K_2	19.60 a	34.83 a	1.50 f	48.19 a
$LSD_{(0.05)}$	0.766	3.342	0.367	3.345
Level of significance	0.05	0.01	0.01	0.01
CV(%)	8.88	4.55	6.68	6.31

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)

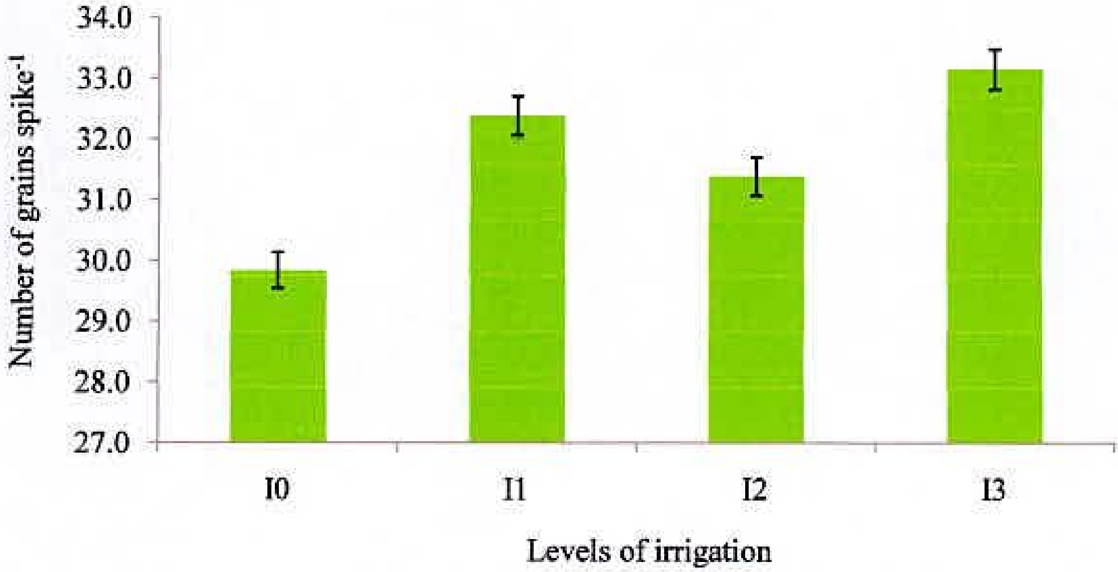
I_2: Irrigation at 55 DAS (flowering stage)

I_3: Irrigation at 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

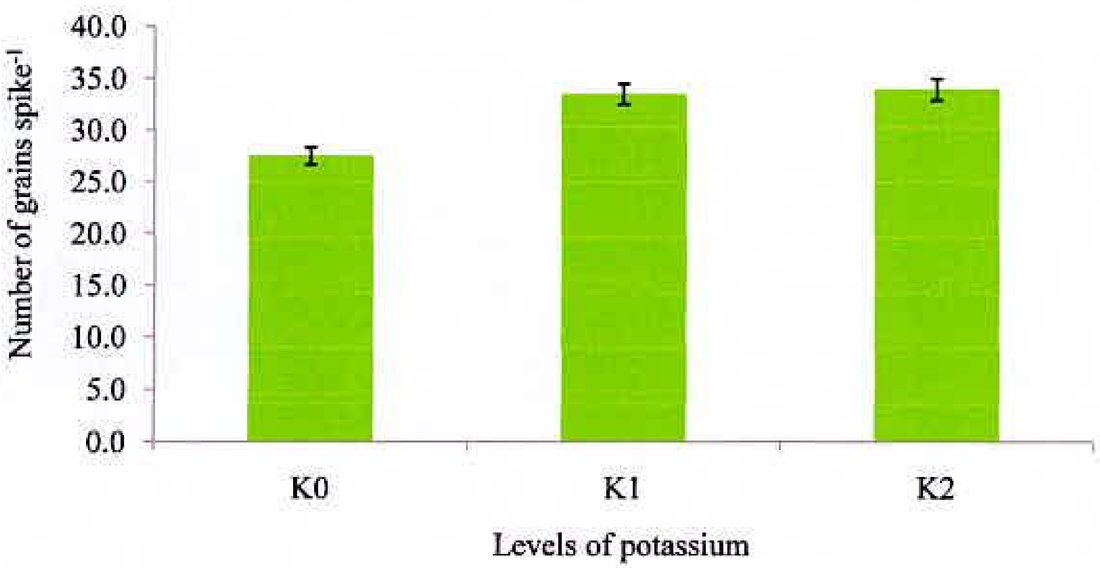
K_2: 100 kg MOP ha^{-1}



I_0: No irrigation i.e. control I_1: Irrigation at 20 DAS

I_2: Irrigation at 55 DAS I_3.: Irrigation at 20, 55 and 75 DAS

Figure 5. Effect of irrigation on number of grains spike^{-1} of wheat. Vertical bars reporesnt LSD value.



K_0: 0 kg MOP ha^{-1} K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Figure 6. Effect of different levels of potassium on number of grains spike^{-1} of wheat. Vertical bars reporesnt LSD value.

Statistically significant variation was observed in terms of number of total grains spike^{-1} of wheat due to different levels of potassium fertilizer (Figure 6). The maximum number of total grains spike^{-1} (33.99) was observed from K_3 treatment, which was statistically similar (33.53) with K_1, while the minimum number of total grains spike^{-1} (27.56) was found in K_0.

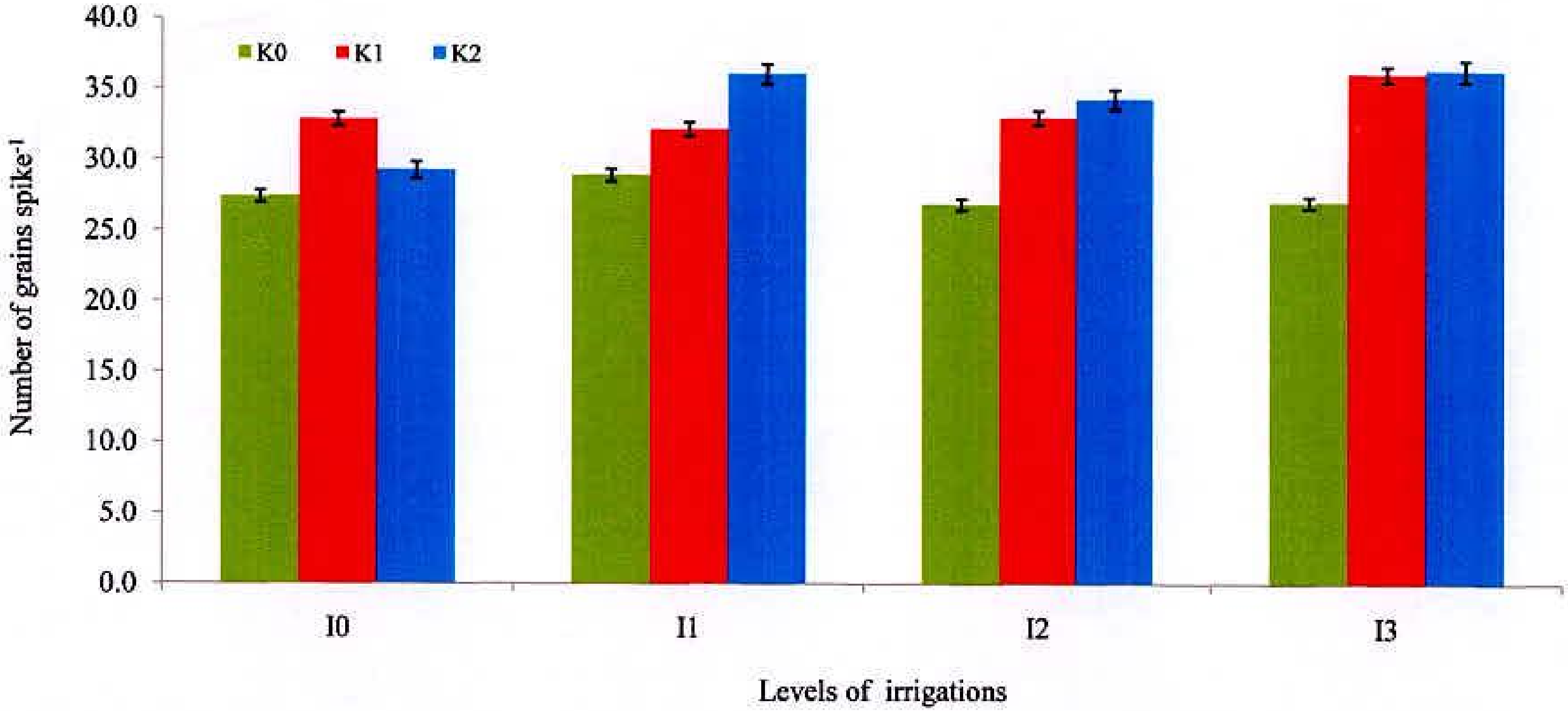
There was s significant variation due to the interaction effect of different levels of irrigation and potassium fertilizer in terms of number of total grains spike^{-1} (Figure 7). The maximum number of total grains spike^{-1} (36.33) was observed from I_3K_2, while the minimum number of total grains spike^{-1} (27.40) was recorded from I_0K_0.

4.2.9. Weight of 1000 grains

Weight of 1000 grains of wheat showed statistically significant variation due to different levels of irrigation (Table 6). The highest weight of 1000 grains (44.46 g) was observed from I_3 which was statistically similar (42.67 g and 42.05 g) with I_1 and I_2, while the lowest weight of 1000 grains (39.51 g) was observed from I_0. Islam (1996) observed that irrigation had no influence of 1000-grain weight.

Statistically significant variation was observed in terms of weight of 1000 grains of wheat due to different levels of potassium fertilizer (Table 6). The highest weight of 1000 grains (43.41 g) was observed from K_3 treatment, which was statistically similar (42.72 g) with K_1, whereas the lowest weight of 1000 grains (40.40 g) was found in K_0.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on weight of 1000 grains (Table 7). The highest weight of 1000 grains (48.19 g) was observed from I_3K_2, again the lowest weight of 1000 grains (37.33 g) was recorded from I_0K_0.



I_0: No irrigation i.e. control I_1: Irrigation at 20 DAS K_0: 0 kg MOP ha^{-1} K_1: 50 kg MOP ha^{-1}

I_2: Irrigation at 55 DAS I_{3}.: Irrigation at 20, 55 and 75 DAS K_2: 100 kg MOP ha^{-1}

Figure 7. Interaction effect of irrigation and levels of potassium on number of grains spike^{-1}. Vertical bars reporesnt LSD value.

4.3. Yield

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

There was statistically significant variation in terms of grain yield of wheat showed due to different levels of irrigation (Table 8). The highest grain yield (3.28 t ha^{-1}) was observed from I_3 which was statistically similar (3.17 t ha^{-1} and 3.08 t ha^{-1}) with I_1 and I_2, while the lowest grain yield (2.23 t ha^{-1}) was observed from I_0. 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.

Different levels of potassium fertilizer showed statistically significant variation in terms of grain yield of wheat due to (Table 8). The highest grain yield (3.25 t ha^{-1}) was observed from K_3 treatment, which was statistically similar (3.17 t ha^{-1}) with K_1, while the lowest grain yield (2.38 t ha^{-1}) was found in K_0. Potassium is reported to improve water relations as well as productivity of different crops under water stress condition (Johnson, 1983, Islam *et al.*, 2004). Saren and Jana (2008) found that application of 50 kg K/ha as top dressing after irrigation gave the highest grains yields.

Statistically significant variation was observed due to the interaction effect of different levels of irrigation and potassium fertilizer on grain yield (Table 8). The highest grain yield (3.79 t ha^{-1}) was observed from I_3K_2, while the lowest grain yield (2.04 t ha^{-1}) was recorded from I_0K_0.

Table 8. Effect of irrigation and potassium fertilizer on grain yield, straw yield, biological yield and harvest index of wheat

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0	2.23 b	3.87 b	6.10 c	36.53
I_1	3.17 a	5.24 a	8.41 b	37.95
I_2	3.08 a	5.35 a	8.42 b	36.33
I_3	3.28 a	5.45 a	8.72 a	37.22
$LSD_{(0.05)}$	0.250	0.271	0.283	NS
Level of significance	0.01	0.01	0.01	--
K_0	2.38 b	4.14 b	6.53 b	36.40 b
K_1	3.17 a	5.34 a	8.51 a	37.22 a
K_2	3.25 a	5.45 a	8.70 a	37.39 a
$LSD_{(0.05)}$	0.186	0.175	0.232	0.819
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.58	7.27	4.08	5.38

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

Table 9. Interaction effect of irrigation and potassium fertilizer on grain yield, straw yield, biological yield and harvest index of wheat

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
I_0K_0	2.04 d	3.77 d	5.81 h	35.10 bc
I_0K_1	2.38 d	4.10 cd	6.48 fg	36.75 bc
I_0K_2	2.27 d	3.74 d	6.01 gh	37.74 a-c
I_1K_0	2.91 c	4.19 c	7.10 e	40.97 a
I_1K_1	3.27 bc	5.50 b	8.77 d	37.25 a-c
I_1K_2	3.33 b	6.02 a	9.35 bc	35.62 bc
I_2K_0	2.30 d	4.27 c	6.57 f	35.01 bc
I_2K_1	3.30 b	5.84 ab	9.14 cd	36.11 bc
I_2K_2	3.62 ab	5.94 a	9.57 a-c	37.86 a-c
I_3K_0	2.29 d	4.33 c	6.62 f	34.53 c
I_3K_1	3.75 a	5.92 a	9.67 ab	38.79 ab
I_3K_2	3.79 a	6.09 a	9.88 a	38.36 a-c
$LSD_{(0.05)}$	0.371	0.351	0.464	3.657
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.58	7.27	4.08	5.38

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 20, 55 and 75 DAS (grain filling stage)

K_0: 0 kg MOP ha^{-1}

K_1: 50 kg MOP ha^{-1}

K_2: 100 kg MOP ha^{-1}

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

Straw yield of wheat showed statistically significant variation due to different levels of irrigation (Table 8). The highest straw yield (5.45 t ha^{-1}) was observed from I_3 which was statistically similar (5.35 t ha^{-1} and 5.24 t ha^{-1}) with I_2 and I_1, whereas the lowest straw yield (3.87 t ha^{-1}) was observed from I_0.

Statistically significant variation was observed in terms of straw yield of wheat due to different levels of potassium fertilizer (Table 8). The highest straw yield (5.45 t ha^{-1}) was observed from K_3 treatment, which was statistically similar (5.34 t ha^{-1}) with K_1, again the lowest straw yield (4.14 t ha^{-1}) was found in K_0. Saren and Jana (2008) found that application of 50 kg K/ha as top dressing after irrigation gave the highest straw yields.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on straw yield (Table 8). The highest straw yield (6.09 t ha^{-1}) was observed from I_3K_2, while the lowest straw yield (3.77 t ha^{-1}) was recorded from I_0K_0.

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

Biological yield of wheat showed statistically significant variation due to different levels of irrigation (Table 8). The highest biological yield (8.72 t ha^{-1}) was observed from I_3 which was followed (8.42 t ha^{-1} and 8.41 t ha^{-1}) with I_2 and I_1, while the lowest biological yield (6.10 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 observed in terms of biological yield of wheat due to different levels of potassium fertilizer (Table 8). The highest biological yield (8.70 t ha^{-1}) was observed from K_3 treatment, which was statistically similar (8.51 t ha^{-1}) with K_1, while the lowest biological yield (6.53 t ha^{-1}) was found in K_0.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on biological yield (Table 8). The highest biological yield (9.88 t ha^{-1}) was observed from I_3K_2, while the lowest biological yield (5.81 t ha^{-1}) was recorded from I_0K_0.

4.3.4. Harvest index (%)

Harvest index of wheat showed statistically non-significant variation due to different levels of irrigation (Table 8). The highest harvest index (37.95%) was observed from I_1, whereas the lowest harvest index (36.33%) was found from I_2. Gupta *et al.* (2001) reported that harvest index decreased to a greater extent when water stress was imposed at the anthesis stage.

Statistically significant variation was observed in terms of harvest index of wheat due to different levels of potassium fertilizer (Table 8). The highest harvest index (37.39%) was observed from K_3 treatment, which was statistically similar (37.22%) with K_1, while the lowest harvest index (36.40%) was found in K_0.

Interaction effect of different levels of irrigation and potassium fertilizer showed significant differences on harvest index (Table 8). The highest harvest index (40.97%) was observed from I_1K_0, while the lowest harvest index (34.53%) was recorded from I_3K_0.

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during from November 2012 to March 2013 to find out the yield response of wheat as affected by irrigation and potassium fertilizer. BARI Gom-24 was used as a test crop of this study. The experiment comprised of 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 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage) and Factor B: Level of potassium fertilizer (3 levels)- K_0: 0 kg MOP ha^{-1}, K_1: 50 kg MOP ha^{-1} and K_2: 100 kg MOP ha^{-1}. The experiment was laid out in Split Plot Design with three replications. Data on growth, yield contributing characters and yield was recorded and variation was observed for different treatment.

In case of different levels of irrigation at 30, 45, 60, 75 DAS and at harvest, the tallest plant was recorded from I_3, while the shortest plant was observed from I_0. In case of different levels of irrigation at 30, 45, 60, 75 DAS and at harvest, the maximum number of tillers hill^{-1} was recorded from I_3, while the shortest plant was observed from I_0. The maximum days required from sowing to flowering (69.00) was observed from I_0, while the minimum days required from sowing to flowering (63.89) was observed from I_0. The maximum days required from sowing to maturity (121.56) was observed from I_0, whereas the minimum days required from sowing to maturity (115.33) was observed from I_3. The maximum number of spikes hill^{-1} (4.17) was observed from I_3, while the minimum number of spikes hill^{-1} (3.14) was observed from I_0. The maximum number of spikelets spike^{-1} (17.80) was observed from I_3, whereas the minimum number of spikelets spike^{-1} (13.63) was observed from I_0. The longest spike (18.19 cm) was observed from I_3, while the shortest spike (15.90) was observed from I_0. The maximum number of filled grains spike^{-1} (31.17) was observed from I_3, whereas the minimum number (26.22) was observed from I_0. The maximum number of unfilled grains spike^{-1} (3.62) was observed from I_0, while the minimum number of unfilled grains spike^{-1} (1.99) was observed from I_3. The maximum number of total grains spike^{-1} (33.16) was observed from I_3, while the minimum number of total grains spike^{-1} (29.84) was observed from I_0. The highest weight of 1000 grains (44.46 g) was observed from I_3, while the lowest weight of 1000 grains (39.51 g) was observed from I_0. The highest grain yield (3.28 t ha^{-1}) was observed from I_3, while the lowest grain yield (2.23 t ha^{-1}) was observed from I_0. The highest straw yield (5.45 t ha^{-1}) was observed from I_3, whereas the lowest straw yield (3.87 t ha^{-1}) was observed from I_0. The highest biological yield (8.72 t ha^{-1}) was observed from I_3, while the lowest biological yield (6.10 t ha^{-1}) was observed from I_0. The highest harvest index (37.95%) was observed from I_1, whereas the lowest harvest index (36.33%) was found from I_2.

For different levels of potassium fertilizer, at 30, 45, 60, 75 DAS and harvest, the tallest plant (21.92, 44.57, 67.16, 79.38 and 82.98 cm, respectively) were observed from K_2, while the shortest plant (17.88, 39.22, 61.07, 69.49 and 72.47 cm) was observed in K_0. At 30, 45, 60 and 75 DAS, the maximum number of tillers hill^{-1} (2.58, 3.91, 5.22 and 5.65, respectively) were observed from K_2 treatment, while the minimum number (2.08, 3.15, 3.88 and 4.33, respectively) was observed in K_0. The maximum days required from sowing to flowering (68.67) were observed from K_0 treatment, whereas the minimum days required from sowing to flowering (65.33) was observed in K_1. The maximum days required from sowing to maturity (120.00) were observed from K_0 treatment, again the minimum days required from sowing to maturity (117.33) was observed in K_1. The maximum number of spikes hill^{-1} (4.08) was observed from K_3 treatment, while the minimum number of spikes hill^{-1} (3.37) was observed in K_0. The maximum number of spikelets spike^{-1} (17.85) was observed from K_3 treatment, again the minimum number of spikelets spike^{-1} (13.72) was observed in K_0. The longest spike (18.63 cm) was observed from K_3 treatment, while the shortest spike (15.03 cm) was observed in K_0. The maximum number of filled grains spike^{-1} (31.54) was observed from K_3 treatment, while the minimum number of filled grains spike^{-1} (24.33) was found in K_0. The maximum number of unfilled grains spike^{-1} (3.22) was observed from K_0 treatment, while the minimum number of unfilled grains spike^{-1} (2.45) was found in K_3. The maximum number of total grains spike^{-1} (33.99) was observed from K_3 treatment, while the minimum number of total grains spike^{-1} (27.56) was found in K_0. The highest weight of 1000 grains (43.41 g) was observed from K_3 treatment, whereas the lowest weight of 1000 grains (40.40 g) was found in K_0. The highest grain yield (3.25 t ha^{-1}) was observed from K_3 treatment, while the lowest grain yield (2.38 t ha^{-1}) was found in K_0. The highest straw yield (5.45 t ha^{-1}) was observed from K_3 treatment, again the lowest straw yield (4.14 t ha^{-1}) was found in K_0. The highest biological yield (8.70 t ha^{-1}) was observed from K_3 treatment, while the lowest biological yield (6.53 t ha^{-1}) was found in K_0. The highest harvest index (37.39%) was observed from K_3 treatment, while the lowest harvest index (36.40%) was found in K_0.

Due to the interaction effect of different levels of irrigation and potassium fertilizer, at 30, 45, 60, 75 DAS and at harvest, the tallest plants (22.82, 46.04, 72.64, 86.14 and 93.58 cm, respectively) were observed from I_3K_2, while the shortest plants as 15.04, 35.46, 60.95, 68.14 and 69.11 cm respectively were recorded from I_0K_0. At 30, 45, 60 and 75 DAS, the maximum number of tillers hill^{-1} (2.67, 4.07, 6.00 and 6.17, respectively) were observed from I_3K_2, while the shortest corresponding number of tillers hill^{-1} as 2.00, 3.03, 3.33 and 4.13, respectively were recorded from I_0K_0. The maximum days required from sowing to flowering (75.00) were observed from I_0K_0 and the minimum days required from sowing to flowering (59.00) was recorded from I_3K_0. The maximum days required from sowing to maturity (125.33) were observed from I_0K_0, whereas the minimum days required from sowing to maturity (114.67) was recorded from I_3K_0. The maximum number of spikes hill^{-1} (4.50) were observed from I_3K_2, while the minimum number of spikes hill^{-1} (3.00) was recorded from I_0K_0. The maximum number of spikelets spike^{-1} (20.60) was observed from I_3K_2, whereas the minimum number of spikelets spike^{-1} (11.90) was recorded from I_0K_2. The longest spike (19.60 cm) were observed from I_3K_2, while the shortest spike (13.80 cm) was recorded from I_0K_0. The maximum number of filled grains spike^{-1} (34.83) was observed from I_3K_2 and the minimum number of filled grains spike^{-1} (23.33) was recorded from I_2K_0. The maximum number of unfilled grains spike^{-1} (4.03) was observed from I_0K_1, while the minimum number of unfilled grains spike^{-1} (1.50) was recorded from I_3K_2. The maximum number of total grains spike^{-1} (36.33) was observed from I_3K_2, while the minimum number of total grains spike^{-1} (27.40) was recorded from I_0K_0. The highest weight of 1000 grains (48.19 g) was observed from I_3K_2, again the lowest weight of 1000 grains (37.33 g) was recorded from I_0K_0. The highest grain yield (3.79 t ha^{-1}) was observed from I_3K_2, while the lowest grain yield (2.04 t ha^{-1}) was recorded from I_0K_0. The highest straw yield (6.09 t ha^{-1}) was observed from I_3K_2, while the lowest straw yield (3.77 t ha^{-1}) was recorded from I_0K_0. The highest biological yield (9.88 t ha^{-1}) was observed from I_3K_2, while the lowest biological yield (5.81 t ha^{-1}) was recorded from I_0K_0. The highest harvest index (40.97%) was observed from I_1K_0, while the lowest harvest index (34.53%) was recorded from I_3K_0.

Conclusion

From the findings it was found that Irrigation at 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage) and 100 kg MOP ha^{-1} gave the better performance in relation to growth and yield of wheat.

Considering the above results of this experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

2. More experiments may be carried out with other organic and inorganic nutrients and also other management practices.

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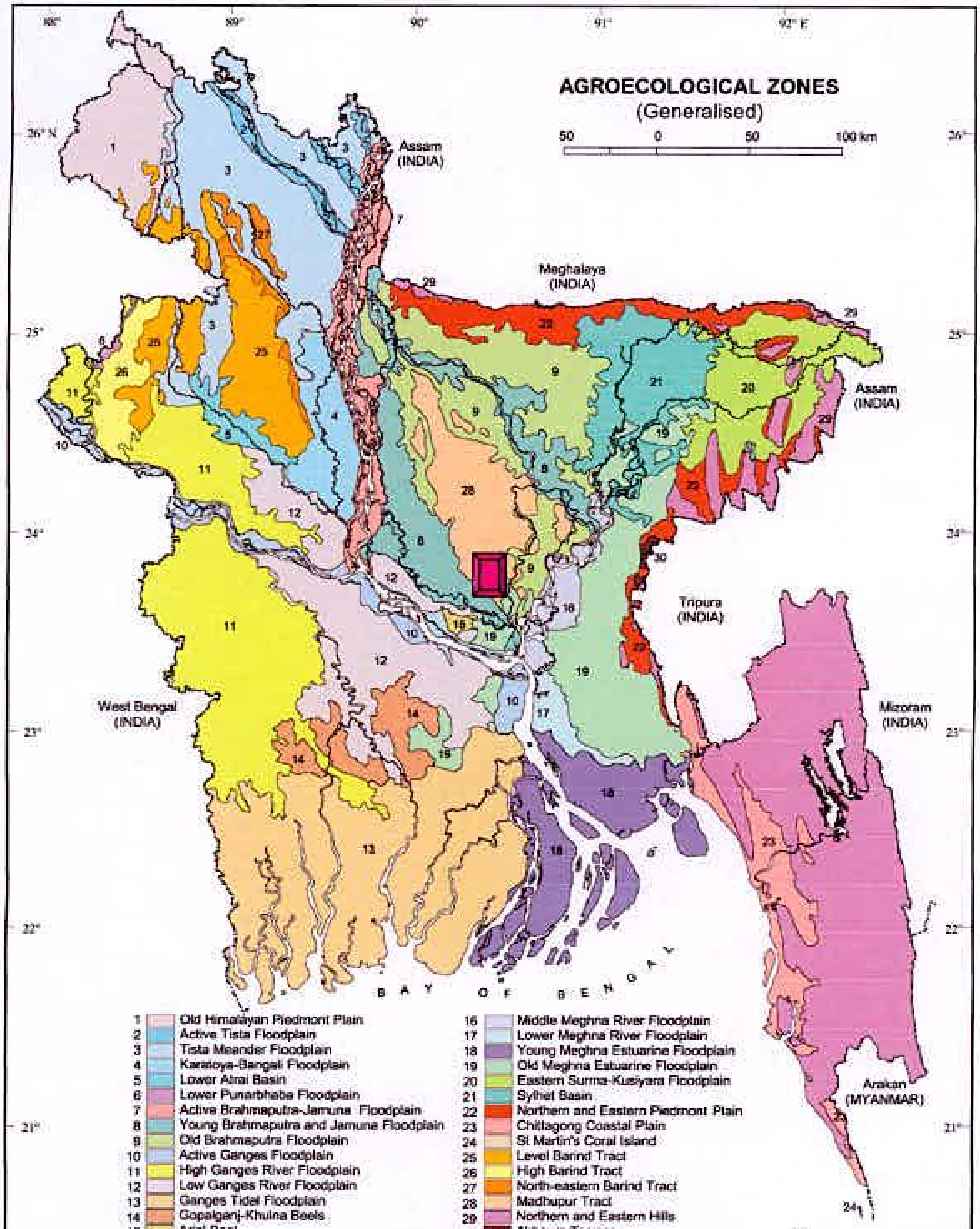
APPENDICES

Appendix I. Map showing the experimental site



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

Month	*Air temperature (°C)		*Relative humidity (%)	*Total rainfall (mm)
	Maximum	Minimum		
November, 2012	25.8	16.0	78	00
December, 2012	22.4	13.5	74	00
January, 2013	25.2	12.8	69	00
February, 2013	27.3	16.9	66	39
March, 2013	31.7	19.2	57	23

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix III. Characteristics of experimenatl field soil (the soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka)

A. Morphological characteristics of the experimental field

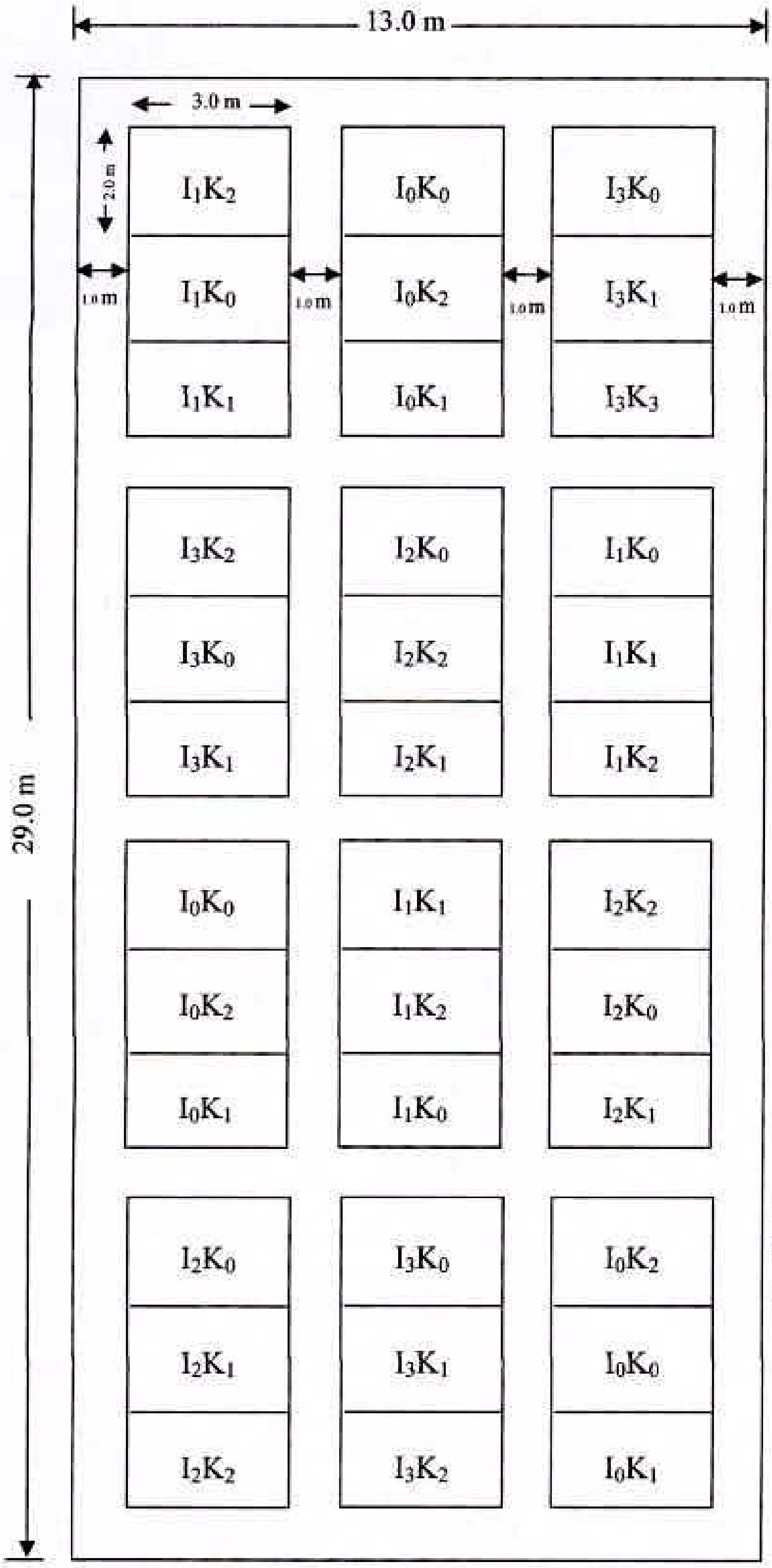
Morphological features	Characteristics
Location	Central Farm , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

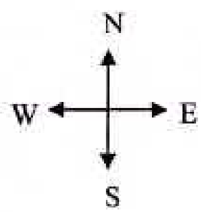
B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
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

Source: SRDI

Appendix IV. Layout of the experimental plot





Plot size: 3.0 m × 2.0 m

Plot spacing: 0.50 m

Between block: 1.00 m

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)

I_3: Irrigation at 20, 55 and 75 DAS (crown root initiation stage, flowering stage and grain filling stage)

Factor B: Level of potassium fertilizer (3 levels)

K_0: 0 kg K_2O ha^{-1}

K_1: 50 kg K_2O ha^{-1}

K_2: 100 kg K_2O ha^{-1}

Appendix V. Analysis of variance of the data on plant height of wheat as influenced by irrigation and potassium fertilizer

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	2	1.277	1.361	0.398	0.825	12.944
Irrigation (A)	3	0.453	0.178	64.289*	148.062**	490.738**
Error	6	3.321	4.757	9.456	7.652	25.373
Potassium fertilizer (B)	2	52.054**	94.343**	122.908**	313.369**	358.767**
Interaction (A×B)	6	12.399*	21.443**	32.469**	44.175**	93.476**
Error	16	4.092	5.780	8.946	10.257	19.560

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

Appendix VI. Analysis of variance of the data on number of tillers hill^{-1} of wheat as influenced by irrigation and potassium fertilizer

Source of variation	Degrees of freedom	Mean square			
		Number of tillers hill^{-1}			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.001	0.001	0.028	0.012
Irrigation (A)	3	0.013	0.014	3.439**	1.103**
Error	6	0.006	0.017	0.005	0.029
Potassium fertilizer (B)	2	0.751**	2.019**	6.054**	6.485**
Interaction (A×B)	6	0.015*	0.043**	0.217*	0.127**
Error	16	0.012	0.010	0.080	0.035

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

Appendix VII. Analysis of variance of the data on phenology and yield contributing charactersof wheat as influenced by irrigation and potassium fertilizer

Source of variation	Degrees of freedom	Mean square			
		Days required from sowing to flowering	Days required from sowing to maturity	Number of spikes $hill^{-1}$	Number of spikelets $spike^{-1}$
Replication	2	1.083	1.750	0.004	0.766
Irrigation (A)	3	44.102**	58.778*	1.890**	28.123**
Error	6	1.935	11.528	0.031	3.766
Potassium fertilizer (B)	2	33.583**	22.333*	1.862**	55.056**
Interaction (A×B)	6	88.991**	11.222*	0.134*	14.309**
Error	16	3.847	4.625	0.038	2.044

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

Appendix VIII. Analysis of variance of the data on yield contributing characters of wheat as influenced by irrigation and potassium fertilizer

Source of variation	Degrees of freedom	Mean square				
		Spike length (cm)	Filled grains $spike^{-1}$	Unfilled grains $spike^{-1}$	Total grains $spike^{-1}$	Weight of 1000 grains (g)
Replication	2	0.003	1.382	0.051	1.608	3.231
Irrigation (A)	3	9.072**	37.859**	4.171**	18.399*	37.716*
Error	6	0.436	3.567	0.055	4.163	5.474
Potassium fertilizer (B)	2	48.798**	189.424**	1.877**	154.597**	29.823**
Interaction (A×B)	6	0.532*	17.442**	1.028**	12.832*	19.092**
Error	16	0.196	3.729	0.045	4.004	3.735

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

Appendix IX. Analysis of variance of the data on yield contributing characters of wheat as influenced by irrigation and potassium fertilizer

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	0.027	0.004	0.022	2.103
Irrigation (A)	3	2.072**	4.946**	13.347**	4.852
Error	6	0.047	0.055	0.060	5.546
Potassium fertilizer (B)	2	2.768**	6.306**	17.430**	3.388*
Interaction (A×B)	6	0.365**	0.641**	1.618**	15.752**
Error	16	0.046	0.041	0.072	4.465

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

PLATES

Plate. 1 Field preparation

Plate:2 Maturity Stage Of Wheat

Plate:3 Harvesting Stage