GROWTH AND YIELD OF WHEAT AS INFLUENCED BY IRRIGATION LEVELS AND GIBBERELLIC ACID

SAMIDUL ISLAM

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2013

GROWTH AND YIELD OF WHEAT AS INFLUENCED BY IRRIGATION LEVELS AND GIBBERELLIC ACID

BY

SAMIDUL ISLAM

REG. NO. : 06-01882

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JANUARY-JUNE, 2013

APPROVED BY:

(Prof. Dr. Md. Shahidul Islam)
Supervisor

(**Prof. Md. Sadrul Anam Sardar)**
Co-Supervisor

(Prof. Dr. A.K.M. Ruhul Amin)
Chairman
Examination Committee


DEDICATED
TO
MY BELOVED PARENTS

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"Growth and Yield of Wheat as Influenced by Irrigation Levels and Gibberellic Acid"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Samidul Islam**, Registration number: **06-01882** 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

(Prof. Dr. Md. Shahidul Islam)
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

ACKNOWLEDGEMENTS

All praises to Almightly and Kindfull trust on to "Omnipotent Allah" for His never-ending blessing, the author deems it a great pleasure to express his profound gratefulness to his respected parents, who entiled much hardship inspiring for prosecuting his studies, receiving proper education.

The author likes to express his deepest sense of gratitude to his respected supervisor Dr. Md. Shahidul Islam, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author also expresses his gratefulness to his respected Co-Supervisor Md. Sadrul Anam Sardar, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author expresses his sincere gratitude towards the sincerity of the Chairman, Dr. A.K.M. Ruhul Amin, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Agronomy, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses his sincere appreciation to his brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

GROWTH AND YIELD OF WHEAT AS INFLUENCED BY IRRIGATION LEVELS AND GIBBERELLIC ACID

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2011 to March 2012 to find out the growth and yield of wheat as influenced by irrigation levels and gibberellic acid. BARI Gom-21 (Shatabdi) 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 condition; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) & I_3: Irrigation at CRI and pre-flowering stage and Factor B: Gibberellic acid (3 levels)- G_0: No GA_3 i.e. control condition; G_1: 100 ppm GA_3 & G_2: 200 ppm GA_3. The experiment was laid out in Split Plot Design with three replications. In case of irrigation, at 50, 60, 70, 80 DAS and harvest, the tallest plant (48.26 cm, 61.63 cm, 76.21 cm, 84.69 cm and 92.36 cm) was recorded from I_3 and the shortest plant (42.82 cm, 50.63 cm, 63.25 cm, 70.88 cm and 78.10 cm) from I_0. The highest number of filled grain spike^{-1} (30.76) was recorded from I_3, whereas the lowest number (24.49) from I_0. The highest grain yield per hectare (3.93 ton) was recorded from I_3, while the lowest grain yield (2.95 ton) from I_0. The highest straw yield per hectare (4.88 ton) was recorded from I_3, again the lowest straw yield (3.83 ton) from I_0. For gibberellic acid, at 50, 60, 70, 80 DAS and harvest, the tallest plant (49.24cm, 59.99 cm, 74.40 cm, 83.23 cm and 89.85 cm) was observed from G_2, again the shortest plant (42.08 cm, 51.30 cm, 63.71 cm, 72.29 cm and 79.30 cm) from G_0. The highest number of filled grain spike^{-1} (30.43) was found from G_2, again the lowest number (26.08) from G_0. The highest grain yield per hectare (3.94 ton) was observed from G_2, whereas the lowest grain yield (3.13 ton) from G_0. The highest straw yield per hectare (4.60 ton) was recorded from G_2, whereas the lowest straw yield (4.20 ton) from G_0. Due to interaction effect of level of irrigation and gibberellic acid at 50, 60, 70, 80 DAS and harvest, the tallest plant (54.04 cm, 68.58 cm, 84.11 cm, 93.39 cm and 98.05 cm) was observed from I_3G_2, while the shortest (39.92 cm, 46.76 cm, 57.79 cm, 66.08 cm and 75.67 cm) was recorded from I_0G_2. The highest number of filled grain spike^{-1} (34.47) was recorded from I_3G_2, while the lowest (22.40) was found from I_0G_0. The highest grain yield per hectare (4.41 ton) was found from I_3G_2, again the lowest grain yield (2.85 ton) from I_0G_0. The highest straw yield per hectare (5.40 ton) was observed from I_2G_2, again the lowest straw yield (3.56 ton) from I_0G_2. Irrigation at CRI and pre-flowering stage and 200 ppm GA_3 performed superior in growth, yield contributing characters and yield of wheat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important protein containing cereal with high amount of carbohydrate and is a staple food for two third of the total world's population (Majumder, 1991). It is cultivated throughout the world and is grown under different environmental conditions ranging from humid to arid, subtropical to temperate zone (Saari, 1998). Dubin and Ginkel (1991) reported that the largest area of wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh, India and Nepal. In Bangladesh, wheat is the second most important cereal crop (FAO, 2007). 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). BARI (1997) reported that wheat supplies mainly carbohydrate (69.60%) and reasonable amount of protein (12%), fat (1.72%), and also minerals (16.20%).

In the environmental condition of Bangladesh, wheat is a well adapted cereal crop for its vegetative growth and development. Though the crop was introduced in Bangladesh during the period of former East Pakistan in 1967, its reputation increased after 1975. Now the popularity of wheat as staple food is increasing day by day in our country. Wheat cultivation has been increased manifolds to meet up the food shortage in the country. But, in spite of its importance, the yield of the crop in the context of our country is low (2.2 t ha^{-1}) in comparison to other countries of the world (FAO, 2007). 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 that of some developed countries like Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 tha^{-1}, respectively (FAO, 2009). At present about 706.33 thousand hectares of land in Bangladesh is covered by wheat with the annual production of 1,592 thousand tons (BBS, 2011).

Yield and quality of seeds of wheat are very low in Bangladesh. The low yield of wheat in Bangladesh however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors irrigation facilities with late planting of wheat is one of the major reasons 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, 2011).

Irrigation plays a vital role on proper 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). 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). 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 (Gao *et al.*, 2009).

Plant growth substances are another factor for growth and development of plant. PGRs comprise a large group of endogenous and exogenous chemical compounds that can regulate plant growth in numerous ways. It is exogenously applied chemical compounds that regulate stem elongation through inhibiting biosynthesis of gibberellins or releasing ethylene. PGRs have been and are still mainly used in modern, high input cereal management to shorten straw and thereby increase lodging resistance of wheat. There are indications that PGRs have potential to modify cereal yield formation and plant stand structure additional to stem elongation. The reduction in plant biomass due to higher PGRs may also have negative consequences for grain yield through reduced photosynthetic area and lower levels of stored reserves for re-translocation at grain filling time of wheat (Espindula *et al*., 2009). It plays an important role in flowering, grain filling, and ripening and also physiochemical changes during storage. Due to the diversified use of productive land, it is necessary to increase the food production, and gibberellic acid (GA_3) may be a contributor in achieving the desired goal. The plant growth regulator treatments significantly increased all physiological and yield characters (Meera and Poonam, 2010). Plant growth regulators (PGR) have potential to increase grain yield and may also alter grain protein levels of cereal crops especially wheat (Ma *et al*., 1994).

Information on the effect of irrigation and gibberellic acid in respect of growth and yield of our modern wheat varieties is inadequate. Considering the present situation, the present research work was carried out with the following objectives-

i. To find out the effect of irrigation levels on growth and yield of wheat.

ii. To observe the growth and yield performance of wheat due to the application of gibberellic acid;

iii. To investigate the interaction effect of irrigation and gibberellic acid on growth and yield of wheat.

CHAPTER II

REVIEW OF LITERATURE

Popularity of wheat as staple food is increasing day by day in our country and horizontal expansion of wheat area, wheat yield $unit^{-1}$ area should be increased to meet this ever-increasing demand of food but it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. Management practices have considerable effects on the growth and development of any crop particularly wheat. Among these, irrigation is a most important and common practices and growth regulator is a modern concept as a management practices and both are also important factors. Numerous studies have been performed evaluating the influence of irrigation and gibberellic acid & other growth regulators on the performance of wheat. Among the above factors some of the recent past information on irrigation and gibberellic acid & other growth regulators on wheat have been reviewed under the following headings:

2.1. Influence of irrigation on growth and yield of wheat

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 followed by irrigation at 1.2 IW/CPE ratio over the irrigation at 0.8 and 1.0 IW/CPE ratio whereas, least net returns (Rs 48,687.4/ha) and B:C ratio (1.34) was under 0.8 IW/CPE ratio.

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 plant height, spike length and spike grains, 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.

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 and yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T_2), while 1000-grain weight, germination count m^{-2} and number of tillers m^{-2} were not affected significantly. 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 and phosphorus use efficiency. Fertilizer P doses 0, 47, 81 and 111 kg P_2O_5 ha^{-1} were calculated by using adsorption isotherms and applied by broadcast and band placement. 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. Wheat grain yield increased from 1.58 Mg ha-1 to 3.94 Mg ha^{-1} with the use of P @ 81 kg P_2O_5 ha^{-1}. 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 and improve phosphorus use efficiency.

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.

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. 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. Consumptive use of water increased while water use efficiency gradually decreased with increase in number of irrigations.

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 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.

Excessive nitrogen (N) and high irrigation in local agricultural systems are raising concern owing to water quality and water quantity in the middle reach of the Heihe River basin. Consequently, a controlled study of irrigation and N was conducted by 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. A complete randomized block split-plot design was employed, with irrigation regimes [0.6, 0.8 and 1.0 estimated wheat evapotranspiration (ET)] and N fertilizer application rates [0, 140, 221, 300 kg/hm^2] as the main-plot and split-plot respectively. Under the experimental conditions, irrigation and N had relative low effects on plant height. 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 during spring wheat growth), accompanied by 221 kg N/hm^2 was the best management system for the relative high economic yield and high WUE in this region.

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

Two field experiments with winter wheat were made by Zhao *et al*. (2009) in Hebei, China and one in Baoding in 2006-2007 and the other in Gaocheng in 2007-2008. 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. In 2006-2007, 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.

The study was carried out by Mangan *et al*. (2008) to evaluate the performance of yield and yield components traits of wheat genotypes under water stress conditions. Four wheat varieties were screened under water stress conditions at Nuclear Institute of Agriculture (NIA) Tandojam. Different irrigation treatments (1, 2, 3 and 4) were applied during various crop growth stages. Grain yield and grain yield contributing traits of wheat varieties were significantly affected under water stress conditions. Except spike yield, Sarsabz had significantly more 1000-

grain weight, grain yield, main spike yield and grains spike^{-1} as compared to other varieties over all irrigation treatments; hence more tolerant to drought. Grain yield ranged between 373 kg ha^{-1} in single irrigation treatment to 3931 kg ha^{-1} in four irrigations, whereas 1000-grain weight ranged between 28.1-41.8 in four treatments.

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. Grain yield, total biomass, number of spike/m^2, harvest index and 1000-kernel weight decreased with increasing irrigation intervals. Water use efficiency was highest with irrigation at 20-day intervals. When a 20 and 30-day irrigation interval were applied, grain yield, number of spike/m^2, harvest index and water use efficiency were higher in cultivars C-75-14 and C-75-9.

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). Four wheat genotypes were grown under five different water stress treatments. 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 grain yield and yield components were statistically significant compared with non-stressed conditions. Grain yield under non-irrigated conditions was reduced by approximately 40%. Among the genotypes, MV-17 gave the highest grain yield.

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

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. Irrigation increased yield of wheat significantly than under control condition.

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 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. Among the yield attributes, number of leaves and number of tillers were positively correlated at the anthesis stage whereas leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

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.

Bazza *et al.* (1999) conducted two experiments in Morocco on wheat and sugar beet with irrigation management practices through water-deficit irrigation. In the case of wheat, high water deficit occurred during the early stages. Irrigation during these stages was the most beneficial for the crop. One water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations. Irrigation during the stage of grain filling caused the kernel weight to be as high as under three irrigations. The lowest value corresponded to the treatment with irrigation during grain filling and that under rainfed conditions.

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).

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.

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.

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.

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.

BARI (1993) reported that maximum grain and straw yields were recorded with three irrigation, applied at CRI, maximum tillering and grain filling stages of crop. 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.

Upadhyaya and Dubey (1991) conducted an experiment in India with three irrigation frequencies eg. 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. 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.

2.2. Influence of growth regulators on growth and yield of wheat

Bennett *et al*. (2012) conducted experiments to investigate the potential of the plant growth regulators (PGRs) Moddus and Cycocel, to increase yields in dryland wheat production systems of the southern Australian wheat belt. Crops were sprayed with varying rates and combinations of Moddus and/or Cycocel applied at three different growth stages, Z14, Z25 and Z31/32. The application of the PGRs was found to significantly decrease the hight of treated plants, especially when applied from the beginning of stem elongation Z25 through to Z31/32. Combining the analysis of yields of the two sites revealed that yields increased by up to 0.4 t/ha when high rates (600 ml/ha) of Moddus were applied. Significant increases in yield both sites were associated with increased ear bearing tillers and increased grain density.

A green house experiment was conducted by Akram *et al*. (2011) during three consecutive years at Ayub Agricultural Research Institute, Faisalabad (Pakistan) to find out the effect of drought stress on yield parameters of wheat. From the study it was reported that water deficit decreased grains per spike; 1000-grain weight, total biomass, grain yield and harvest index significantly while application of growth substances improved them. Pre-sowing seed soaking in ethephon solution produced the highest 1000-grain weight of 44.39 g, increased per hectare yield by 37 percent and harvest index by 8 percent in comparison with control. Biological yield was significantly decreased by shortage of moisture supply. While number of productive tillers per plant was decreased under moisture stress conditions by 6 percent, this was enhanced by application of growth substances. Growth substances application though was found not to be much beneficial under normal moisture supply, but under moisture stress economic returns were enhanced significantly. Thus, the maximum increase of 36 percent in net income was obtained from ethephon application under drought stress.

A field experiment was conducted by Meera and Poonam (2010) during the rabi season in Kanpur, Uttar Pradesh, India to evaluate the effects of Alar [daminozide] (100 and 200 ppm) and Cycocel [chlormequat] (1000 and 2000 ppm) on wheat cv. K 9107 subjected to different irrigation levels (5 irrigations and one irrigation). Observations on physiological characters (relative water content, photosynthesis, water potential, nitrate reductase activity and transpiration) were recorded at pre-anthesis (75 days after sowing) and post-anthesis (95 days after sowing). Observations on yield characters (number of grains per plant, grain weight per plant, 1000-grain weight, biological yield, grain yield and harvest index) were recorded at harvest. The plant growth regulator treatments significantly increased all physiological and yield characters in comparison to the untreated control. The highest yield was obtained when wheat was treated with 1000 ppm Cycocel under 5 irrigations. It appears that the internal water status of the plant has a significant contribution to its yield improvement.

Zekeriya (2009) conducted an experiment with the objective to evaluate, the effect of pre-sowing the plant growth regulators (kinetin and gibberellic acid) treatments on micro nutrients composition of young wheat and barley plants under saline conditions. Before sowing, the seeds were soaked in distilled water (Control, C) and in aqueous solutions containing growth regulators in predetermined concentrations (0.5 mM Kinetin (KIN) and 2.0 mM Gibberellic Acid (GA_3). The soaked seeds were sown in the soil containing four different levels of NaCl (0, 94, 164 and 240 mM NaCl). In wheat, iron and manganes content decreased as salinity levels increases. However, the highest values of Fe and Mn and Zn in wheat were obtained from 0 NaCl and treatment that had no hormone.

Field experiments were conducted by Matysiak (2006) in Winna Gora, Poland, to determine the effect of Sanisal A and Sanisal B (15 kg/ha) in increasing crop yields in winter cereals (wheat and triticale), spring cereals (wheat and barley), white mustard, lupin, pea and maize. An additional dose of liquid Sanisal (0.2 litre/ha) was applied to each treatment. An increase in the yield of cereals after Sanisal application was observed and spring cereals better responded to the growth regulator treatment. The smallest yield increase or even yield decrease after Sanisal treatment was observed in pod plants.

A pot experiment was conducted by Ahmad *et al*. (2004) to evaluate the effect of calcium carbide (a source of acetylene, the precursor of ethylene) on the nutrient uptake of wheat. Wheat cv. Inqalab-91 was sown in pots (12 kg soil per pot) at field capacity moisture and without or with half (60-45-30 kg/ha) or full (120-90-60 kg/ha) dose of N, P and K fertilizers. Half dose of N and full dose of P and K was applied at sowing while the remaining half dose was applied during the first irrigation. Calcium carbide at 60 kg/ha was applied one and 8 weeks after seed germination. Data were recorded on N, P and K uptake. N, P and K uptake by wheat grain and straw was significantly enhanced when CaC_2 was applied one week after seed germination.

Field trials were carried out in the Agricultural Experimental Farm in Winna Góra by Stachecki *et al*. (2004). The plant growth regulators were applied alone at normal rate and at a reduced rate with and without adjuvants. Two adjuvants were used: Adpros 85 SL, a methylated rapeseed oil and Break-Thru S-240, an organosilicone surfactant. Crop height, lodging, yield and quality of the harvested crop were assessed. Physicochemical properties of spray solution were measured. Adjuvants improved the biological activity of both, CCC and prohexadione-calcium, especially when reduced doses were applied. Efficacy of the plant growth regulators used at normal rate without adjuvant and at reduced rates with adjuvantswas similar. Break-Thru S-240 increased the efficacy of CCC and prohexadione calcium more compared to Adpros 85 SL measured in terms of reduction of plant height.

A pot experiment was carried out by Naseer *et al*. (2001) to examine the effect of foliar application of Indole-3-Acetic Acid (IAA, 25 mg L) on growth and yield of two lines of spring wheat, Kohistan-97 and Parwaz-94 under different levels (8, 12 and 16 dS m^{-1}) of NaCl salinity. The results revealed that all the growth and yield parameters such as plant height, root length, number of leaves $plant^{-1}$, flag leaf area, number of fertile tillers, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, 100-grain weight and grain yield $plant^{-1}$ decreased progressively with increasing salinity. Application of growth regulator either at the time of salinization or 15 days after salt treatment proved beneficial in alleviating the adverse effect of salinity on all these parameters compared to control (no growth regulator) but more pronounced effect was of the treatment of the growth regulator which was applied at the time of salinization.

A study investigated by McKee and Long (2001) to evaluate the role of two plant growth regulators in affecting wheat-yield responses to elevated [O_3]. In a controlled factorial experiment, wheat plants were treated with combinations of Ethephon, which releases ethene, Chlormequat, which blocks gibberellin synthesis, and elevated [O_3]. • Spring-wheat plants were subjected to lifelong exposures to ambient or moderately elevated [O_3]. At flag-leaf emergence, the plants were treated with Ethepon and/or Chlormequat, or untreated (controls). Gas-exchange measurements were made at anthesis; morphology, biomass, and yield components were recorded at harvest. • Elevated [O_3] accelerated development and decreased the number of grains per ear and ears per plant. Chlormequat abolished these O_3 effects, protecting against yield reduction though not biomass loss. Ethepon treatment partially protected against O_3-induced biomass loss though not yield reduction. • This study suggests that the effects of elevated [O_3] on development and allocation are more important in determining the yield response of wheat than the accompanying decline in photosynthesis and biomass accumulation.

A green-house experiment was conducted by Stahli *et al*. (1995) to compared the effects of two PGRs on flag leaf characteristics and yield of winter wheat. Chlormequat chloride + choline chloride (CCC) and chlormequat chloride + choline chloride + imazaquin (CCC+I) were applied to winter wheat at growth stage 5 (Feekes Large scale). CCC and CCC+I significantly increased flag leaf surface area at anthesis. Both treatments also enhanced chlorophyll content of the main stem flag leaf. The grain filling period was extended with PGR application by 2 days. CCC and CCC+I significantly increased net CO_2 assimilation rates during the flag leaf life. No effects of PGR spraying were observed on the pattern of ^{14}C labelled assimilate distribution. Increased grain yield was due to the increase in average grain weight. The results indicate that PGR treatments increased flag leaf contribution to grain filling. The addition of imazaquin (I) to chlormequat (CCC) improved the effects of CCC.

A 3 years field experiment with spring barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.) cultivars was conducted by Ma *et al*. (1994) to determine whether ethephon treatment increased protein concentration, protein yield, and grain yield. A greenhouse experiment was also conducted to evaluate the response of barley grain protein concentration to gradual addition of ethephon (2.2×10^{-3} mM) or chlormequat (5.8×10^{-3}mM) solution after anthesis. Under field conditions, ethephon treatment increased barley and wheat grain protein concentrations by as much as 16 % but decreased grain yield so that protein yield increases were small or did not occur. Greenhouse data showed that i) the gradient in grain size and protein concentration among spikelets of a spike, which is established before anthesis, was not affected by either chlormequat or ethephon; and ii) chlormequat increased grain protein by 7 to 11 % whereas ethephon increased protein concentration by up to 13 % in one of the two experiments. The greenhouse data confirmed that a portion of the increase in grain protein concentration due to PGR application is caused by increased protein accumulation in the barley grain.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2011 to March 2012 to study the growth and yield of wheat as influenced by irrigation levels and gibberellic acid. The details of the materials and methods i.e. the location of the experimental site, soil and climatic conditions of the experimental plot, materials used, design of the experiment, data collection procedure and 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.

3.1.2. Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February, 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 and rainfall during experimental period was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and presented in Appendix I.

3.1.3. Soil

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 matter 0.78%. 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 II.

3.2. Experimental details

The experiment comprised of two factors

Factors A: Irrigation (4 levels)

I_0: No irrigation i.e., control condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation at both CRI and pre-flowering stage

Factor B: Gibberellic acid (3 levels)

G_0: No GA_3 i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

There were in total 12 (4×3) treatment combinations such as I_0G_0, I_0G_1, I_0G_2, I_1G_0, I_1G_1, I_1G_2, I_2G_0, I_2G_1, I_2G_2, I_3G_0, I_3G_1 and I_3G_2.

3.2.2. Experimental design and layout

The experiment was laid out in Split-Plot Design with three replications. The irrigation levels were assigned in the main-plots and the gibberellic acid in the sub-plots.

3.3. Growing of crops

3.3.1. Seed collection

BARI Gom-21 (Shatabdi) was used as a test crop of this study. The seeds were collected from Agronomy Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka**.**

3.3.2. Preparation of the main field

The piece of land selected for the experiment was open in the last week of October 2011 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 stubbles were removed and finally a desirable tilth of soil was obtained for sowing seeds.

3.3.3. Seeds sowing

Furrows were made for sowing the wheat seeds when the land was in proper joe condition. On 4th November, 2011 seeds were sown continuous with maintaining 20 cm line to line distance and plant to plant 5 cm. After sowing, seeds were covered with soil and slightly pressed by hand.

3.3.4. Application of fertilizers and manure

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

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

Fertilizers	Dose (per ha)	Application (%)	
		Basal	1st installment
Urea	220 kg	66.66	33.33
TSP	180 kg	100	--
MP	50 kg	100	--
Gypsum	120 kg	100	--
Cowdung	10 ton	100	--

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

3.3.5. After care

After the germination of seeds, various intercultural operations such as irrigation and drainage, weeding, top dressing of urea and plant protection measures were accomplished for better growth and development of the wheat seedlings as per the recommendation of BARI (2006).

3.3.5.1. Irrigation and drainage

Irrigation was practiced as per treatment. 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 at tillering (30 DAS) and panicle initiation stage (45 DAS) manually.

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 5 January and sumithion 40 ml/20 litre of water was applied on 25 January as plant protection measure.

3.4. Harvesting, threshing and cleaning

The crop was harvested manually depending upon the maturity of plant from each plot starting from the third week of March, 2012. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of wheat grain. Fresh weight of wheat grain and straw were recorded plot wise from 1 m^2 area. The grains were cleaned and weighed. 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 50, 60, 70, 80 DAS (Days After Sowing) and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot that were tagged earlier. The height was measured from the ground level to the tip of the plant by a meter scale.

Dry matter content per plant

Data from five sample plants from each plot were collected and gently washed with tap water, thereafter soaked with paper towel. Then fresh weight was taken immediately after soaking by paper towel. After taking fresh weight, the sample was oven dried at 70^0C for 72 hours. Then oven-dried samples were transferred into a desiccator and allowed to cool down to room temperature, thereafter dry weight of plant was taken and expressed in gram. Dry matter content per plant was recorded at 50, 60, 70 and 80 DAS.

Estimated growth parameter

Using the data on dry matter, the following growth parameters were derived (Hunt, 1978):

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula:

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

Where,

GA = Ground area (m^2)

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

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

T_1 = Date of previous sampling

T_2 = Date of current sampling

Relative Growth Rate (RGR)

Relative growth rate was calculated using the following formula:

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

Where,

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

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

T_1 = Date of previous sampling

T_2 = Date of current sampling

Ln = Natural logarithm

3.5.2. Yield contributing Characters

Number of spike hill^{-1}

The total number of spike hill^{-1} was estimated by counting the number of spike from 5 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.

Ear length

The length of ear was measured with a meter scale from 5 selected ears 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 5 randomly selected spikes from each plot and average value was recorded.

Unfilled grains spike^{-1}

The total number of unfilled grains spike^{-1} was counted as the number of unfilled grains from 5 randomly selected spikes from each plot and average value was recorded.

Number of total grains spike^{-1}

The total number of grains spike^{-1} was counted by adding the number of filled and unfilled grains from 5 randomly selected spike from each plot and average value was recorded.

Weight of 1000-grain

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

3.5.3. Yields

Grain yield ha^{-1}

Grains obtained from 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 grains obtained from m^{-2} were converted into t ha^{-1}.

Straw yield ha^{-1}

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

Biological yield

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

$$\text{Biological yield} = \text{Grain yield} + \text{Straw yield}$$

Harvest index

The ratio of economic yield to biological yield is termed as harvest index (HI) and it usually expressed as percentage. Harvest index was calculated using the following formula-

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

3.6. Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the different levels of irrigation and gibberellic acid and 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

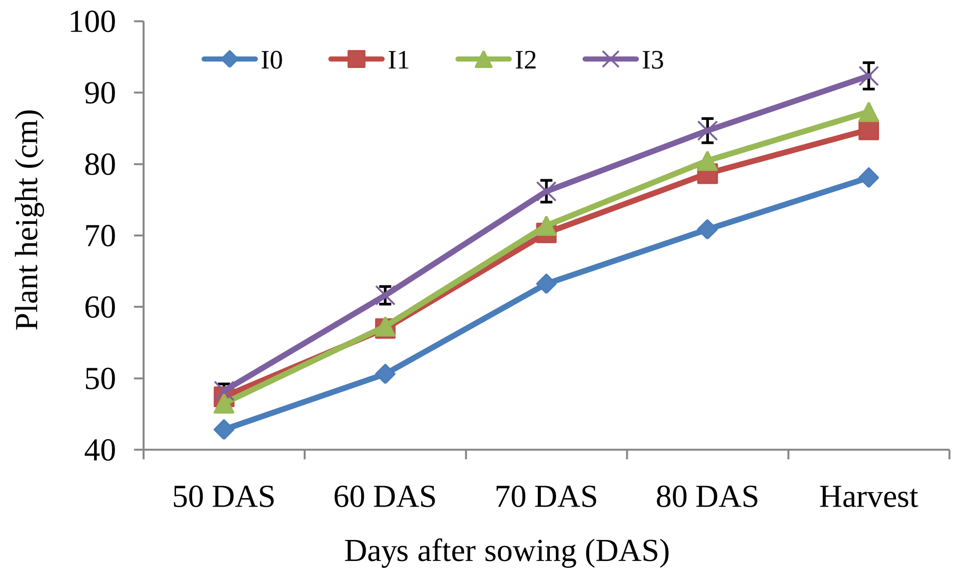
RESULTS AND DISCUSSION

The experiment was conducted to study the growth and yield of wheat as influenced by irrigation levels and gibberellic acid. Data on different growth and yield of wheat were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations have been given under the following headings:

4.1. Crop Growth Characters

4.1.1. Plant height

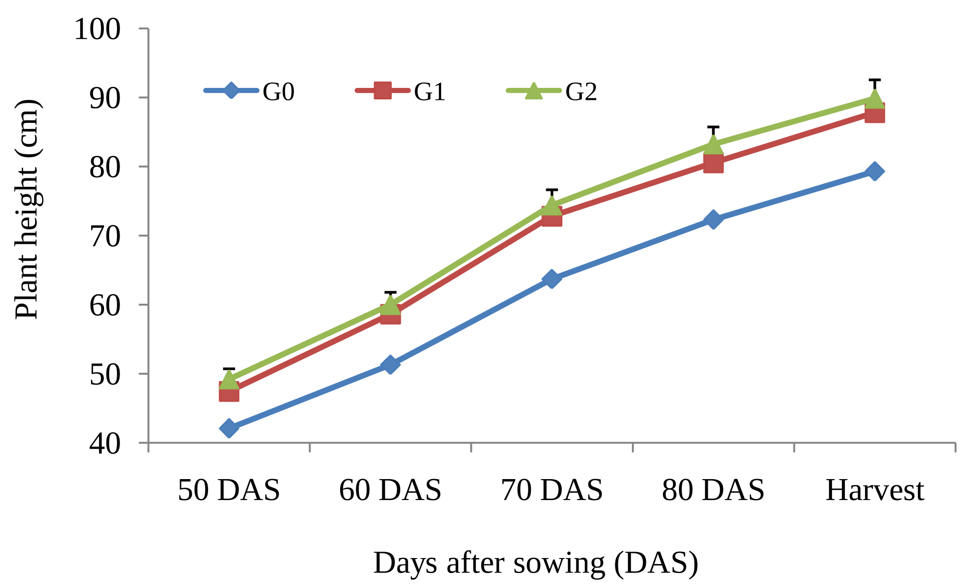
Statistically significant variation was recorded for plant height of wheat due to different levels of irrigation at 50, 60, 70, 80 DAS and at harvest under the present trial (Figure 1). At 50, 60, 70, 80 DAS and at harvest, the tallest plant (48.26 cm, 61.63 cm, 76.21 cm, 84.69 cm and 92.36 cm) was recorded from I_3 (irrigation both at CRI and pre-flowering stage), which was statistically similar (47.43 cm and 46.50 cm) with I_2 (irrigation at pre-flowering stage-45 DAS) and I_1 (irrigation at crown root initiation-CRI stage at 18 DAS) for 50 DAS and closely followed by I_2 (57.29 cm, 71.40 cm, 80.49 cm and 87.34 cm) and I_1 (56.98 cm, 70.37 cm, 78.68 cm and 84.81 cm) for 60, 70 and 80 DAS and at harvest and they were statistically similar. On the other hand, the shortest plant (42.82 cm, 50.63 cm, 63.25 cm, 70.88 cm and 78.10 cm) was observed from I_0 (no irrigation i.e., control condition). Providing 2 irrigations at crown root initiation stage and pre flowering stage ensured the optimum vegetative growth of the wheat and the ultimate results were the longest plant. Zhai *et al*. (2003) reported that water stress significantly inhibited the growth and yield of winter wheat. Gupta *et al.* (2001) reported that when water stress was imposed at booting stage caused a greater reduction in plant height. Islam (1997) reported that plant height increased with increasing number of irrigations.



I_0: No irrigation I_1: Irrigation at CRI stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS) I_3: Irrigation at CRI and pre-flowering stage

Figure 1. Effect of irrigation level on plant height of wheat at different days after sowing ($LSD_{0.05}$ =1.73, 1.94, 4.05, 3.91 and 4.30)



G_0: No GA_3 G_1.: 100 ppm GA_3 G_2.: 200 ppm GA_3

Figure 2. Effect of gibberellic acid on plant height of wheat at different days after sowing ($LSD_{0.05}$ =3.74, 3.29, 3.37, 3.83 and 3.53)

Different levels of gibberellic acid showed significant variation for plant height of wheat at 50, 60, 70, 80 DAS and at harvest (Figure 2). At 50, 60, 70, 80 DAS and at harvest, the tallest plant (49.24cm, 59.99 cm, 74.40 cm, 83.23 cm and 89.85 cm) was observed from G_2 (200 ppm GA_3), which was statistically similar (47.44 cm, 58.61 cm, 72.81 cm, 80.53 cm and 87.81 cm) to G_1 (100 ppm GA_3), again the shortest plant (42.08 cm, 51.30 cm, 63.71 cm, 72.29 cm and 79.30 cm) was recorded from G_0 (no GA_3 i.e. control condition). Meera and Poonam (2010) reported that treatment with plant growth regulator significantly increased all physiological parameters in comparison to that of untreated (control).

Interaction between irrigation level and gibberellic acid showed significant differences on plant height of wheat at 50, 60, 70, 80 DAS and at harvest (Table 2). At 50, 60, 70, 80 DAS and at harvest, the tallest plant (54.04 cm, 68.58 cm, 84.11 cm, 93.39 cm and 98.05 cm) was observed from I_3G_2 (irrigation at CRI and pre-flowering stage with 200 ppm GA_3), while the shortest (39.92 cm, 46.76 cm, 57.79 cm, 66.08 cm and 75.67 cm) was recorded from I_0G_2 (no irrigation with 200 ppm gibberellic acid). These results indicated that in relation to plant height of wheat without irrigation plant responded positively only at lower concentration of GA_3 but under irrigated condition positive response continued in both lower and higher concentration of GA_3. The results were also similar to that of Akram *et al*. (2011).

4.1.2. Dry matter content plant^{-1}

Significant variation was recorded for dry matter content plant^{-1} due to different levels of irrigation at 50, 60, 70 and 80 DAS of wheat under the present trial (Figure 3). At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (8.79 g, 15.56 g, 21.99 g and 28.69 g) was obtained from I_3, which was statistically similar (8.65 g, 15.25 g, 21.71 g and 27.99 g) with I_2 and closely followed (8.29 g, 14.60 g, 20.53 g and 26.94 g) by I_1, again the lowest dry matter content plant^{-1} (6.89 g, 11.62 g, 18.23 g and 20.30 g) from I_0.

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

Treatment	Plant height (cm) at				
	50 DAS	60 DAS	70 DAS	80 DAS	Harvest
I_0G_0	40.45 c	47.04 e	60.41 d	68.54 f	75.67 f
I_0G_1	48.08 abc	58.10 bcd	71.53 c	78.02 cde	84.64 cde
I_0G_2	39.92 c	46.76 e	57.79 d	66.08 f	73.99 f
I_1G_0	42.56 c	51.08 de	62.25 d	71.12 ef	77.80 ef
I_1G_1	48.19 abc	58.37 bcd	72.65 bc	80.47 cd	85.62 cd
I_1G_2	51.55 ab	61.49 bc	76.21 bc	84.46 bc	91.01 abc
I_2G_0	41.90 c	51.54 de	62.70 d	72.09 def	78.60 def
I_2G_1	46.16 abc	57.21 bcd	72.00 c	80.39 cd	87.09 bc
I_2G_2	51.44 ab	63.12 ab	79.50 ab	88.99 ab	96.33 a
I_3G_0	43.40 bc	55.54 cd	69.47 c	77.41 cde	85.14 cde
I_3G_1	47.34 abc	60.78 bc	75.06 bc	83.26 bc	93.89 ab
I_3G_2	54.04 a	68.58 a	84.11 a	93.39 a	98.05 a
$LSD_{(0.05)}$	7.48	6.57	6.75	7.67	7.07
Level of significance	0.05	0.01	0.01	0.01	0.01
CV(%)	9.34	6.70	5.54	5.63	4.77

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

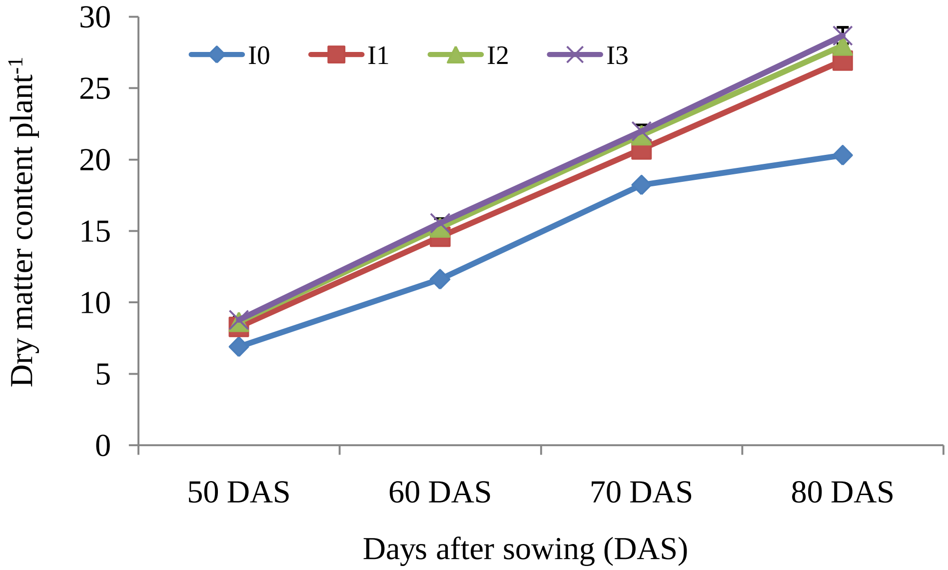
I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3



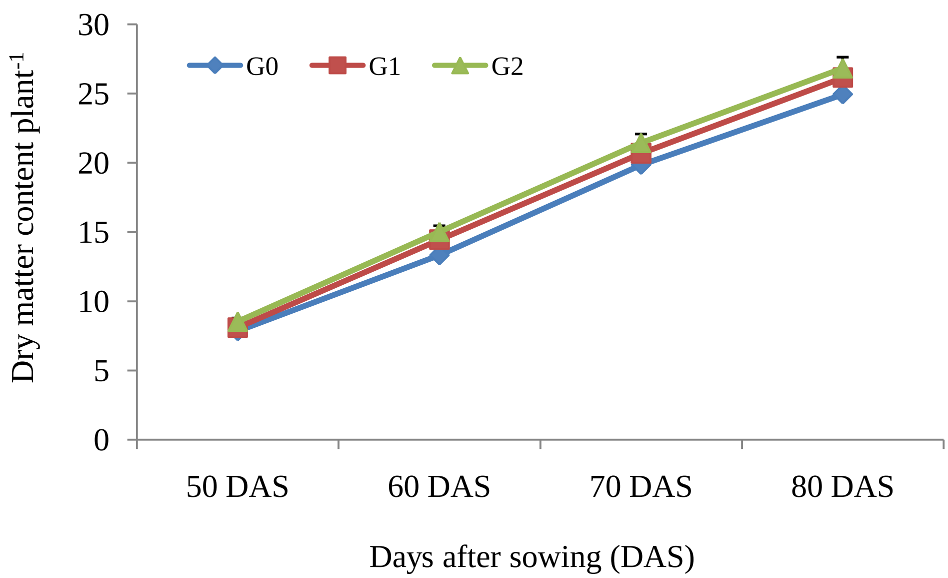
I_0: No irrigation

I_1: Irrigation at CRI stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation at CRI and pre-flowering stage

Figure 3. Effect of irrigation level on dry matter content plant^{-1} of wheat at different days after sowing ($LSD_{0.05}$ =0.38, 0.68, 1.40 and 1.35)



G_0: No GA_3

G_1.: 100 ppm GA_3

G_2.: 200 ppm GA_3

Figure 4. Effect of gibberellic acid on dry matter content plant^{-1} of wheat at different days after sowing (LSD0.05 =0.34, 0.43, 0.89 and 0.80)

Dry matter content plant^{-1} of wheat showed significant variation for 50, 60, 70 and 80 DAS due to different levels of gibberellic acid (Figure 4). At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (8.53 g, 15.00 g, 21.44 g and 26.83 g) was recorded from G_2, which was closely followed by (8.10 g and 14.45 g) for 50 and 60 DAS and statistically similar (20.69 g and 26.15 g) for 70 and 80 DAS with G_1, whereas the lowest dry matter content plant^{-1} (7.84 g, 13.32 g, 19.86 g and 24.95 g) was observed from G_0.

Interaction effect of different levels of irrigation and gibberellic acid showed significant influences on dry matter content plant^{-1} of wheat at 50, 60, 70 and 80 DAS under the present trial (Table 3). At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (9.36 g, 16.64 g, 22.77 g and 29.92 g) was found from I_3G_2 and the lowest dry matter content plant^{-1} (6.67 g, 11.29 g, 17.59 g and 19.11 g) was obtained from I_0G_0.

4.1.3. Crop Growth Rate (CGR)

Data revealed that crop growth rate (CGR) varied significantly due to different levels of irrigation at 50-60 and 70-80 DAS but non significant for 60-70 DAS of wheat under the present trial (Table 4). At 50-60 DAS, the highest CGR (6.77 g $m^{-2}day^{-1}$) was found from I_3, which was statistically similar (6.60 g $m^{-2}day^{-1}$ and 6.31 g $m^{-2}day^{-1}$) with I_2 and I_1, while the lowest CGR (4.72 g $m^{-2}day^{-1}$) from I_0. At 60-70 DAS, the highest CGR (6.61 g $m^{-2}day^{-1}$) was recorded from I_0, again the lowest CGR (6.13 g $m^{-2}day^{-1}$) from I_1. At 70-80 DAS, the highest CGR (6.69 g $m^{-2}day^{-1}$) was attained from I_3, which was statistically similar (6.29 g $m^{-2}day^{-1}$ and 6.21 g $m^{-2}day^{-1}$) with I_2 and I_1, whereas the lowest CGR (2.08 g $m^{-2}day^{-1}$) from I_0. Naser (1996) reported the highest crop growth rate were recorded when two irrigations were applied.

Table 3. Interaction effect of irrigation level and gibberellic acid on dry matter content plant^{-1} at different days after sowing (DAS) of wheat

Treatment	Dry matter content plant^{-1} (g) at			
	50 DAS	60 DAS	70 DAS	80 DAS
I_0G_0	6.67 d	11.29 f	17.59 g	19.11 f
I_0G_1	7.01 d	11.86 f	19.18 efg	21.86 e
I_0G_2	7.01 d	11.71 f	17.91 fg	19.93 f
I_1G_0	7.80 c	13.75 e	19.56 def	25.94 d
I_1G_1	8.27 bc	14.76 cd	20.83 bcde	26.72 cd
I_1G_2	8.79 ab	15.29 cd	21.80 abc	28.14 bc
I_2G_0	8.08 bc	13.76 e	20.33 cde	26.73 cd
I_2G_1	8.57 b	15.63 bc	21.52 abcd	27.92 bc
I_2G_2	9.30 a	16.37 ab	23.27 a	29.34 ab
I_3G_0	8.45 bc	14.48 de	21.98 abc	28.03 bc
I_3G_1	8.56 b	15.55 bc	21.23 bcd	28.11 bc
I_3G_2	9.36 a	16.64 a	22.77 ab	29.92 a
$LSD_{(0.05)}$	0.68	0.86	1.79	1.59
Level of significance	0.05	0.05	0.04	0.05
CV(%)	4.78	6.49	5.00	5.54

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Table 4. Effect of irrigation level and gibberellic acid on Crop Growth Rate of wheat

Treatment	Crop Growth Rate (g $m^{-2}day^{-1}$) at		
	50-60 DAS	60-70 DAS	70-80 DAS
Irrigation levels			
I_0	4.72 b	6.61	2.08 b
I_1	6.31 a	6.13	6.21 a
I_2	6.60 a	6.45	6.29 a
I_3	6.77 a	6.44	6.69 a
$LSD_{(0.05)}$	0.82	--	1.44
Level of significance	0.01	NS	0.01
Gibberellic acid			
G_0	5.48 b	6.54	5.09
G_1	6.34 a	6.24	5.46
G_2	6.47 a	6.44	5.40
$LSD_{(0.05)}$	0.50	--	--
Level of significance	0.01	NS	NS
CV(%)	9.45	17.67	19.19

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

At 50-60 DAS different levels of gibberellic acid showed significant variation for CGR of wheat and non significant for 60-70 DAS and 70-80 DAS (Table 4). At 50-60 DAS, the highest CGR (6.47 g $m^{-2}day^{-1}$) was recorded from G_2, which was statistically similar (6.34 g $m^{-2}day^{-1}$) with G_1 and lowest CGR (5.48 g $m^{-2}day^{-1}$) was observed from G_0. At 60-70 DAS, the highest CGR (6.54 g $m^{-2}day^{-1}$) was observed from G_0, again the lowest CGR (6.24 g $m^{-2}day^{-1}$) was recorded from G_1. At 70-80 DAS, the highest CGR (5.46 g $m^{-2}day^{-1}$) was observed from G_1, while the lowest CGR (5.09 g $m^{-2}day^{-1}$) was found from G_0.

It was found that interaction effect of different levels of irrigation and gibberellic acid varied significantly for CGR of wheat at 50-60 DAS and non significant at 60-70 DAS and 70-80 DAS, respectively (Table 5). At 50-60 DAS, the highest CGR (7.29 g $m^{-2}day^{-1}$) was attained from I_3G_2, while the lowest CGR (4.28 g $m^{-2}day^{-1}$) was recorded from I_0G_0. At 60-70 DAS, the highest CGR (7.50 g $m^{-2}day^{-1}$) was observed from I_3G_0, whereas the lowest CGR (5.68 g $m^{-2}day^{-1}$) was found from I_3G_1. At 70-80 DAS, the highest CGR (7.15 g $m^{-2}day^{-1}$) was observed from I_3G_2 and the lowest CGR (1.53 g $m^{-2}day^{-1}$) was recorded from I_0G_0.

4.1.4. Relative Growth Rate (RGR)

Statistically non significant variation was recorded for relative growth rate (RGR) of wheat due to different levels of irrigation at 50-60 and 60-70 DAS but significant for 70-80 DAS under the present trial (Table 6). At 50-60 DAS, the highest RGR (0.057 g g^{-1} day^{-1}) was recorded from I_1, I_2 and I_3 and the lowest RGR (0.052 g g^{-1} day^{-1}) from I_0. At 60-70 DAS, the highest RGR (0.045 g g^{-1} day^{-1}) was found from I_0, again the lowest RGR (0.035 g g^{-1} day^{-1}) from I_1, I_2 and I_3. At 70-80 DAS, the highest RGR (0.027 g g^{-1} day^{-1}) was obtained from I_3 which was statistically similar (0.026 g g^{-1} day^{-1}) with I_2 and I_1, again the lowest RGR (0.011 g g^{-1} day^{-1}) from I_0.

Table 5. Interaction effect of irrigation level and gibberellic acid on Crop Growth Rate of wheat

Treatment	Crop Growth Rate (g $m^{-2}day^{-1}$) at		
	50-60 DAS	60-70 DAS	70-80 DAS
I_0G_0	4.28 f	6.30	1.53
I_0G_1	4.85 ef	7.32	2.68
I_0G_2	5.04 def	6.21	2.02
I_1G_0	5.95 bcd	5.81	6.38
I_1G_1	6.48 abc	6.07	5.89
I_1G_2	6.50 abc	6.51	6.34
I_2G_0	5.68 cde	6.56	6.40
I_2G_1	7.05 ab	5.90	6.39
I_2G_2	7.06 ab	6.90	6.07
I_3G_0	6.03 bcd	7.50	6.05
I_3G_1	6.99 ab	5.68	6.87
I_3G_2	7.29 a	6.13	7.15
$LSD_{(0.05)}$	1.00	--	--
Level of significance	0.05	NS	NS
CV(%)	9.45	17.67	19.19

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No $GA_{3,}$ i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Table 6. Effect of irrigation level and gibberellic acid on Relative Growth Rate of wheat

Treatment	Relative growth rate (g g^{-1} day^{-1}) at		
	50-60 DAS	60-70 DAS	70-80 DAS
Irrigation levels			
I_0	0.052	0.045	0.011 b
I_1	0.057	0.035	0.026 a
I_2	0.057	0.035	0.026 a
I_3	0.057	0.035	0.027 a
$LSD_{(0.05)}$	--	--	0.012
Level of significance	NS	NS	0.01
Gibberellic acid			
G_0	0.053	0.040	0.022
G_1	0.058	0.036	0.023
G_2	0.056	0.036	0.022
$LSD_{(0.05)}$	--	--	--
Level of significance	NS	NS	NS
CV(%)	10.16	15.36	10.39

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Different levels of gibberellic acid showed non significant variation for RGR of wheat at 50-60 DAS, 60-70 DAS and 70-80 DAS (Table 6). At 50-60 DAS, the highest RGR (0.058 g g^{-1} day^{-1}) was observed from G_1, while the lowest RGR (0.053 g g^{-1} day^{-1}) from G_0. At 60-70 DAS, the highest RGR (0.040 g g^{-1} day^{-1}) was observed from G_0, again the lowest RGR (0.036 g g^{-1} day^{-1}) was recorded from G_1 and G_2. At 70-80 DAS, the highest RGR (0.023 g g^{-1} day^{-1}) was observed from G_1, whereas the lowest RGR (0.022 g g^{-1} day^{-1}) was found from G_0 and G_2.

Interaction effect of different levels of irrigation and gibberellic acid showed non significant differences for RGR of wheat at 50-60 DAS, 60-70 DAS and 70-80 DAS (Table 7). At 50-60 DAS, the highest RGR (0.061 g g^{-1} day^{-1}) was observed from I_3G_1, whereas the lowest RGR (0.048 g g^{-1} day^{-1}) from I_0G_0. At 60-70 DAS, the highest RGR (0.048 g g^{-1} day^{-1}) was observed from I_0G_1, while the lowest RGR (0.030 g g^{-1} day^{-1}) from I_3G_2. At 70-80 DAS, the highest RGR (0.029 g g^{-1} day^{-1}) was observed from I_3G_2 and the lowest RGR (0.008 g g g^{-1} day^{-1}) from I_0G_0.

4.2. Yield contributing Characters

4.2.1. Number of spike $hill^{-1}$

Different levels of irrigation showed statistically significant variation for number of spike $hill^{-1}$ of wheat (Table 8). The highest number of spike $hill^{-1}$ (4.49) was found from I_3 which was closely followed (4.13) by I_2, whereas the lowest number (3.16) was recorded from I_0.

Significant variation was recorded for different levels of gibberellic acid for number of spike $hill^{-1}$ (Table 8). The highest number of spike $hill^{-1}$ (4.13) was recorded from G_2, which was statistically similar (3.88) with G_1, while the lowest number (3.58) was observed from G_0.

Number of spike $hill^{-1}$ showed significant differences for the interaction effect of different levels of irrigation and gibberellic acid (Table 9). The highest number of spike $hill^{-1}$ (4.93) was observed from I_3G_2, again the lowest number (3.12) was attained from I_0G_0. Akram *et al*. (2011) reported that number of productive tillers per plant was decreased under moisture stress conditions by 6 percent, this was enhanced by application of growth substances.

Table 7. Interaction effect of irrigation level and gibberellic acid on Relative Growth Rate of wheat

Treatment	Relative growth rate (g g^{-1} day^{-1}) at		
	50-60 DAS	60-70 DAS	70-80 DAS
I_0G_0	0.048	0.044	0.008
I_0G_1	0.053	0.048	0.013
I_0G_2	0.056	0.042	0.011
I_1G_0	0.057	0.035	0.028
I_1G_1	0.058	0.034	0.025
I_1G_2	0.055	0.035	0.026
I_2G_0	0.053	0.039	0.028
I_2G_1	0.060	0.032	0.026
I_2G_2	0.056	0.035	0.023
I_3G_0	0.054	0.042	0.024
I_3G_1	0.061	0.031	0.028
I_3G_2	0.058	0.030	0.029
$LSD_{(0.05)}$	--	--	--
Level of significance	NS	NS	NS
CV(%)	10.16	15.36	10.39

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Table 8. Effect of irrigation level and gibberellic acid on number of spikes hill^{-1}, number of spikelets spike^{-1} and ear length of wheat

Treatment	Number of spikes hill^{-1}	Number of spikelets spike^{-1}	Ear length (cm)
Irrigation levels			
I_0	3.16 d	15.16 c	13.18 b
I_1	3.69 c	17.58 b	15.94 a
I_2	4.13 b	18.53 ab	17.07 a
I_3	4.49 a	19.00 a	17.48 a
$LSD_{(0.05)}$	0.25	1.23	1.90
Level of significance	0.01	0.01	0.01
Gibberellic acid			
G_0	3.58 b	15.77 b	14.30 b
G_1	3.88 a	17.98 a	16.48 a
G_2	4.13 a	18.95 a	16.98 a
$LSD_{(0.05)}$	0.25	1.15	1.08
Level of significance	0.01	0.01	0.01
CV(%)	7.54	7.58	7.87

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Table 9. Interaction effect of irrigation level and gibberellic acid on number of spikes hill^{-1}, number of spikelets spike^{-1} and ear length of wheat

Treatment	Number of spikes hill^{-1}	Number of spikelets spike^{-1}	Ear length (cm)
I_0G_0	3.12 g	15.13 d	12.68 d
I_0G_1	3.20 fg	16.00 cd	15.28 bc
I_0G_2	3.13 g	14.33 d	11.58 d
I_1G_0	3.40 efg	15.33 d	13.73 cd
I_1G_1	3.73 def	18.20 bc	16.61 b
I_1G_2	3.93 cde	19.20 ab	17.50 ab
I_2G_0	3.73 def	16.40 cd	15.23 bc
I_2G_1	4.13 bcd	18.53 bc	16.49 b
I_2G_2	4.53 ab	20.67 ab	19.48 a
I_3G_0	4.07 bcd	16.20 cd	15.55 bc
I_3G_1	4.47 abc	19.20 ab	17.53 ab
I_3G_2	4.93 a	21.60 a	19.36 a
$LSD_{(0.05)}$	0.51	2.30	2.17
Level of significance	0.05	0.05	0.01
CV(%)	7.54	7.58	7.87

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

4.2.2. Number of spikelets spike^{-1}

Statistically significant variation was recorded for number of spikelet spike^{-1} of wheat due to different levels of irrigation (Table 8). The highest number of spikelet spike^{-1} (19.00) was observed from I_3 which was statistically similar (18.53) with I_2 and closely followed (17.58) by I_1, again the lowest number (15.16) was recorded from I_0. Naser (1996) reported the highest number of grains per spike were recorded when two irrigations were applied.

Different levels of gibberellic acid showed significant variation for number of spikelet spike^{-1} (Table 8). The highest number of spikelet spike^{-1} (18.95) was observed from G_2, which was statistically similar (17.98) with G_1, while the lowest number (15.77) was found from G_0.

Interaction effect of different levels of irrigation and gibberellic acid showed significant differences on number of spikelet spike^{-1} (Table 9). The highest number of spikelet spike^{-1} (21.60) was recorded from I_3G_2, whereas the lowest number (14.33) was found from I_0G_2. Akram *et al.* (2011) reported that number of productive tillers per plant was decreased under moisture stress conditions by 6 percent, this was enhanced by application of growth substances.

4.2.3. Ear length

It was revealed that ear length of wheat varied significantly due to different levels of irrigation (Table 8). The longest ear (17.48 cm) was recorded from I_3 which was statistically similar (17.07 cm and 15.94 cm) with I_2 and I_1, whereas the shortest ear (13.18 cm) was recorded from I_0. Naser (1996) reported the highest spike length when two irrigations were applied.

Different levels of gibberellic acid showed significant variation for ear length (Table 8). The longest ear (16.98 cm) was found from G_2, which was statistically similar (16.48 cm) with G_1, while the shortest ear (14.30 cm) from G_0.

From the value of ear length it was found that interaction effect of different levels of irrigation and gibberellic acid showed significant differences (Table 9). The longest ear (19.48 cm) was observed from I_2G_2, again the shortest ear (11.58 cm) was recorded from I_0G_2.

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

Significant variation was recorded for number of filled grain spike^{-1} of wheat due to different levels of irrigation (Table 10). The highest number of filled grain spike^{-1} (30.76) was recorded from I_3 which was statistically similar (30.09 and 28.84) with I_2 and I_1, whereas the lowest number (24.49) was recorded 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.

Number of filled grain spike^{-1} varied significantly for different levels of gibberellic acid (Table 10). The highest number of filled grain spike^{-1} (30.43) was found from G_2, which was statistically similar (29.12) with G_1, again the lowest number (26.08) was observed from G_0.

Different levels of irrigation and gibberellic acid showed significant differences on number of filled grain spike^{-1} due to their interaction effect (Table 11). The highest number of filled grain spike^{-1} (34.47) was recorded from I_3G_2, while the lowest (22.40) was found from I_0G_0.

4.2.5. Unfilled grains spike^{-1}

Statistically significant variation was recorded for number of unfilled grain spike^{-1} of wheat due to different levels of irrigation (Table 10). The highest number of unfilled grain spike^{-1} (2.49) was found from I_0 which was closely followed (2.36 and 2.27) by I_1 and I_2 and they were statistically similar, again the lowest number (2.13) was observed from I_3.

Different levels of gibberellic acid showed significant variation for number of unfilled grain spike^{-1} (Table 10). The highest number of unfilled grain spike^{-1} (2.53) was observed from G_0, whereas the lowest number (2.18) was found from G_2 which was statistically similar (2.22) with G_1.

Table 10. Effect of irrigation level and gibberellic acid on filled, unfilled and total grains spike^{-1} and weight of 1000-grain of wheat

Treatment	Filled grains spike^{-1}	Unfilled grains spike^{-1}	Total Grains spike^{-1}	Weight of 1000-grain (g)
Irrigation levels				
I_0	24.49 b	2.49 a	26.98 b	35.51 c
I_1	28.84 a	2.36 b	31.20 a	44.89 b
I_2	30.09 a	2.27 b	32.36 a	46.15 ab
I_3	30.76 a	2.13 c	32.89 a	47.13 a
$LSD_{(0.05)}$	2.39	0.12	2.44	1.61
Level of significance	0.01	0.01	0.01	0.01
Gibberellic acid				
G_0	26.08 b	2.53 a	28.62 b	39.99 b
G_1	29.12 a	2.22 b	31.33 a	44.77 a
G_2	30.43 a	2.18 b	32.62 a	45.51 a
$LSD_{(0.05)}$	1.58	0.15	1.57	1.72
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.38	7.56	5.89	4.56

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Table 11. Interaction effect of irrigation level and gibberellic acid on filled, unfilled and total grains spike^{-1} and weight of 1000-grain of wheat

Treatment	Filled grains spike^{-1}	Unfilled grains spike^{-1}	Total Grains spike^{-1}	Weight of 1000-grain (g)
I_0G_0	22.40 e	2.73 a	25.13 e	34.05 d
I_0G_1	28.00 cd	2.60 abc	30.60 cd	37.04 d
I_0G_2	23.07 e	2.13 de	25.20 e	35.43 d
I_1G_0	26.27 d	2.67 ab	28.93 d	40.75 c
I_1G_1	29.33 cd	2.27 d	31.60 cd	46.03 ab
I_1G_2	30.93 bc	2.13 de	33.07 bc	47.90 a
I_2G_0	27.67 cd	2.40 bcd	30.07 cd	41.54 c
I_2G_1	29.33 cd	2.13 de	31.47 cd	47.73 a
I_2G_2	33.27 ab	2.27 d	35.53 ab	49.19 a
I_3G_0	28.00 cd	2.33 cd	30.33 cd	43.61 bc
I_3G_1	29.80 cd	1.87 e	31.67 cd	48.29 a
I_3G_2	34.47 a	2.20 de	36.67 a	49.50 a
$LSD_{(0.05)}$	3.15	0.31	3.14	3.43
Level of significance	0.01	0.05	0.01	0.05
CV(%)	6.38	7.56	5.89	4.56

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 condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Interaction effect of different levels of irrigation and gibberellic acid showed significant differences on number of unfilled grain spike^{-1} (Table 11). The highest number of unfilled grain spike^{-1} (2.73) was recorded from I_0G_0, while the lowest (1.87) was found from I_3G_1.

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

Number of total grain spike^{-1} of wheat varied significantly due to different levels of irrigation (Table 10). The highest number of total grain spike^{-1} (32.89) was found from I_3 which was statistically similar (32.36 and 31.20) with I_2 and I_1, while the lowest number (26.98) was recorded from I_0. Islam (1996) observed that irrigation had no influence of grains per ear.

Statistically significant variation was recorded for different levels of gibberellic acid for number of total grain spike^{-1} (Table 10). The highest number of total grain spike^{-1} (32.62) was found from G_2, which was statistically similar (31.33) with G_1, again the lowest number (28.62) was recorded from G_0.

Significant variation was recorded for the interaction effect of different levels of irrigation and gibberellic acid on number of total grain spike^{-1} (Table 11). The highest number of total grain spike^{-1} (36.67) was observed from I_3G_2 and the lowest (25.13) was found from I_0G_0. Akram *et al*. (2011) reported that water deficit decreased grains per spikebut significantly improved while application of growth substances.

4.2.7. Weight of 1000-grain

Statistically significant variation was recorded for weight of 1000-grain of wheat due to different levels of irrigation (Table 10). The highest weight of 1000-grain (47.13 g) was observed from I_3 which was statistically similar (46.15 g) with I_2 and closely followed (44.89 g) by I_1, whereas the lowest weight (35.51 g) was found from I_0. Islam (1996) observed that irrigation had no influence of 1000-grain weight.

Different levels of gibberellic acid showed significant variation for weight of 1000-grain (Table 10). The highest weight of 1000-grain (45.51 g) was obtained from G_2, which was statistically similar (44.77 g) with G_1, again the lowest weight (39.99 g) was observed from G_0. Akram *et al*. (2011) reported that pre-sowing seed soaking in ethephon solution produced the highest 1000-grain weight of 44.39 in comparison with control.

Interaction effect of different levels of irrigation and gibberellic acid showed significant differences on weight of 1000-grain (Table 11). The highest weight of 1000-grain (49.50 g) was found from I_3G_2, while the lowest weight (34.05 g) from I_0G_0. Akram *et al*. (2011) reported that water deficit condition decreased 1000-grain weight but significantly improved while application of growth substances.

4.3. Yield

4.3.1. Grain yield ha^{-1}

Data revealed that statistically significant variation was found for grain yield per hectare of wheat due to different levels of irrigation (Table 12). The highest grain yield per hectare (3.93 ton) was recorded from I_3 which was statistically similar (3.86 ton and 3.62 ton) with I_2 and I_1, respectively, while the lowest grain yield (2.95 ton) was recorded 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. 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.

Grain yield per hectare varied significantly for different levels of gibberellic acid (Table 12). The highest grain yield per hectare (3.94 ton) was observed from G_2, which was closely followed (3.69 ton) by G_1, whereas the lowest grain yield (3.13 ton) was attained from G_0. Akram *et al*. (2011) reported that pre-sowing seed soaking in ethephon solution increased per hectare yield by 37 percent in comparison with control.

Table 12. Effect of irrigation level and gibberellic acid on yield of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Irrigation levels				
I_0	2.95 b	3.83 c	6.78 c	43.50 c
I_1	3.62 a	4.26 b	7.88 b	45.85 a
I_2	3.86 a	4.70 a	8.56 ab	44.92 ab
I_3	3.93 a	4.88 a	8.82 a	44.45 bc
$LSD_{(0.05)}$	0.41	0.43	0.808	1.31
Level of significance	0.01	0.01	0.01	0.05
Gibberellic acid				
G_0	3.13 c	4.20 b	7.33 b	42.68 b
G_1	3.69 b	4.46 a	8.15 a	45.23 a
G_2	3.94 a	4.60 a	8.54 a	46.13 a
$LSD_{(0.05)}$	0.19	0.26	0.606	1.47
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.19	6.70		3.79

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

I_0: No irrigation, i.e., control condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation both at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

Different levels of irrigation and gibberellic acid showed significant differences on grain yield per hectare for their interaction effect (Table 13). The highest grain yield per hectare (4.41 ton) was found from I_3G_2, again the lowest grain yield (2.85 ton) was found from I_0G_0. Akram *et al*. (2011) reported that water deficit decreased grain yield but significantly improved while application of growth substances.

4.3.2. Straw yield ha^{-1}

Different levels of irrigation showed statistically significant variation for straw yield per hectare of wheat (Table 12). The highest straw yield per hectare (4.88 ton) was recorded from I_3 which was statistically similar (4.70 ton) with I_2 and closely followed (4.26 ton) by I_1, again the lowest straw yield (3.83 ton) was found from I_0.

Statistically significant variation was recorded for different levels of gibberellic acid for straw yield per hectare (Table 12). The highest straw yield per hectare (4.60 ton) was recorded from G_2, which was statistically similar (4.46 ton) with G_1, whereas the lowest straw yield (4.20 ton) was observed from G_0.

Interaction effect of different levels of irrigation and gibberellic acid showed significant differences on straw yield per hectare (Table 13). The highest straw yield per hectare (5.40 ton) was observed from I_2G_2, again the lowest straw yield (3.56 ton) was found from I_0G_2.

4.3.3. Biological yield

Biological yield per hectare of wheat varied significantly due to different levels of irrigation (Table 12). The highest biological yield per hectare (8.82 ton) was observed from I_3 which was statistically similar (8.56 ton) with I_2 and closely followed (7.88 ton) by I_1, whereas the lowest biological yield (6.78 ton) was recorded 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.

Table 13. Interaction effect of irrigation level and gibberellic acid on yield of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0G_0	2.85 c	3.85 cd	6.70 d	42.57 de
I_0G_1	3.06 c	4.09 bcd	7.15 cd	42.80 cde
I_0G_2	2.93 c	3.56 d	6.49 d	45.15 abcde
I_1G_0	3.17 c	4.19 bc	7.36 cd	43.07 bcde
I_1G_1	3.77 b	4.34 bc	8.11 bc	46.62 a
I_1G_2	3.91 b	4.26 bc	8.16 bc	47.87 a
I_2G_0	3.22 c	4.29 bc	7.51 cd	42.93 bcde
I_2G_1	3.82 b	4.42 bc	8.23 bc	46.22 ab
I_2G_2	4.53 a	5.40 a	9.93 a	45.61 abcd
I_3G_0	3.26 c	4.47 b	7.73 cd	42.16 e
I_3G_1	4.13 ab	4.99 a	9.13 ab	45.28 abcde
I_3G_2	4.41 a	5.19 a	9.59 a	45.91 abc
$LSD_{(0.05)}$	0.38	0.51	1.213	2.93
Level of significance	0.01	0.01	0.01	0.05
CV(%)	6.19	6.70	5.52	3.79

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

I_0: No irrigation, i.e., control condition

I_1: Irrigation at crown root initiation (CRI) stage (18 DAS)

I_2: Irrigation at pre-flowering stage (45 DAS)

I_3: Irrigation at CRI and pre-flowering stage

G_0: No GA_3, i.e., control condition

G_1: 100 ppm GA_3

G_2: 200 ppm GA_3

It was found that different levels of gibberellic acid varied significantly for biological yield per hectare (Table 12). The highest biological yield per hectare (8.54 ton) was found from G_2, which was statistically similar (8.15 ton) with G_1, and the lowest biological yield (7.33 ton) from G_0. Meera and Poonam (2010) reported that plant growth regulator significantly increased yield characters.

Statistically significant variation was recorded for the interaction effect of different levels of irrigation and gibberellic acid on biological yield per hectare (Table 13). The highest biological yield per hectare (6.49 ton) was recorded from I_2G_2, while the lowest biological yield (9.93 ton) was found from I_0G_2. Akram *et al*. (2011) reported that water deficit decreased total biomass but improved significantly while application of growth substances.

4.3.4. Harvest index

Significant variation was recorded for harvest index of wheat due to different levels of irrigation (Table 12). The maximum harvest index (45.85%) was attained from I_1 which was statistically similar (44.92%) with I_2 and closely followed (44.45%) by I_3, while the minimum harvest index (43.50%) was recorded from I_0. Boogaard *et al*. (1996) reported that under rainfed conditions harvest index was increased. Gupta *et al.* (2001) reported that harvest index decreased to a greater extent when water stress was imposed at the anthesis stage.

Harvest index showed significant differences for different levels of gibberellic acid (Table 12). The highest harvest index (46.13%) was found from G_2, which was statistically similar (45.23%) with G_1 and the lowest harvest index (42.68%) from G_0. Akram *et al*. (2011) reported that pre-sowing seed soaking in ethephon solution increased harvest index by 8 percent in comparison with control.

Data revealed that the interaction effect of different levels of irrigation and gibberellic acid showed significant variation on harvest index (Table 13). The highest harvest index (47.87%) was recorded from I_1G_2, whereas the lowest harvest index (42.16%) was found from I_3G_0.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2011 to March 2012 to find out the growth and yield of wheat as influenced by irrigation levels and gibberellic acid. BARI Gom-21 (Shatabdi) was used as a test crop in this study. The experiment comprised two factors; Factors A: Irrigation (4 levels)- I_0: No irrigation i.e., control condition; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) & I_3: Irrigation at CRI and pre-flowering stage and Factor B: Gibberellic acid (3 levels)- G_0: No GA_3 i.e., control condition; G_1: 100 ppm GA_3 & G_2: 200 ppm GA_3. The experiment was laid out in Split Plot Design with three replications. Data on different growth and yield of wheat were recorded and significant differences was recorded for the studied characters.

In case of irrigation, at 50, 60, 70, 80 DAS and harvest, the tallest plant (48.26 cm, 61.63 cm, 76.21 cm, 84.69 cm and 92.36 cm) was recorded from I_3 and the shortest plant (42.82 cm, 50.63 cm, 63.25 cm, 70.88 cm and 78.10 cm) from I_0. At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (8.79 g, 15.56 g, 21.99 g and 28.69 g) was attained from I_3, again the lowest (6.89 g, 11.62 g, 18.23 g and 20.30 g) from I_0. At 50-60 DAS, the highest CGR (6.77 g m^{-2}day^{-1}) was found from I_3, while the lowest CGR (4.72 g m^{-2}day^{-1}) from I_0. At 60-70 DAS, the highest CGR (6.61 g m^{-2}day^{-1}) was recorded from I_0, again the lowest (6.13 g m^{-2}day^{-1}) from I_1. At 70-80 DAS, the highest CGR (6.69 g m^{-2}day^{-1}) was attained from I_3, whereas the lowest (2.08 g m^{-2}day^{-1}) from I_0. At 50-60 DAS, the highest RGR (0.057 g g^{-1} day^{-1}) was recorded from I_1, I_2 and I_3 and the lowest RGR (0.052 g g^{-1} day^{-1}) from I_0. At 60-70 DAS, the highest RGR (0.045 g g^{-1} day^{-1}) was found from I_0, again the lowest RGR (0.035 g g^{-1} day^{-1}) from I_1, I_2 and I_3. At 70-80 DAS, the highest RGR (0.027 g g^{-1} day^{-1}) was obtained from I_3, again the lowest RGR (0.011 g g^{-1} day^{-1}) from I_0. The highest number of spike hill^{-1} (4.49) was found from I_3, whereas the lowest number (3.16) from I_0. The highest number of spikelet spike^{-1} (19.00) was observed from I_3, again the lowest number (15.16) from I_0. The longest ear (17.48 cm) was recorded from I_3, whereas the shortest ear (13.18 cm) from I_0. The highest number of filled grain spike^{-1} (30.76) was recorded from I_3, whereas the lowest number (24.49) from I_0. The highest number of unfilled grain spike^{-1} (2.49) was found from I_0, again the lowest number (2.13) from I_3. The highest number of total grain spike^{-1} (32.89) was found from I_3, while the lowest number (26.98 from I_0. The highest weight of 1000-grain (47.13 g) was observed from I_3, whereas the lowest weight (35.51 g) from I_0. The highest grain yield per hectare (3.93 ton) was recorded from I_3, while the lowest (2.95 ton) from I_0. The highest straw yield per hectare (4.88 ton) was recorded from I_3, again the lowest (3.83 ton) from I_0. The highest biological yield per hectare (8.82 ton) was observed from I_3, whereas the lowest (6.78 ton) from I_0. The maximum harvest index (45.85%) was attained from I_1, while the minimum (43.50%) from I_0.

For gibberellic acid, at 50, 60, 70, 80 DAS and harvest, the tallest plant (49.24cm, 59.99 cm, 74.40 cm, 83.23 cm and 89.85 cm) was observed from G_2, again the shortest plant (42.08 cm, 51.30 cm, 63.71 cm, 72.29 cm and 79.30 cm) from G_0. At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (8.53 g, 15.00 g, 21.44 g and 26.83 g) was recorded from G_2, whereas the lowest (7.84 g, 13.32 g, 19.86 g and 24.95 g) from G_0. At 50-60 DAS, the highest CGR (6.47 g m^{-2}day^{-1}) was recorded from G_2, and lowest CGR (5.48 g m^{-2}day^{-1}) from G_0. At 60-70 DAS, the highest CGR (6.54 g m^{-2}day^{-1}) was observed from G_0, again the lowest CGR (6.24 g m^{-2}day^{-1}) from G_1. At 70-80 DAS, the highest CGR (5.46 g m^{-2}day^{-1}) was observed from G_1, while the lowest CGR (5.09 g m^{-2}day^{-1}) from G_0. At 50-60 DAS, the highest RGR (0.058 g g^{-1} day^{-1}) was observed from G_1, while the lowest RGR (0.053 g g^{-1} day^{-1}) from G_0. At 60-70 DAS, the highest RGR (0.040 g g^{-1} day^{-1}) was observed from G_0, again the lowest RGR (0.036 g g^{-1} day^{-1}) from G_1 and G_2. At 70-80 DAS, the highest RGR (0.023 g g^{-1} day^{-1}) was observed from G_1, whereas the lowest RGR (0.022 g g^{-1} day^{-1}) from G_0 and G_2. The highest number of spike hill^{-1} (4.13) was recorded from G_2, while the lowest number (3.58) from

G_0. The highest number of spikelet spike^{-1} (18.95) was observed from G_2, while the lowest number (15.77) from G_0. The longest ear (16.98 cm) was found from G_2, while the shortest ear (14.30 cm) from G_0. The highest number of filled grain spike^{-1} (30.43) was found from G_2, again the lowest number (26.08) from G_0. The highest number of unfilled grain spike^{-1} (2.53) was observed from G_0, whereas the lowest number (2.18) from G_2. The highest number of total grain spike^{-1} (32.62) was found from G_2, again the lowest number (28.62) from G_0. The highest weight of 1000-grain (45.51 g) was obtained from G_2, again the lowest weight (39.99 g) from G_0. The highest grain yield per hectare (3.94 ton) was observed from G_2, whereas the lowest (3.13 ton) from G_0. The highest straw yield per hectare (4.60 ton) was recorded from G_2, whereas the lowest (4.20 ton) from G_0. The highest biological yield per hectare (8.54 ton) was found from G_2, again the lowest (7.33 ton) from G_0. The highest harvest index (46.13%) was found from G_2, and the lowest (42.68%) from G_0.

Due to interaction effect of level of irrigation and gibberellic acid at 50, 60, 70, 80 DAS and harvest, the tallest plant (54.04 cm, 68.58 cm, 84.11 cm, 93.39 cm and 98.05 cm) was observed from I_3G_2, while the shortest (39.92 cm, 46.76 cm, 57.79 cm, 66.08 cm and 75.67 cm) was recorded from I_0G_2. At 50, 60, 70 and 80 DAS, the highest dry matter content plant^{-1} (9.36 g, 16.64 g, 22.77 g and 29.92 g) was found from I_3G_2 and the lowest (6.67 g, 11.29 g, 17.59 g and 19.11 g) from I_0G_0. At 50-60 DAS, the highest CGR (7.29 g m^{-2}day^{-1}) was attained from I_3G_2, while the lowest CGR (4.28 g m^{-2}day^{-1}) from I_0G_0. At 60-70 DAS, the highest CGR (7.50 g m^{-2}day^{-1}) was observed from I_3G_0, whereas the lowest CGR (5.68 g m^{-2}day^{-1}) from I_3G_1. At 70-80 DAS, the highest CGR (7.15 g m^{-2}day^{-1}) was observed from I_3G_2 and the lowest CGR (1.53 g m^{-2}day^{-1}) from I_0G_0. At 50-60 DAS, the highest RGR (0.061 g g^{-1} day^{-1}) was observed from I_3G_1, whereas the lowest RGR (0.048 g g^{-1} day^{-1}) from I_0G_0. At 60-70 DAS, the highest RGR (0.048 g g^{-1} day^{-1}) was observed from I_0G_1, while the lowest RGR (0.030 g g^{-1} day^{-1}) from I_3G_2. At 70-80 DAS, the highest RGR (0.029 g g^{-1} day^{-1}) was observed from I_3G_2 and the lowest RGR (0.008 g g g^{-1} day^{-1}) from I_0G_0. The highest number of spike hill^{-1}

(4.93) was observed from I_3G_2, again the lowest number (3.12) from I_0G_0. The highest number of spikelet spike^{-1} (21.60) was recorded from I_3G_2, whereas the lowest number (14.33) from I_0G_2. The longest ear (19.48 cm) was observed from I_2G_2, again the shortest ear (11.58 cm) from I_0G_2. The highest number of filled grain spike^{-1} (34.47) was recorded from I_3G_2, while the lowest (22.40) from I_0G_0. The highest number of unfilled grain spike^{-1} (2.73) was recorded from I_0G_0, while the lowest (1.87) from I_3G_1. The highest number of total grain spike^{-1} (36.67) was observed from I_3G_2 and the lowest (25.13) from I_0G_0. The highest weight of 1000-grain (49.50 g) was found from I_3G_2, while the lowest weight (34.05 g) from I_0G_0. The highest grain yield per hectare (4.41 ton) was found from I_3G_2, again the lowest (2.85 ton) from I_0G_0. The highest straw yield per hectare (5.40 ton) was observed from I_2G_2, again the lowest (3.56 ton) from I_0G_2. The highest biological yield per hectare (6.49 ton) was recorded from I_2G_2, while the lowest (9.93 ton) from I_0G_2. The highest harvest index (47.87%) was recorded from I_1G_2, whereas the lowest (42.16%) was found from I_3G_0.

Conclusion

Among the combination of different irrigations and gibberellic acid, the treatment with irrigation at CRI and pre-flowering stage and 200 ppm GA_3 performed better than others in relation to growth, yield contributing characters and yield of wheat.

Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Considering different growth stages another level of irrigation may be included in the future study; and
3. Another plant growth regulator with different concentration need to be consider before final recommendation.

REFERENCE

Ahmad, Z., Azam, F., Mahmood, T., Arshad, M. and Nadeem, S. (2004). Use of plant growth regulators (PGRS) in enhancing crop productivity. *Internl. J. Biol. Biotec*., **1**(3): 305-312.

Akram, H.M., Shahid, M. and Sattar, A. (2011). Impact of growth substances applications on yield parameters of wheat under water stress. *Iranian J. Plant Physiol*., **1**(3), 141-156.

BARI (Bangladesh Agricultural Research Institute). (2006). Krishi Projukti Hat Boi. BARI. Joydevpur, Gazipur. p. 14.

BARI. (1993). Annual Report (1991-92). Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. pp. 19-33.

BARI. (1997). Increase wheat cultivation and decrease irrigation cost (A folder in Bengali). Wheat Res. Centre. Bangladesh Agril. Res. Inst. Nashipur, Dinajpur. pp. 12-15.

Baser, I., Sehirali, S., Orta, H., Erdem, T., Erdem, Y. and Yorganclar, O. (2004). Effect of different water stresses on the yield and yield components of winter wheat. *Cereal Res. Comn*., **32**(2): 217-223.

Bazza, M.J., Sadaria, S.G., Patel, J.C. (1999). Wheat and sugar beet with irrigation management practices through water-deficit irrigation. *Indian J. Agril. Sci*., **69**(13): 431-435.

BBS (Bangladesh Bureau of Statistics). (2011). Monthly Statistical Bulletin, Bangladesh. Statistics Division. Ministry of Planning. Government of the Peoples Republic of Bangladesh. Dhaka. pp. 72.

Bennett, J.T., Virgona, J.M., Martin, P.J. and Connell, P.O. (2012). Effects of plant growth regulators that reduce stem height on yield of wheat in southern Australia. *Australian Agro. Conf., 2012*. University of New England in Armidale, NSW, 14-18th October, 2012.

Boogaard, C.E., Mitra, P.L. And Rajesh, R. (1996). Effect of rainfed and irrigated conditions for wheat cultivation. *Plant Nutri. and Fert. Sci*., **4**(2): 21-26.

Debelo, Y.P. Randra, P.P. and Tendon, R.R. (2001). Effect of moisture regioms on the growth and yield of wheat. *Exp. Agric*. **33**(1): 75-78.

Dubin, Y.P. and Ginkel, P.M. (1991). Wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh. *Indian J. Agril. Sci*., **58**(1): 131-135.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh. Govt. People's Republic of Bangladesh. 118 p.

Espindula, M.C., Rocha, V.S., Grossi, J.A.S., Souza, M.A., Souza, L.T. and Favarato, L.F. (2009). Use of growth retardants in wheat. *Planta Daninha*. **27**: 379-387.

FAO. (1988). Production Year Book. Food and Agricultural of the United Nations Rome, Italy. **42**: 190-193.

FAO. (2007). Production Year Book. Food and Agricultural of the United Nations Rome, Italy. **49**: 201-212.

FAO. (2009). Production Year Book. Food and Agricultural of the United Nations Rome, Italy. **54**: 176-186.

Gao, C.H., Zhang, Y.L. and Yu, Z.W. (2009). Differences in water consumption characteristics and grain yield of different wheat cultivars under high-yielding cultivation conditions. *J. Triticeae Crops*. **30**(1): 101-105.

Ghodpage, R.M. and Gawande, R.L. (2001). Effect of scheduling of irrigation on yield of late sown wheat (*Triticum aestivum* L.) on Morna command area. Annals Plant Physio., **15**(1): 77-79

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., A Willey Int. Sci., pp. 28-192.

Gupta, P.K., Gautam, R.C. and Ramesh, C.R. (2001). Effect of water stress on different stages of wheat cultivation. *Plant Nutri. and Fert. Sci*., **7**(2): 33-37.

Hunt, R. (1978). Plant growth analysis. The institute of Biology's studies in Biology No. 96. Edward Arnold (Publishers) Limited, London, UK.

Islam, M. M. (1997). Effect of irrigation on different growth stages of wheat cultivation. *Bangladesh J. Tr. and Dev*. **6**(1): 41-44.

Islam, M. T. (1996). A review on the effect of soil moisture stress on the growth phases of wheat. *Bangladesh J. Tr. and Dev*. **5**(2): 55-64.

Khajanij, S.N. and Swivedi, R.K. (1988). Response of wheat (*Triticum aestivum* L.) to irrigation and fertilizer mixture under late condition. *Bhartiya Krishi Anusandhan Patrika*. **3**(1): 37-42.

Li, R.Y., Li, Q.Y., Yin, J., Liu, W.D. and Du, P.X. (2010). Effects of water treatments on photosynthetic characteristics and yield of semi-winter wheat. *J. Henan Agril. Sci*., **6**: 9-12.

Ma, B. L., Leibovitch, S. and Smith, D.L. (1994). Plant Growth Regulator Effects on Protein Content and Yield of Spring Barley and Wheat. *J. Agron. Crop Sci*., **72**(1): 9–18.

Majumder, A. R. (1991). Assessment of yield loss caused by common root rot in wheat a cultivar in Queensland *(Bipolaris sorokiniana*). *Australian. J. Agril. Res*. (Australia). **13**(3): 143-151.

Malik, A.U., Hussain, I., Chaudhary, A.K. Bukhsh, M.A.A.H.A. (2010). Effect of different irrigation regimes on grain yield of wheat under local conditions of Dera Ghazi Khan. *Soil & Envir*., **29**(1): 73-76.

Mangan, B.N., Tunio, S.D., Shah, S.Q.A., Sial, M.A. and Abro, S.A. (2008). Studies on grain and grain yield associated traits of bread wheat (*Triticum aestivum* L.) varieties under water stress conditions. *Pakistan J. Agric. Agril. Engin. Vet. Sci*., **24**(2): 5-9.

Matysiak, K. (2006). Role of new plant growht regulator Sanislal in advantage of crop yield potential. *Prog. Plant Protc*., **46**(2): 109-115.

McKee, F. and Long, S. P. (2001). Plant Growth Regulators Control Ozone Damage to Wheat Yield. *J. Agron. Crop Sci*., **152(1): 41-51.**

Meena, B. S., Gautam, R. C. and Kaushik, S. K. (1998). Pearlmillet (*Pennlsetum glaucum*) and wheat (*Triticum aestivum*) cropping sequence as influenced by cultural, nutritional and irrigation factors under limited moisture conditions. *Indian J. Agril. Sci*. **68**(10): 638-643.

Meera, S. and Poonam, S. (2010). Response of growth regulators on some physiological traits and yield of wheat (*Triticum aestivum* L.). *Prog. Agric*. **10**(2): 387-388.

Mishra, A.K. and Padmakar, T. (2010). Effect of irrigation frequencies on yield and water use efficiency of wheat varieties. *Pantnagar J. Res*., **8**(1): 1-4.

Naeem, S., Maqsood, M., Mubeen, K., Shehzad, M., Bhullar, M.S., Qamar, R. and Akbar, N. (2010). Effect of different levels of irrigation on yield and yield components of wheat cultivars. *Pakistan J. Agric. Sci*., **47**(4): 371-374

Naseer, S., Rasul, E. and Ashraf, M. (2001). Effect of Foliar application of Indole-3-Acetic Acid on Growth and Yield Attributes of Spring Wheat (*Triticum aestivum* L.) Under Salt Stress. *Intl. J. Agri. Biol*., **3**(1): 139-142.

Naser, H. M. (1996). Response of wheat to irrigation. MS Thesis, Dept. of Soil Sci., Bangladesh Agril. Univ., Mymensingh. p. 1-77.

Rahim, A., Ranjha, A.M., Rahamtullah. and Waraich, E.A. (2010). Effect of phosphorus application and irrigation scheduling on wheat yield and phosphorus use efficiency. *Soil & Envir*., **29**(1): 15-22.

Razi-us-Shams (1996). Effect of irrigation treatments on yield and yield contributing characters (cv. Sonalika). *Bangladesh J. Tr. and Dev*. **6**(1): 33-37.

Razzaque, A., Das, N. and Roy, S. (1992). Wheat is the most important cereal crop that contributes to the national economy. *Indian J. Agron*. **26**(1): 35-39.

Saari E.E. (1998). Leaf Blight Diseases and Associated Soil Borne Fungal Pathogens of Wheat in North and South East Asia. In: *Helminthosporium* Blights of Wheat: Spot Blotch and Tan Spot (eds.) by Duveiller E, Dubin HJ, Reeves J and Mc Nab A, CIMMYT, Mexico, D.F. pp. 37-51.

Sah, J., Sadaria, S. G., Patel, J. C. and Vyas, M. N. (1990). Response of irrigated late sown wheat at to nitrogen application. *Indian J. Agron*. **36**(2): 276-277.

Stachecki, S., Praczyk, T. and Adamczewski, K. (2004). Adjuvant effects on plant growth regulators in winter wheat. *J. Plant Protec. Res*. **44**(4): 265-271.

Stahli, D., Perrissin-Fabert, D., Blouet, A. and Guckert, A. (1995). Contribution of the wheat (*Triticum aestivum* L.) flag leaf to grain yield in response to plant growth regulators. *Pl. Growth Regul.*, **16**(3): 293-297.

Upadhyaya, V.B. and Dubey, J.P. (1991). Influence of nitrogen, seed rate and mulch on wheat (*Triticum aestivum*) varieties under late sown conditions. *Indian J. Agron*. **41**(4): 562-565.

Vinod, K., Saini, S.K. and Tyagi, S. (2011). Effect of irrigation and fertilizer management on yield and economics of simultaneous planting of winter sugarcane plus wheat. *Envir. & Ecol*., **29**(1A): 310-315.

Wang, Q., Sun, Y.S., Wang, T.T., Fan, G.Y., Zhang, E.H., Li, F.R. and Wei, W.L. (2009). Effect of different irrigation and N supply levels on spring wheat growth characteristics, water consumption and grain yield on recently reclaimed sandy farmlands in Heihe River basin. *Arid Land Geography*. **32**(2): 240-248.

Wang, Z.H., Li, S.X., Wang, Z.H. and Li, S.X. (2002). Effect of water stress and supplement irrigation at different growing stages on the uptake and distribution of NPK in winter wheat. *Pl. Nutri. and Fert. Sci.*, **8**(2): 265-270.

Wu, J.C., Yang, Y.H., Jia, Y.Y., Wang, H.B., Guan, X.J. (2011). Effect of different compensation irrigation on yield and water-use-efficiency of winter wheat in Henan province. *J. Henan Agril. Sci*., **40**(1): 74-78.

Yadav, B.S., Verma, B.L. and Ramdeo, A. (1995). Irrigation requirement of wheat under shallow waster table condition. *J. Indian Soc. Sci*. **43**(2): 259-261.

Zarea, F.A. and Ghodsi, M. (2004). Evaluation of yield and yield components of facultative and winter bread wheat genotypes (*Triticum aestivum* L.) under different irrigation regimes in Khorasam Province in Iran. *J. Agron*., **3**(3): 184-187.

Zekeriya, A. (2009). Effects of Plant Growth Regulators on Nutrient Content of Young Wheat and Barley Plants under Saline Conditions. *J. Animal and Vet. Adv., 8:* 2018-2021.

Zhai, B.N., Li, S.X., Zhai, B.N. and Li, S.X. (2003). Combined effects of water and nitrogen fertilizer on yield and quality of winter wheat. *Pl. Nutri.and Fert. Sci*. **9**(1): 26-32.

Zhao, X.F., Wang, L.J., Li, R.Q. and Li, Y.M. (2009). Effects of irrigation frequency and nitrogen application rate on population dynamics and grain yield of winter wheat. *J. Triticeae Crops*. **29**(6): 1004-1009.

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2011 to March 2012

Month	*Air temperature (^oC)		*Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
November, 2011	25.82	16.04	78	00
December, 2011	22.4	13.5	74	00
January, 2012	24.5	12.4	68	00
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	11

* Monthly average

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

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the soil before experimentation

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

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

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		50 DAS	60 DAS	70 DAS	80 DAS	Harvest
Replication	2	0.340	0.502	1.466	1.748	0.538
Irrigation levels (A)	3	51.886*	184.738**	257.822**	300.556**	316.823**
Error	6	2.242	2.825	12.304	11.463	13.912
Gibberellic acid (B)	2	166.440**	261.819**	399.637**	389.985**	375.319**
Interaction (A×B)	6	37.701**	59.708**	98.073**	93.459**	73.852**
Error	16	18.650	14.414	15.191	19.621	16.662

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

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

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

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

Apendix V. Analysis of variance of the data on Crop Growth Rate (CGR) at different days after sowing (DAS) of wheat influenced by irrigation level and gibberellic acid

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

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

Apendix VI. Analysis of variance of the data on Relative Growth Rate (RGR) at different days after sowing (DAS) of wheat influenced by irrigation level and gibberellic acid

Source of variation	Degrees of freedom	Mean square		
		Relative growth rate (g g^{-1} day^{-1}) at		
		50-60 DAS	60-70 DAS	70-80 DAS
Replication	2	0.0001	0.0001	0.0001
Irrigation levels (A)	3	0.0001	0.0001	0.001
Error	6	0.0001	0.0001	0.0001
Gibberellic acid (B)	2	0.0001	0.0001	0.0001
Interaction (A×B)	6	0.0001	0.0001	0.0001
Error	16	0.0001	0.0001	0.0001

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

Apendix VII. Analysis of variance of the data on number of spikes hill^{-1}, number of spikelets spike^{-1} and ear length of wheat influenced by irrigation level and gibberellic acid

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

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

Apendix VIII. Analysis of variance of the data on filled, unfilled and total grains spike^{-1} and weight of 1000-grain of wheat influenced by irrigation level and gibberellic acid

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

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

Apendix IX. Analysis of variance of the data on yield of wheat influenced by irrigation level and gibberellic acid

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

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