# EFFECT OF IRRIGATION ON THE GROWTH AND YIELD OF DIFFERENT WHEAT VARIETIES

BY

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MY BELOVED PARENTS

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## CERTIFICATE

This is to certify that the thesis entitled "**Effect of Irrigation on the Growth and Yield of Different Wheat Varieties**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **Shubha Ankur Bhattacharje**, Registration number: **07-02587** 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: 24-06-2009
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The Author

# EFFECT OF IRRIGATION ON THE GROWTH AND YIELD OF DIFFERENT WHEAT VARIETIES

## ABSTRACT

An experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2007 to March 2008 to study the effect of irrigation on the growth and yield of different wheat varieties. The experiment comprised two factors; Irrigation: 3 levels ($I_0$: Control, $I_1$: One irrigation at crown root initiation stage, $I_2$: Two irrigation at crown root initiation stage and grain filling stage) and Variety: 4 ($V_1$: Bijoy, $V_2$: Prodip, $V_3$: Sufi and $V_4$: BAW1064). Results showed that the effect of irrigation on different plant parameters and yield was significant. Significantly the longest plant (79.99 cm), highest tiller number (4.89 plant$^{-1}$), spike length (11.30 cm), grain yield (2.54 t ha$^{-1}$) and straw yield (3.80 t ha$^{-1}$) were recorded from $I_2$. Whereas, significantly the lowest values of these parameters were obtained from $I_0$. Genotypes also showed significant variations in the plant parameters studied. Significantly the highest plant height (80.03 cm), tiller number (4.87 plant$^{-1}$), spike length (10.90 cm), grain yield (2.50 t ha$^{-1}$) and straw yield (3.56 t ha$^{-1}$) were obtained from the genotype $V_2$ whereas, the corresponding the lowest values were obtained from $V_4$. Significant interaction effect of irrigation and genotype was also observed on different plant parameters. The longest plant (83.79 cm), the maximum number of total tillers (5.27 plant$^{-1}$), grain yield (2.75 t ha$^{-1}$) and straw yield (4.36 t ha$^{-1}$) was recorded from the treatment combination of $I_2V_2$, while the corresponding lowest values were obtained from $I_0V_4$.

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# CHAPTER I

## INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops as well as staple food all over the world. About two third of the world's population consume wheat as staple food (Majumder, 1991). It supplies mainly carbohydrate (69.60%) and also protein (12%), fat (1.72%), and minerals (16.20%) (BARI, 1997).

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 it is the second most important cereal crops next to rice that contribute to the national economy by reducing the volume of import of cereals for fulfilling the food requirements of the country (Razzaque *et al.*, 1992). Besides these, grain and straw of wheat are also used as animal feed. Wheat straw is also used as fuel or house material of the poor man of Bangladesh.

Wheat is a well adapted cereal crop for its vegetative growth and development in our native climatic condition. Though the crop was introduced in Bangladesh during the former East Pakistan in 1967, its reputation increased after 1975. Now the popularity of wheat as staple food is rising 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 our country is low (2.2 t $ha^{-1}$) in comparison to other countries of the world, where average yield estimated 2.69 t $ha^{-1}$ (FAO, 1997). The area, production and yield of wheat have been increasing dramatically during the last two decades, but its present yield is too low in comparison to some developed countries like USA, Canada, Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 t ha$^{-1}$, respectively (FAO, 2000). At present about 707.56 thousand hectares of land in Bangladesh is covered by wheat with the annual production of 1578 thousand tons (BBS, 2008).

In Bangladesh, wheat is grown during Rabi (winter) season and the month duration extends from November to March. The Rabi season in Bangladesh 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, 1998).

Irrigation plays a vital role in terms of bringing good growth and development of wheat. Insufficient soil moisture affects both the germination of seed and uptake of nutrients from the soil. Irrigation frequency also has a significant influence on growth and yield of wheat (Khajanij and Swivedi, 1988).

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 reduction in plant height and number of tillers (Gupta *et al.*, 2001). High water deficit occurred during the early stage and irrigation during this stage was the most beneficial for the crop.

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 (Bazza *et al.*, 1999).

In some cases, irrigation appeared to be inversely related to protein content (Mikhail *et al.*, 1999). It was also reported that irrigation influenced seed protein content in an additive manner (Mascagni and Sabbe, 1991; Biskupski *et al.*, 1986).

Variety plays an important role in producing high yield and good quality wheat. Different varieties respond differently to input supply, cultivation practices and the prevailing environment during the growing season.

Recently, efforts were taken to increase the yield of wheat in Bangladesh by releasing a number of high yielding varieties. Among them, the performance of the selected ones under local conditions and quality levels should be known.

With the selection of superior variety its productivity needs to be tested with proper irrigation facilities. Lack of enough 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 (Ahmed and Elias, 1986). Information on the effect of irrigation on aspects of yield of our modern wheat varieties is inadequate. So, the present piece of research work was carried out with the following objectives-

i. to find out the effect of irrigation at different stages on the growth and yield of wheat

ii. to evaluate different wheat varieties in respect of plant growth, yield contributing characters and yield

iii. to examine the interaction effect (if any) between irrigation and varieties of wheat.

# CHAPTER II

## REVIEW OF LITERATURE

Wheat is an important cereal crop which attracted less concentration in respect of various agronomic aspects than the high yielding boro rice. During the cultivation of wheat farmers of our country mainly depends on rainfall. Selection of suitable variety is another problem for wheat cultivation. Very few research works related to growth, yield and development of wheat variety with the application of irrigation have been carried out in our country. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the irrigation and varieties of wheat, so far been done at home and abroad on this crop, have been reviewed in this chapter under the following heads-

### 2.1 Effect of irrigation on yield contributing characters and yield of wheat

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 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 when water stress was imposed at the anthesis stage while imposition of water stress at booting stage reduced 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.

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. One 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 in 1995).

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 irrigations, 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 par in respect of number of spikes/m$^2$ and grains/spikes, but had higher spikes and grains over control condition.

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 irrigations (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.

Singh and Singh (1991) conducted a field experiment at Lakhaoti, Uttar pradesh, India during 1983-84 and 1984-85 with irrigation at 20, 27, 34 and 41 DAS and reported that spike length increased significantly when irrigation was applied at 20 and 27 DAS.

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. They found that higher yield with three irrigations given at CRI, tillering and milking stages of wheat than other treatments. They also found maximum water use efficiency with three irrigations given at CRI, tillering and milking stages.

Khola *et al.* (1989) observed that wheat grown with 5 and 7 irrigations (with 600 mm water) gave yields of 3.27 and 3.05 t/ha respectively, and with 4, 2 and 1 irrigations wheat yields were 3.66 and 2.97 and 2.11 t/ha, respectively. English and Nakarume (1989) reported that wheat yield decreased with increasing number of irrigation. They found the highest grain yield of 3.6 t $ha^{-1}$ with 4 irrigations.

**2.2 Effect of variety on yield contributing characters and yield of wheat**

Maiksteniene *et al.* (2006) carried out a field experiment at the Lithuanian Institute of Agriculture's Joniskelis Experimental Station during 2004-2005 to estimate the changes in productivity and quality indicators of winter wheat varieties. The tests involved: Ada and Bussard (with very good food qualities), Lars and Tauras (with satisfactory food qualities) varieties. The higher grain yield was produced in varieties with satisfactory food qualities compared with those with very good food qualities. The highest contents of protein for grain quality improvement at ripening stage without urea solution application were accumulated by the varieties.

Sulewska (2004) carried out an experiment with 22 wheat genotypes for comparing vegetation period, plant height, number of stems and spikes, yield per spike. He noticed a variability of plant and spike productivity and of other morphological characters due to variety. He reported that the variety Waggershauser Hohenh Weisser Kolben gave the highest economic value among the tested genotypes.

Jalleta (2004) conducted an experiment in farmer's level with a number of improved bread wheat varieties for production in different climatic zones. Farmers identified earliness, yield and quality as the main criteria for adaptation of wheat varieties and they found that the variety HAR-710 gave 2.56 t $ha^{-1}$ and PAVON-76 gave 2.49 t $ha^{-1}$ grain yield.

Wheat Research Center (2003) of Bangladesh conducted an experiment in the Wheat Research Centre Nashipur, Dinajpur to examine the performance of genotypes among various tillage operations and to understand the effects of interaction between genotypes and tillage operations. Two cultivation methods were applied in the main plot and 10 wheat genotypes (Kanchan, Gourav, Shatabdi, Sourav, BAW 1008, BAW 1006, BAW 1004, BAW 969, BAW 968 and BAW 966) were tested in the sub plots. The genotypes showed a wide range of variation for yield and related characters. Under bed condition, all the genotypes significantly produced higher grain yield except Gourav and Sourav. Variety Shatabdi produced maximum grain $spike^{-1}$ and 1000 grain weight.

BARI (2003) tested performance of different varieties of wheat and found Shatabdi produced the highest yield (2.72 t $ha^{-1}$) followed by Gourav (2.66 t $ha^{-1}$). The lowest yield was produced by Kanchan (2.52 t $ha^{-1}$).

Litvinrnko *et al.* (1997) produced winter wheat with high grain quality for bread making in Southern Ukraine. Wheat breeding was started more than 80 years ago. Over this time, seven wheat varieties were selected where yield potential increased from 2.73 to 6.74 t $ha^{-1}$.

Samson *et al.* (1995) reported that among the different varieties the significant highest grain yield (3.5 t $ha^{-1}$) was produced by the variety Sowghat which was closely followed by the variety BAW-748. Other four varieties namely Sonalika, CB-84, Kanchan and Seri-82 yielded 2.70, 2.83, 3.08 and 3.15 t $ha^{-1}$, respectively.

Arbinda *et al.* (1994) observed that the grain yield was significantly affected by different varieties in Bangladesh. The genotypes CB-15 produced higher grain yield (3.7 t $ha^{-1}$) that was attributed to more number of spikes $m^{-2}$ and grains $spike^{-1}$.

In varietal demonstration at different districts of Bangladesh BARI (1993) reported that mean yield of Kanchan, Akbar, Agrani and Sonalika were 3.59, 3.29, 3.12 and 2.81 t $ha^{-1}$, respectively. Variety Kanchan, Akbar, Aghrani showed 28, 17 and 12% higher grain yield over check variety Sonalika.

## CHAPTER III

## MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2007 to March 2008 to study the effect of irrigation on the growth and yield of different wheat varieties. The details of the materials and methods have been presented below:

### 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 $23^{0}74^{\prime}$ N latitude and $90^{0}35^{\prime}$ E longitude with an elevation of 8.2 meter from sea level.



#### 3.1.2 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 carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix I.

#### 3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to

February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979). Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

### 3.2 Experimental details

#### 3.2.1 Treatments

The experiment comprised two factors.

Factor A: Irrigation: 3 levels

i. $I_0$: Control

ii. $I_1$: One irrigation at crown root initiation stage (20 DAS)

iii. $I_2$: Two irrigations at crown root initiation stage (20 DAS) and grain filling stage (75 DAS)

Factor B: Variety: 4

i. $V_1$: Bijoy

ii. $V_2$: Prodip

iii. $V_3$: Sufi

iv. $V_4$: BAW1064

There were on the whole 12 (3 × 4) treatment combinations such as $I_0V_1$, $I_0V_2$, $I_0V_3$, $I_0V_4$, $I_1V_1$, $I_1V_2$, $I_1V_3$, $I_1V_4$, $I_2V_1$, $I_2V_2$, $I_2V_3$ and $I_2V_4$.

#### 3.2.2 Experimental design and layout

The experiment was laid out in split plot design with three replications. There were 36 plots having size 3 m × 2.5 m. Irrigation treatment were distributed in the main plot whereas, the varieties in the sub-plot. Detailed layout of the experimental plot was presented in Appendix III.

## 3.3 Growing of crops

### 3.3.1 Seed collection

The seeds of the test crops of this experiment Bijoy, Prodip, Sufi and BAW1064 were collected from Bangladesh Agricultural Research Institute, Joydevpur, Gazipur.

### 3.3.2 Preparation of the main field

The plot selected for the experiment was opened in the second week of November 2007 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 of seed.

### 3.3.3 Application of fertilizers and manure

The fertilizers N, P, K and S in the form of Urea, TSP, MP and Gypsum respectively were applied. In the irrigated treatment ($I_1$ and $I_2$) the entire amount of TSP, MP and Gypsum, 2/3[rd] of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation. In the non-irrigated plots ($I_0$) all fertilizers were applied at the final land preparation (BARI, 2006). The dose and method of application of fertilizer are shown in Table 1.

**Table 1. Dose and method of application of fertilizers in wheat field**

| Fertilizers | Dose (ha) | Application in irrigated plot (%) | | Application in non irrigated plot (%) |
|---|---|---|---|---|
| | | Basal | $1^{st}$ installment | Basal |
| Urea | 220 kg | 66.66 | 33.33 | 100 |
| TSP | 180 kg | 100 | -- | 100 |
| MP | 50 kg | 100 | -- | 100 |
| Gypsum | 120 kg | 100 | -- | 100 |
| Cowdung | 10 ton | 100 | -- | 100 |

Source: BARI, 2006

### 3.3.4 After care

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

#### 3.3.4.1 Irrigation and drainage

Flood irrigation was given as per treatment. Proper drainage system was also developed for draining out excess water.

#### 3.3.4.2 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 (55 DAS) manually.

### 3.3.4.3 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 to control leaf blight of wheat.

## 3.4 Harvesting, threshing and cleaning

The crop was harvested manually from each plot through the last week of March, 2008 depending upon the maturity of plant. 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. The grains were cleaned and weighted. The weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of wheat grain and straw $plot^{-1}$ were recorded and converted to t $ha^{-1}$.

## 3.5 Data collection

### 3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 40, 50, 60 DAS (Days after sowing) and at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

### 3.5.2 Number of tillers hill$^{-1}$

The number of tillers hill$^{-1}$ was recorded at the time of 30, 40, 50, 60 DAS (Days after sowing) and at harvest. Data were recorded as the average of 10 hills selected at random from the inner rows of each plot.

### 3.5.3 Spike length

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

### 3.5.4 Number of spikelet spike$^{-1}$

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

### 3.5.5 Number of grains spikelets$^{-1}$

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

### 3.5.6 Number of filled grains spike$^{-1}$

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

### 3.5.7 Number of unfilled grains spike$^{-1}$

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

### 3.5.8 Number of total grains spike$^{-1}$

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

### 3.5.9 Weight of 1000 seeds

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

### 3.5.10 Grain yield

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

### 3.5.11 Straw yield

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

### 3.5.12 Biological yield

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

Biological yield = Grain yield + Straw yield.

### 3.5.13 Harvest index

Harvest index was calculated from per hectare grain and straw yield that were obtained from each unit plot and expressed in percentage.

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

## 3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments. 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

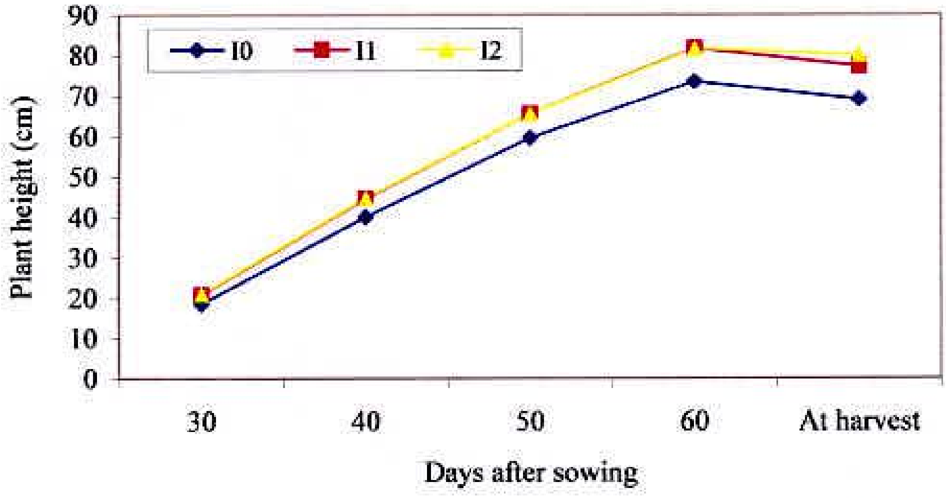
# RESULTS AND DISCUSSION

The experiment was conducted to determine the effect of irrigation on the growth and yield of different wheat varieties. Data on different growth parameter, yield attributes and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-VII. The results have been presented and possible interpretations given under the following headings:

## 4.1 Plant height

Plant height of wheat showed significant differences at 30, 40, 50 and 60 DAS and at harvest due to the application of irrigation (Figure 1). At 30 DAS, the longest plant (20.93 cm) was recorded from $I_2$ (two irrigation at crown root initiation and grain filling stage) which was however, statistically similar (20.87 cm) to $I_1$ (one irrigation at root initiation stage), while the shortest plant (18.53 cm) was found from $I_0$ (control). At 40 DAS the longest plant (44.73 cm) was observed from $I_2$ which was statistically similar (44.67 cm) to $I_1$ and the shortest plant (40.15 cm) was observed from $I_0$. AT 50 DAS, the longest plant (65.60 cm) was observed from $I_2$ which was also statistically at par (65.58 cm) to $I_1$. Again the shortest plant (59.65 cm) was observed from $I_0$. At 60 DAS, the longest plant (81.75 cm) was recorded from $I_1$ which was statistically similar (81.69 cm) to $I_2$ and the shortest plant (73.49 cm) was observed from $I_0$. At harvest, the longest plant (79.99 cm) was recorded from $I_2$ which was then closely followed (77.25 cm) by $I_1$. On the contrary the shortest plant (69.08 cm) was found from $I_0$. The above mentioned results revealed that irrigation had significant effect on plant height. Probably irrigation ensured the favorable condition for growth of wheat plant and the ultimate result was the tallest plant whereas control condition hindered the growth and plant height. Zhai *et al.* (2003) reported that water stress significantly inhibited the growth of winter wheat. Gupta *et al.* (2001) reported that water stress at booting stage caused a greater reduction in plant height.

Different wheat variety showed significant differences on plant height at 30, 40, 50 and 60 DAS and at harvest (Figure 2). At 30 DAS, the longest plant (21.42 cm) was observed from $V_2$ (Prodip) which was closely followed (20.64 cm) by $V_3$ (Sufi) and the shortest plant (18.54 cm) was found from $V_4$ (BAW 1064) which was closely followed (19.84 cm) by $V_1$ (Bijoy). At 40 DAS the longest plant (45.40 cm) was recorded from $V_2$ which was closely followed by $V_3$ (44.35 cm) and the shortest plant was observed from $V_4$ (39.97 cm) which was closely followed by $V_1$ (43.00 cm). At 50 DAS, the longest plant (66.58 cm) was found from $V_2$ which was closely followed by $V_3$ (65.13 cm), whereas the shortest plant (58.84 cm) was recorded from $V_4$ which was at par with $V_1$ (63.88 cm). At 60 DAS the longest plant (83.04 cm) was observed from $V_2$ which was statistically similar (81.11 cm) to $V_3$, while the shortest plant (72.29 cm) was found from $V_4$ which was closely followed by $V_1$ (79.46 cm). At harvest, the longest plant (80.03 cm) was recorded from $V_2$ which was statistically similar to $V_3$ (78.23 cm). The shortest plant (69.50 cm) was found from $V_4$ which was at par (74.01 cm) with $V_1$. Different variety produced different plant height on the basis of their varietal characters. Wheat Research Center (2003) reported from their experiments that the genotypes showed a wide range of variation for yield related characters.

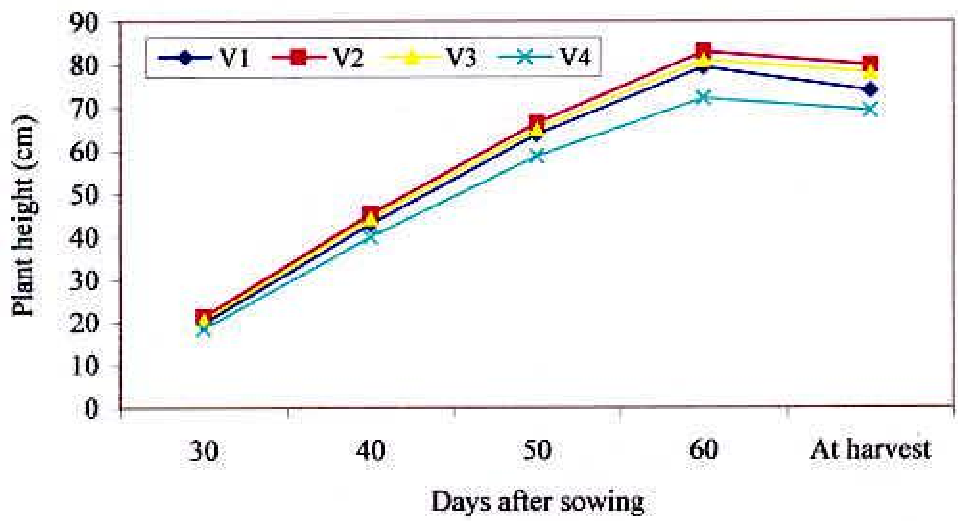



$I_0$: No irrigation

$I_1$: One irrigation (crown root initiation stage)

$I_2$: Two irrigations (crown root initiation and grain filling stage)

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




$V_1$: Bijoy $V_2$: Prodip

$V_3$: Sufi $V_4$: BAW1064

Figure 2. Effect of variety on the plant height of wheat

Interaction effect of irrigation and variety showed significant effect on plant height of wheat at 30, 40, 50 and 60 DAS and at harvest (Table 2). At 30 DAS, the longest plant (22.42 cm) was recorded from the treatment combination of $I_2V_2$ (two irrigation at crown root initiation and grain filling stage × Prodip), whereas, the shortest plant height (17.07 cm) was observed from the treatment combination of $I_0V_4$ (control × BAW1064). At 40 DAS, the longest plant (47.23 cm) was recorded from the treatment combination of $I_2V_2$, while the shortest (35.11 cm) was found from the treatment combination of $I_0V_4$. At 50 DAS, the longest plant (68.96 cm) was obtained from the treatment combination of $I_2V_2$ and the shortest (52.99 cm) was recorded from the treatment combination of $I_0V_4$. AT 60 DAS, the longest plant (86.26 cm) was found from $I_2V_2$, while the shortest (64.27 cm) was observed from the treatment combination of $I_0V_4$. At harvest, the longest plant (83.79 cm) was obtained from the treatment combination of $I_2V_2$ whereas the shortest (60.41 cm) was observed from the treatment combination of $I_0V_4$. Thus during this experiment different varieties responded differently to input supply, method of cultivation and the prevailing environment during the growing season. Similar findings were reported by Islam, 1997.



### 4.2 Number of total tillers plant$^{-1}$

Statistically significant variation was recorded for number of total tillers plant$^{-1}$ of wheat at 30, 40, 50 and 60 DAS and at harvest due to the application of irrigation (Figure 3). At 30 DAS, the maximum number of total tillers plant$^{-1}$ was recorded from $I_2$ (2.17) which was statistically similar to $I_1$ (2.13) and the minimum tillers (1.74) at this stage was observed from $I_0$. At 40 DAS, the maximum number

**Table 2. Interaction effect of irrigation and variety on the plant height of wheat**

| Treatments | Plant height (cm) at | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| $I_0V_1$ | 18.68 d | 41.48 d | 61.37 f | 75.93 d | 67.85 e |
| $I_0V_2$ | 19.48 cd | 42.16 d | 62.40 ef | 77.17 d | 73.29 cd |
| $I_0V_3$ | 18.89 cd | 41.84 d | 61.83 ef | 76.58 d | 74.79 bcd |
| $I_0V_4$ | 17.07 e | 35.11 e | 52.99 g | 64.27 e | 60.41 f |
| $I_1V_1$ | 21.09 b | 45.43 bc | 66.57 bc | 83.15 ab | 77.41 b |
| $I_1V_2$ | 22.36 a | 46.82 ab | 68.40 ab | 85.69 a | 83.02 a |
| $I_1V_3$ | 20.75 b | 44.59 c | 65.51 cd | 81.62 bc | 77.26 bc |
| $I_1V_4$ | 19.26 cd | 41.82 d | 61.85 ef | 76.55 d | 71.31 de |
| $I_2V_1$ | 19.74 c | 42.10 d | 63.71 de | 79.31 cd | 76.77 bc |
| $I_2V_2$ | 22.42 a | 47.23 a | 68.96 a | 86.26 a | 83.79 a |
| $I_2V_3$ | 22.28 a | 46.62 ab | 68.06 ab | 85.14 ab | 82.63 a |
| $I_2V_4$ | 19.28 cd | 42.99 d | 61.68 f | 76.06 d | 76.77 bc |
| Sx | 0.275 | 0.539 | 0.608 | 1.229 | 1.234 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 |
| CV(%) | 7.37 | 5.16 | 10.66 | 6.70 | 8.83 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

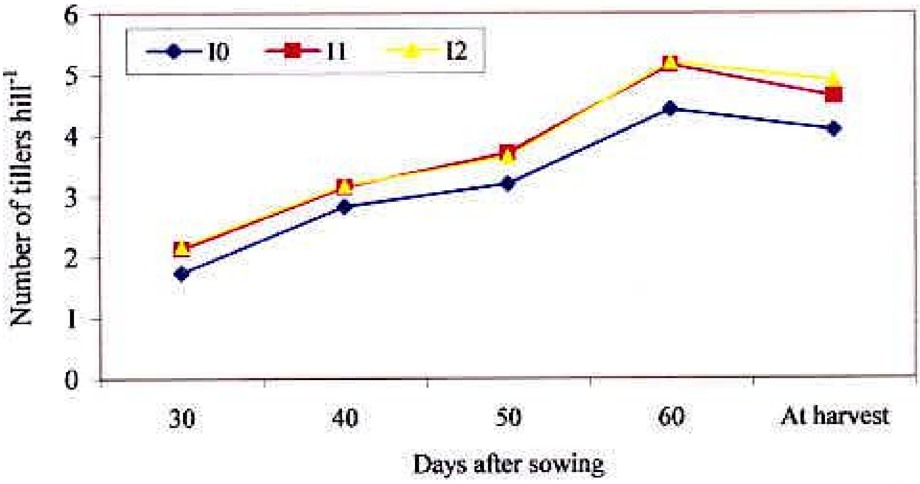
$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

of total tillers plant$^{-1}$ (3.17) was recorded from $I_2$ which was statistically similar (3.15) to $I_1$, again the minimum number of total tillers plant$^{-1}$ (2.83) was observed from $I_0$. At 50 DAS, the maximum number of total tillers plant$^{-1}$ (3.71) was recorded from $I_1$ which was statistically similar (3.65) to $I_2$ and the minimum number of total tillers plant$^{-1}$ (3.20) was recorded from $I_0$. At 60 DAS, the maximum number of total tillers plant$^{-1}$ (5.19) was found from $I_2$ which was statistically similar (5.15) to $I_1$. The minimum number of total tillers plant$^{-1}$ (4.42) at this stage was observed from $I_0$. At harvest, the maximum number of total tillers plant$^{-1}$ (4.89) was recorded from $I_2$ which was at par (4.63) with $I_1$, whereas the minimum (4.08) was found from $I_0$. The increased production of tiller due to irrigation ensured the moisture supply. In the previous studies, moisture regimes were found to ensure all essential nutrients for the plant growth and the ultimate result was the maximum growth with maximum number of tillers hill$^{-1}$. Gupta *et al.* (2001) reported that water stress at booting stage caused a greater reduction in number of tillers.

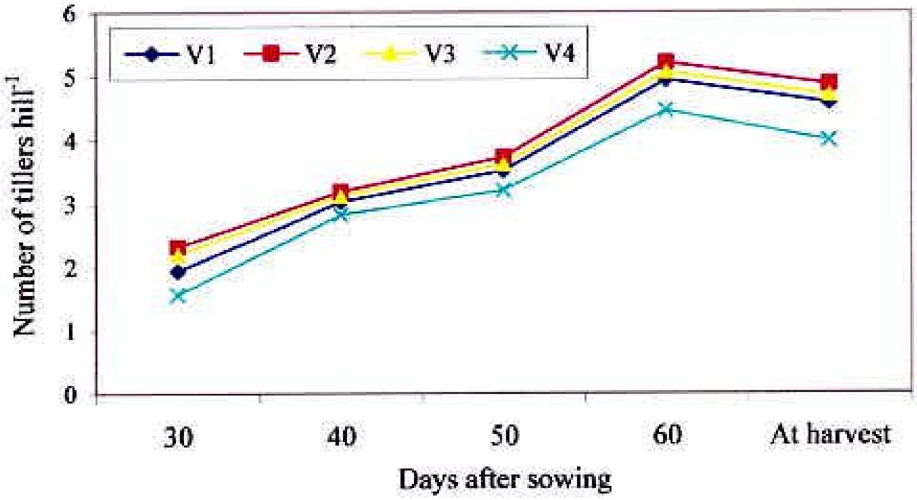


Number of total tillers plant$^{-1}$ at 30, 40, 50 and 60 DAS and at harvest showed significant differences due to different wheat varieties (Figure 4). At 30 DAS, the maximum number of total tillers plant$^{-1}$ (2.33) was found from $V_2$ (Prodip) which was closer (2.21) to that of $V_3$ (Sufi). The minimum number of total tillers plant$^{-1}$ (1.57) at this stage was obtained from $V_4$ (BAW 1064) which was at par with $V_1$ (1.94). At 40 DAS, the maximum number of total tillers plant$^{-1}$ (3.19) was recorded from $V_2$ which was statistically similar (3.12) to $V_3$. Again the




$I_0$: No irrigation
$I_1$: One irrigation (crown root initiation stage)
$I_2$: Two irrigations (crown root initiation and grain filling stage)

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




$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Figure 4. Effect of variety on the number of tillers hill$^{-1}$ of wheat

minimum number of total tillers plant$^{-1}$ (2.83) at this DAS was observed from $V_4$ which was a bit lower than the value (3.03) as was shown by $V_1$. At 50 DAS, the maximum number of total tillers plant$^{-1}$ (3.73) was recorded from $V_2$ which was closely followed (3.62) by $V_3$, whereas the minimum number of total tillers plant$^{-1}$ (3.21) was recorded from $V_4$ which however, was slightly lower than the value shown (3.52) by $V_1$. At 60 DAS, the maximum number of total tillers plant$^{-1}$ (5.21) was found from $V_2$ which was closely followed (5.06) by $V_3$ and the minimum (4.46) was recorded from $V_4$ which was closely followed (4.94) by $V_1$. At harvest, the maximum number of total tillers plant$^{-1}$ (4.87) was obtained from $V_2$ which was statistically similar (4.70) with $V_3$, while the minimum number of total tillers plant$^{-1}$ (3.99) was recorded from $V_4$ which was nearer to 4.58 shown by $V_1$. Previous findings suggested that management practices influences the number of tillers plant$^{-1}$ but variety itself manipulated the number of tillers hill$^{-1}$. It was observed that wheat varieties differed significantly in producing various yield components and yield (Hasan, 1995).

The variation was also found due to the interaction effect of irrigation and variety in terms of number of total tillers plant$^{-1}$ of wheat at 30, 40, 50 and 60 DAS and at harvest (Table 3). At 30 DAS, the maximum number of total tillers plant$^{-1}$ (2.48) was obtained from the treatment combination of $I_2V_2$, while the minimum (1.10) was recorded from the treatment combination of $I_0V_4$. At 40 DAS, the maximum number of total tillers plant$^{-1}$ (3.30) was recorded from the treatment combination of $I_2V_2$, again the minimum (2.50) was found from the treatment combination of $I_0V_4$. At 50 DAS, the maximum number of total tillers plant$^{-1}$ (3.83) was recorded from the treatment combination of $I_2V_2$ and the minimum (2.67) was obtained from the treatment combination of $I_0V_4$. At 60 DAS, the maximum number of total tillers plant$^{-1}$ (5.49) was observed from the treatment combination of $I_2V_2$, while the minimum (3.77) was recorded from the treatment combination of $I_0V_4$. Finally at harvest, the maximum number of total tillers plant$^{-1}$ (5.27) was found from the treatment combination of $I_2V_2$ whereas the minimum (3.37) was recorded from the treatment combination of $I_0V_4$.

### 4.3 Spike length

Due to the application of irrigation, spike length of wheat showed significant differences (Table 4). The highest spike length (11.30 cm) was obtained from $I_2$ which was closely followed (10.45 cm) by $I_1$. On the other hand, the lowest (9.04 cm) was observed from $I_0$.

A statistically significant difference was also recorded due to different wheat variety in terms of spike length (Table 4). The highest spike length (10.90 cm) was found from $V_2$ which was statistically similar (10.71 cm) to $V_3$. The lowest spike length (9.44 cm) was obtained from $V_4$ which was slightly lower than that (10.01 cm) of $V_1$. Spike length had positive relationships with yield which Jalleta (2004) reported to be one of the main criteria for adaptation of wheat varieties.

**Table 3. Interaction effect of irrigation and variety on the number of total tillers per plant of wheat**

| Treatment | Number of total tillers per plant at | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| $I_0V_1$ | 1.77 e | 2.83 d | 3.27 g | 4.57 e | 4.30 ef |
| $I_0V_2$ | 2.07 bc | 3.00 c | 3.50 de | 4.70 e | 4.33 ef |
| $I_0V_3$ | 2.03 bcd | 2.97 c | 3.37 f | 4.63 e | 4.33 ef |
| $I_0V_4$ | 1.10 f | 2.50 e | 2.67 h | 3.77 f | 3.37 g |
| $I_1V_1$ | 2.13 b | 3.17 ab | 3.74 bc | 5.22 abc | 4.77 bc |
| $I_1V_2$ | 2.43 a | 3.27 a | 3.87 a | 5.45 a | 5.00 ab |
| $I_1V_3$ | 2.17 b | 3.14 b | 3.70 c | 5.15 bc | 4.57 cde |
| $I_1V_4$ | 1.77 e | 3.00 c | 3.54 d | 4.78 de | 4.17 f |
| $I_2V_1$ | 1.92 cde | 3.10 bc | 3.56 d | 5.03 cd | 4.67 cd |
| $I_2V_2$ | 2.48 a | 3.30 a | 3.83 a | 5.49 a | 5.27 a |
| $I_2V_3$ | 2.42 a | 3.27 a | 3.79 ab | 5.39 ab | 5.20 a |
| $I_2V_4$ | 1.85 de | 3.00 c | 3.43 ef | 4.83 de | 4.43 def |
| Sx | 0.066 | 0.039 | 0.028 | 0.087 | 0.103 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 |
| CV(%) | 5.72 | 12.21 | 10.37 | 9.06 | 6.93 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Spike length of wheat showed significant differences due to the interaction effect of irrigation and variety (Table 5). The highest spike length (11.96 cm) was obtained from the treatment combination of $I_2V_3$ which was statistically similar (11.93 cm) to $I_2V_2$. The lowest spike length (7.42 cm) was observed from the treatment combination of $I_0V_4$.

## 4.4 Number of spikelets spike$^{-1}$

Number of spikelets spike$^{-1}$ of wheat showed statistically significant differences due to the application of irrigation (Table 4). The maximum number of spikelets spike$^{-1}$ (19.25) was found from $I_2$ which was statistically similar (19.14) to $I_1$. The minimum number of spikelets spike$^{-1}$ (15.33) was observed in $I_0$. Irrigation conforms favorable environment for grain formation. Yadav *et al.* (1995) also reported similar findings earlier from their experiment.

Statistically significant variation was observed due to different wheat variety on number of spikelets spike$^{-1}$ (Table 4). The maximum number of spikelets spike$^{-1}$ (18.31) was recorded from $V_3$ which was statistically similar (18.26) to $V_1$. On the contrary, the minimum number of spikelets spike$^{-1}$ (17.38) was recorded from $V_4$ which was statistically similar (17.68) with $V_2$.

Table 4. Effect of irrigation and variety on spike length, number of spikelets spike$^{-1}$, number of grains spikelets$^{-1}$, number of filled and unfilled grains spike$^{-1}$ of wheat

| Treatments | Spike length (cm) | Number of spikelets spike$^{-1}$ | Number of grains spikelet$^{-1}$ | Number of filled grains spike$^{-1}$ | Number of unfilled grains spike$^{-1}$ |
|---|---|---|---|---|---|
| **Irrigation** | | | | | |
| $I_0$ | 9.04 c | 15.33 b | 2.14 c | 27.36 c | 5.43 a |
| $I_1$ | 10.45 b | 19.14 a | 2.49 b | 42.87 b | 4.81 b |
| $I_2$ | 11.30 a | 19.25 a | 2.78 a | 49.21 a | 4.14 c |
| Sx | 0.099 | 0.097 | 0.032 | 0.472 | 0.083 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Variety** | | | | | |
| $V_1$ | 10.01 b | 18.26 a | 2.37 c | 38.60 b | 4.90 ab |
| $V_2$ | 10.90 a | 17.68 b | 2.65 a | 42.87 a | 4.58 c |
| $V_3$ | 10.71 a | 18.31 a | 2.49 b | 41.17 a | 4.64 c |
| $V_4$ | 9.44 c | 17.38 b | 2.38 c | 36.61 c | 5.04 a |
| Sx | 0.136 | 0.192 | 0.030 | 0.641 | 0.091 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 7.98 | 5.22 | 9.67 | 6.83 | 5.68 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

**Table 5. Interaction effect of irrigation and variety on spike length, number of spikelets spike$^{-1}$, number of grains spikelets$^{-1}$, number of filled and unfilled grains spike$^{-1}$ of wheat**

| Treatments | Spike length (cm) | Number of spikelets spike$^{-1}$ | Number of grains spikelet$^{-1}$ | Number of filled grains spike$^{-1}$ | Number of unfilled grains spike$^{-1}$ |
|---|---|---|---|---|---|
| $I_0V_1$ | 9.17 e | 15.67 c | 2.10 hi | 27.27 fg | 5.57 ab |
| $I_0V_2$ | 9.70 de | 14.30 d | 2.23 fgh | 26.63 g | 5.27 abc |
| $I_0V_3$ | 9.89 de | 16.07 c | 2.20 gh | 30.20 f | 5.13 bcd |
| $I_0V_4$ | 7.42 f | 15.30 c | 2.03 i | 25.33 g | 5.73 a |
| $I_1V_1$ | 10.47 bcd | 19.40 a | 2.53 d | 44.30 cd | 4.83 cd |
| $I_1V_2$ | 11.09 b | 19.30 a | 2.73 c | 47.93 b | 4.83 cd |
| $I_1V_3$ | 10.27 cd | 19.77 a | 2.37 ef | 41.83 d | 4.90 cd |
| $I_1V_4$ | 9.97 d | 18.10 b | 2.33 efg | 37.40 e | 4.67 de |
| $I_2V_1$ | 10.39 bcd | 19.71 a | 2.47 de | 44.23 cd | 4.30 ef |
| $I_2V_2$ | 11.93 a | 19.44 a | 2.97 a | 54.03 a | 3.63 g |
| $I_2V_3$ | 11.96 a | 19.11 ab | 2.90 ab | 51.47 a | 3.90 fg |
| $I_2V_4$ | 10.94 bc | 18.74 ab | 2.77 bc | 47.10 bc | 4.73 de |
| Sx | 0.236 | 0.333 | 0.052 | 1.110 | 0.157 |
| Level of Significance | 0.01 | 0.05 | 0.01 | 0.01 | 0.05 |
| CV(%) | 7.98 | 5.22 | 9.67 | 6.83 | 5.68 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Interaction effect of irrigation and variety showed significant differences in terms of number of spikelets spike$^{-1}$ of wheat (Table 5). The maximum number of spikelets spike$^{-1}$ (19.77) was observed from the treatment combination of $I_1V_3$ whereas the minimum (15.30) was recorded from the treatment combination of $I_0V_4$.

### 4.5 Number of grains spikelets$^{-1}$

Number of grains spikelets$^{-1}$ of wheat differed significantly due to the application of irrigation under the trial (Table 4). The maximum number of grains spikelet$^{-1}$ (2.78) was found from $I_2$ which was closely followed by $I_1$ (2.49). In contrast, the minimum number of grains spikelet$^{-1}$ (2.14) was observed from $I_0$ condition. Previous works revealed the importance of water supply in favor of grain production. Zhai *et al.* (2003) reported that water stress significantly inhibited the yield components of winter wheat.

Number of grains spikelet$^{-1}$ showed statistically significant differences due to different wheat variety (Table 4). The maximum number of grains spikelet$^{-1}$ (2.65) was observed from $V_2$ which was closely followed by $V_3$ (2.49). On the other hand, the minimum number of grains spikelet$^{-1}$ (2.37) was recorded from $V_1$ which was statistically similar with $V_4$ (2.38).

Significant differences were also recorded due to the interaction effect of irrigation and variety in respect of number of grains spikelet$^{-1}$ of wheat (Table 5). The maximum number of grains spikelet$^{-1}$ (2.97) was recorded from the treatment combination of $I_2V_2$ which was statistically at par (2.90) with $I_2V_3$. The minimum grains spikelet$^{-1}$ (2.03) was recorded from the treatment combination of $I_0V_4$. Different varieties responded differently to input supply, method of cultivation and the prevailing environment during the growing season. These sorts of findings has been reported by Naser, 1996.

### 4.6 Number of filled grains spike$^{-1}$

Statistically significant variation was noticed number of filled grains spike$^{-1}$ of wheat due to the application of irrigation (Table 4). The maximum number of filled grains spike$^{-1}$ (49.21) was obtained from $I_2$ which was closely followed (42.87) by $I_1$ and the minimum number of filled grains spike$^{-1}$ (27.36) was observed from $I_0$ condition. Zhai *et al.* (2003) also reported that water stress significantly inhibited the filled grains spike$^{-1}$ of winter wheat.

Different wheat varieties differ significantly for number of filled grains spike$^{-1}$ (Table 4). The maximum number of filled grains spike$^{-1}$ (42.87) was recorded from $V_2$ which was statistically similar (41.17) with $V_3$. On the other hand, the minimum number of filled grains spike$^{-1}$ (36.61) was recorded from $V_4$ which was closely followed (38.60) by $V_4$. Wheat Research Center (2003) reported from their experiments that the genotypes showed a wide range of variation for yield related characters. Arbinda *et al.* (1994) also observed that filled grains of wheat significantly affected by different varieties in Bangladesh.

Interaction effect of irrigation and variety in terms of number of filled grains spike$^{-1}$ of wheat showed significant differences under the trial (Table 5). The maximum number of filled grains spike$^{-1}$ (54.03) was found from the treatment combination of $I_2V_2$ which was statistically similar (51.47) to $I_2V_3$ and the minimum (25.33) was recorded from the treatment combination of $I_0V_4$.

### 4.7 Number of unfilled grains spike$^{-1}$

Number of unfilled grains spike$^{-1}$ of wheat showed statistically significant variation due to the application of irrigation (Table 4). The minimum number of unfilled grains spike$^{-1}$ (4.14) was found from $I_2$ which was followed (4.81) by $I_1$ and the maximum number of unfilled grains spike$^{-1}$ (5.43) was observed from $I_0$ condition.

Different wheat varieties differed significantly in terms of number of unfilled grains spike$^{-1}$ (Table 4). The minimum number of unfilled grains spike$^{-1}$ (4.58) was observed from $V_2$ which was statistically similar (4.64) with $V_3$, while the maximum number of unfilled grains spike$^{-1}$ (5.04) was recorded from $V_4$ which was statistically similar (4.90) with $V_1$.

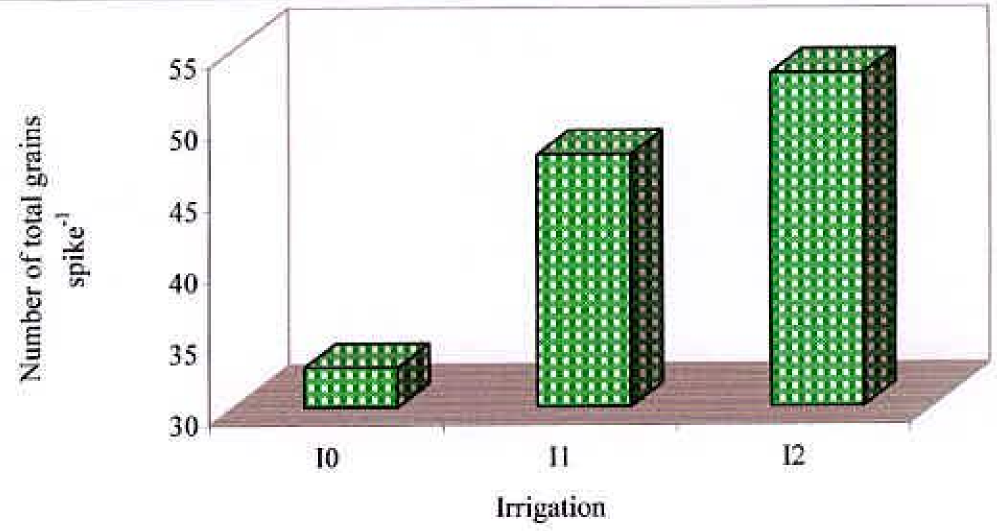
The variation was recorded due to the interaction effect of irrigation and variety for number of unfilled grains spike$^{-1}$ of wheat (Table 5). The minimum number of unfilled grains spike$^{-1}$ (3.63) was found from the treatment combination of $I_2V_2$ which was statistically similar (3.90) to $I_2V_3$ and the maximum (5.73) was obtained from the treatment combination of $I_0V_4$.

### 4.8 Number of total grains spike$^{-1}$

Statistically significant variation was recorded for number of total grains spike$^{-1}$ of wheat due to the application of irrigation (Figure 5). The maximum number of total grains spike$^{-1}$ (53.35) was recorded from $I_2$ which was followed (47.67) by $I_1$, whereas the minimum number (32.78) was observed from $I_0$. Debelo *et al.* (2001) also reported considerable direct or indirect contribution of water to grain yield under low soil moisture conditions.

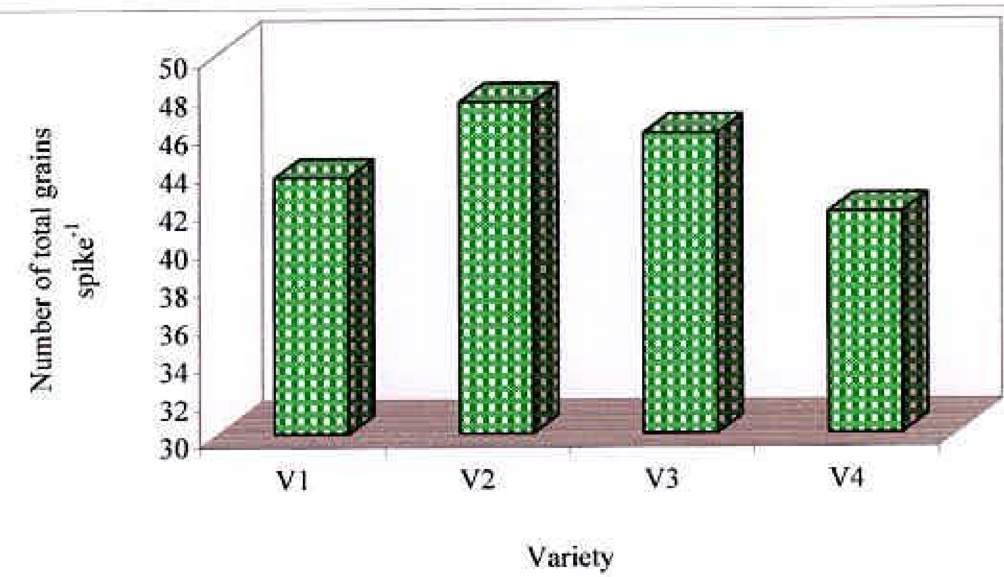
Number of total grains spike$^{-1}$ showed significant differences for different wheat variety (Figure 6). The maximum number (47.44) was found from $V_2$ which however, was statistically similar (45.81) to $V_3$. The minimum number of total grains spike$^{-1}$ (41.66) was obtained from $V_4$ which was closer with $V_1$ (43.50).

Interaction effect of irrigation and variety showed significant variation in terms of number of total grains spike$^{-1}$ of wheat (Figure 7). The maximum number (57.67) was observed in $I_2V_2$ which was statistically similar (55.37) with $I_2V_3$. Under interaction the minimum value (31.07) was found in the treatment combination of $I_0V_4$.



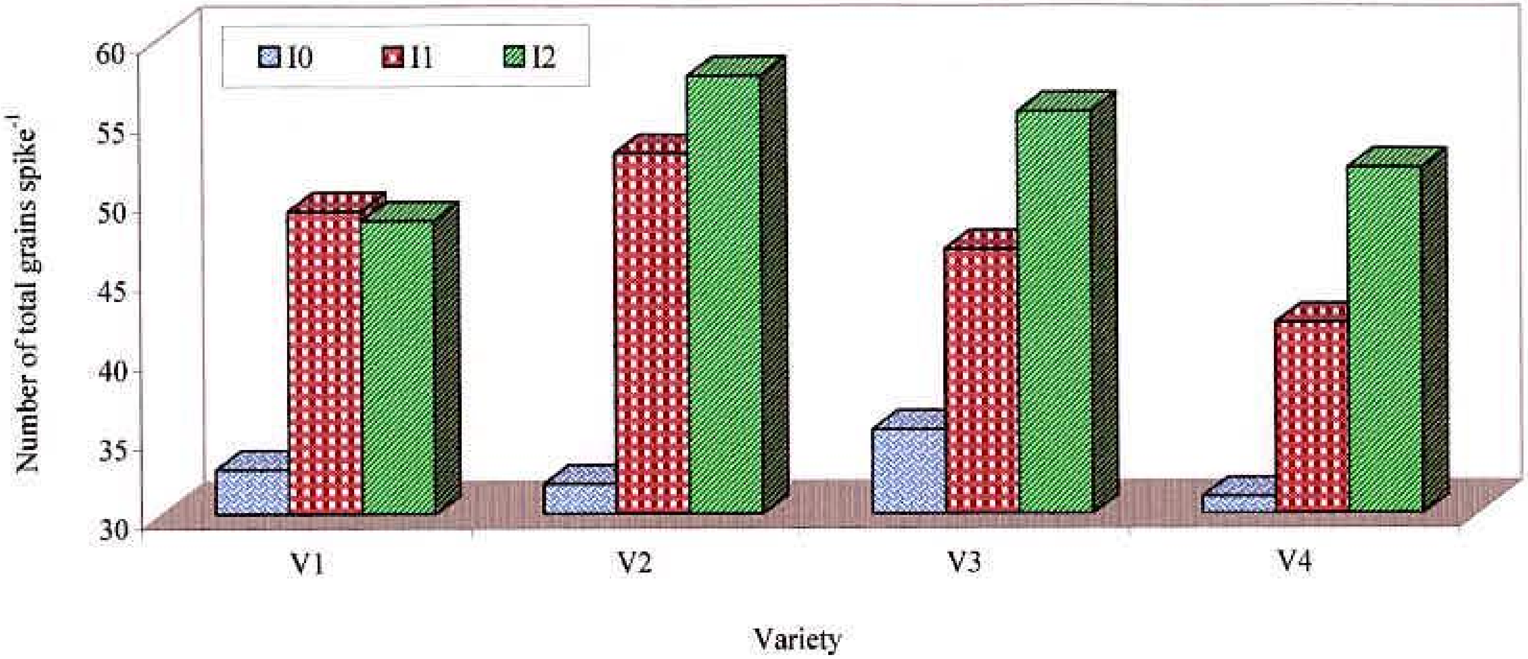

$I_0$: No irrigation
$I_1$: One irrigation (crown root initiation stage)
$I_2$: Two irrigations (crown root initiation and grain filling stage)

Figure 5. Effect of irrigation on the number of total grains spike$^{-1}$ of wheat




$V_1$: Bijoy $V_2$: Prodip
$V_3$: Sufi $V_4$: BAW1064

Figure 6. Effect of variety on the number of total grains spike$^{-1}$ of wheat




$I_0$: No irrigation
$I_1$: One irrigation (crown root initiation stage)
$I_2$: Two irrigations (crown root initiation and grain filling stage)

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Figure 7. Interaction effect of irrigation and variety on the number of total grains spike$^{-1}$ of wheat

### 4.9 Weight of 1000 seeds

Weight of 1000 seeds of wheat showed significant differences for the application of irrigation (Table 6). The highest weight of 1000 seeds (46.98 g) was found from $I_2$ which was slightly higher than that (44.93 g) of $I_1$. On the other hand, the lowest (39.20 g) was observed in $I_0$.

Results of this study revealed that different wheat variety showed remarkable variation on 1000 seed weight (Table 6). The highest weight (46.35 g) was observed in $V_2$ which was then followed (43.89 g) by $V_3$. The lowest weight (41.85 g) was in $V_4$ which however, was statistically similar (42.72 g) with $V_1$.

Statistically significant variation was recorded due to the interaction effect of irrigation and variety in terms of weight of 1000 seeds of wheat (Table 7). The highest weight (49.33 g) was obtained from the treatment combination of $I_2V_2$ which was statistically similar to $I_2V_3$ and $I_1V_2$. The lowest value (36.30 g) was obtained from the treatment combination of $I_0V_4$.



### 4.10 Grain yield

Grain yield of wheat showed significant variation due to the application of irrigation (Table 6). The highest grain yield (2.54 t $ha^{-1}$) was recorded from $I_2$ which was then followed by $I_1$ (2.38 t $ha^{-1}$). The lowest grain yield (2.10 t $ha^{-1}$) was observed from $I_0$. The yield of wheat was found to increase following the application of water in the field. Zhai *et al.* (2003) also reported that water stress significantly inhibited the yield of winter wheat. But the highest grain yield (3.71 t

$ha^{-1}$) was obtained with the application of three irrigations (25, 45 and 60 DAS) and the lowest was with no irrigation (2.61 t $ha^{-1}$).

Variety also showed significant variation in grain yield (Table 6). The highest grain yield (2.50 t $ha^{-1}$) was recorded from $V_2$ that was followed by the value of (2.37 t $ha^{-1}$) of $V_3$. The lowest grain yield (2.22 t $ha^{-1}$) was observed in $V_4$ which was statistically similar (2.26 t $ha^{-1}$) to $V_1$. Crop yield is mainly a genetical character. Wheat Research Center (2003) reported from their experiments that the genotypes showed a wide range of variation in yield of wheat. Arbinda *et al.* (1994) also observed that the grain yield was significantly governed by genotypes.

Interaction effect of irrigation and variety showed statistically significant differences in terms of grain yield of wheat (Table 7). The highest grain yield (2.75 t $ha^{-1}$) was obtained from the treatment combination of $I_2V_2$ that was statistically similar (2.69 t $ha^{-1}$) to $I_2V_3$. On the other hand, the lowest grain yield (2.01 t $ha^{-1}$) was recorded from the treatment combination of $I_0V_4$ (Table 7). Generally, different varieties respond differently to input supply, method of cultivation and the prevailing environment during the growing season.

**Table 6. Effect of irrigation and variety on the weight of 1000 seeds, grain & straw yield and harvest index of wheat**

| Treatments | Weight of 1000 seeds (g) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| **Irrigation** | | | | |
| $I_0$ | 39.20 c | 2.10 c | 2.43 c | 46.28 a |
| $I_1$ | 44.93 b | 2.38 b | 3.18 b | 42.91 b |
| $I_2$ | 46.98 a | 2.54 a | 3.80 a | 40.27 c |
| Sx | 0.325 | 0.036 | 0.041 | 0.165 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.01 |
| **Variety** | | | | |
| $V_1$ | 42.72 bc | 2.26 c | 2.89 c | 44.00 a |
| $V_2$ | 46.35 a | 2.50 a | 3.56 a | 41.82 b |
| $V_3$ | 43.89 b | 2.37 b | 3.22 b | 43.01 ab |
| $V_4$ | 41.85 c | 2.22 c | 2.88 c | 43.77 a |
| Sx | 0.405 | 0.031 | 0.063 | 0.428 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 12.78 | 7.94 | 5.98 | 12.97 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

**Table 7. Interaction effect of irrigation and variety on the weight of 1000 seeds, grain & straw yield and harvest index of wheat**

| Treatments | Weight of 1000 seeds (g) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| $I_0V_1$ | 38.83 f | 2.05 gh | 2.41 g | 46.04 a |
| $I_0V_2$ | 41.84 de | 2.21 efg | 2.54 fg | 46.62 a |
| $I_0V_3$ | 39.83 ef | 2.11 fgh | 2.45 g | 46.27 a |
| $I_0V_4$ | 36.30 g | 2.01 h | 2.34 g | 46.17 a |
| $I_1V_1$ | 45.07 bc | 2.39 cd | 3.20 cd | 42.82 bc |
| $I_1V_2$ | 47.89 a | 2.54 bc | 3.79 b | 40.18 d |
| $I_1V_3$ | 43.29 cd | 2.31 de | 2.93 de | 44.17 ab |
| $I_1V_4$ | 43.46 cd | 2.25 def | 2.81 ef | 44.45 ab |
| $I_2V_1$ | 44.26 bc | 2.33 de | 3.08 de | 43.13 b |
| $I_2V_2$ | 49.33 a | 2.75 a | 4.36 a | 38.66 d |
| $I_2V_3$ | 48.54 a | 2.69 ab | 4.29 a | 38.59 d |
| $I_2V_4$ | 45.80 b | 2.39 cd | 3.49 bc | 40.69 cd |
| Sx | 0.702 | 0.053 | 0.108 | 0.741 |
| Level of Significance | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 12.78 | 7.94 | 5.98 | 12.97 |

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

$I_0$: No irrigation
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

### 4.11 Straw yield

Statistically significant variation was recorded in straw yield of wheat due to the variation of irrigation (Table 6). The highest straw yield (3.80 t $ha^{-1}$) was observed from $I_2$ which was then followed (3.18 t $ha^{-1}$) by $I_1$. The lowest straw yield (2.43 t $ha^{-1}$) was obtained from $I_0$ condition. Wang *et al.* (2002) reported that irrigation increased straw yield of wheat significantly over the control.

Significant variation was also observed in different wheat varieties on straw yield (Table 6). The highest straw yield (3.56 t $ha^{-1}$) was observed in $V_2$ and the second highest with $V_3$ (3.22 t $ha^{-1}$). The lowest straw yield (2.88 t $ha^{-1}$) was recorded from $V_4$ which was statistically similar (2.89 t $ha^{-1}$) to $V_1$.

A significant difference was observed due to the interaction effect of irrigation and variety in terms of straw yield of wheat (Table 7). The highest straw yield (4.36 t $ha^{-1}$) was recorded from the treatment combination of $I_2V_2$ which was statistically similar to $I_2V_3$ (4.29 t $ha^{-1}$). The lowest straw yield (2.34 t $ha^{-1}$) was recorded from the treatment combination of $I_0V_4$.

### 4.12 Biological yield

Biological yield of wheat differed significantly due to the application of irrigation (Figure 8). The highest biological yield (6.35 t $ha^{-1}$) was found from $I_2$ which was then closely followed (5.56 t $ha^{-1}$) by $I_1$. The lowest biological yield (4.53 t $ha^{-1}$) was recorded from $I_0$.

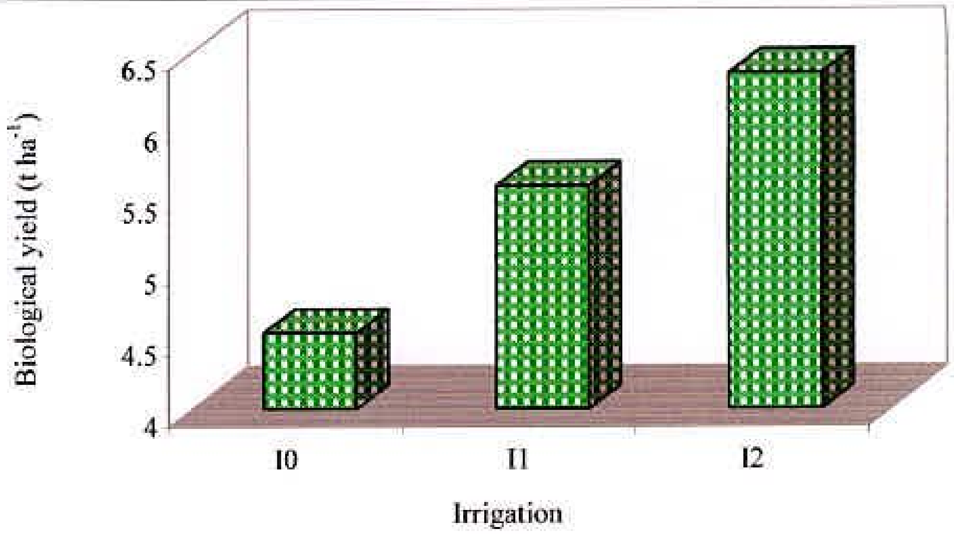
Different wheat variety showed significant variations in biological yield (Figure 9). The highest biological yield (6.06 t $ha^{-1}$) was recorded from $V_2$ which was similar to $V_3$ (5.59 t $ha^{-1}$). The lowest biological yield (5.10 t $ha^{-1}$) was obtained from $V_4$ which was statistically similar (5.16 t $ha^{-1}$) to $V_1$.

Interaction effect of irrigation and variety was significant in terms of biological yield of wheat (Figure 10). The highest biological yield (7.11 t $ha^{-1}$) was found from the $I_2V_2$. The second highest statistically similar biological yield (6.98 t $ha^{-1}$) was obtained with $I_2V_3$. Significantly the lowest biological yield (4.35 t $ha^{-1}$) was recorded from the treatment combination of $I_0V_4$.

### 4.13 Harvest index

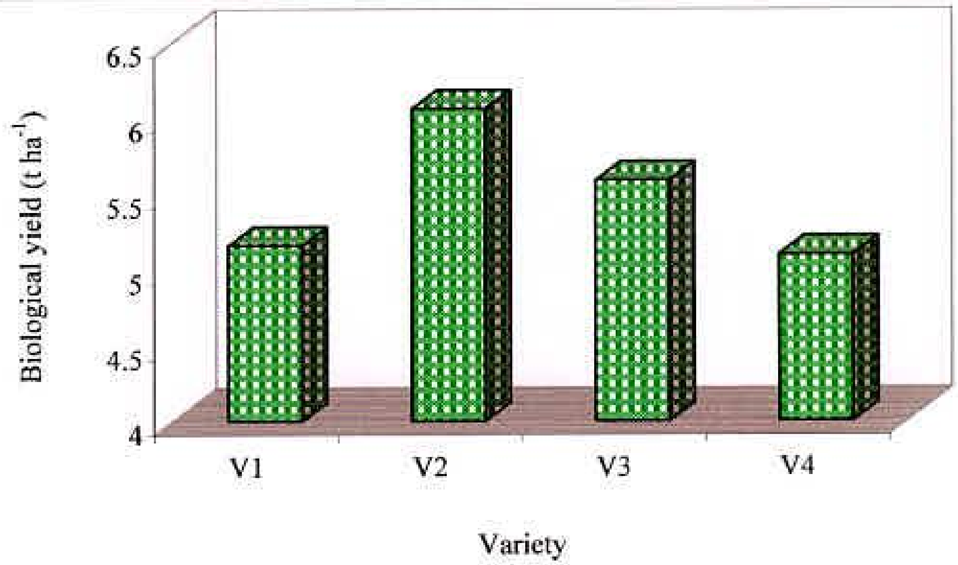
Statistically significant variation was recorded for harvest index of wheat due to the application of irrigation (Table 6). The minimum harvest index (40.27%) was obtained from $I_2$ and the maximum (46.28%) was from $I_0$.

Wheat varieties differed significantly in terms of the harvest index (Table 6). The minimum harvest index (41.82%) was recorded from $V_2$ but the maximum was recorded from (44.00%) from $V_1$. The maximum HI was statistically similar (43.77%) to $V_4$.



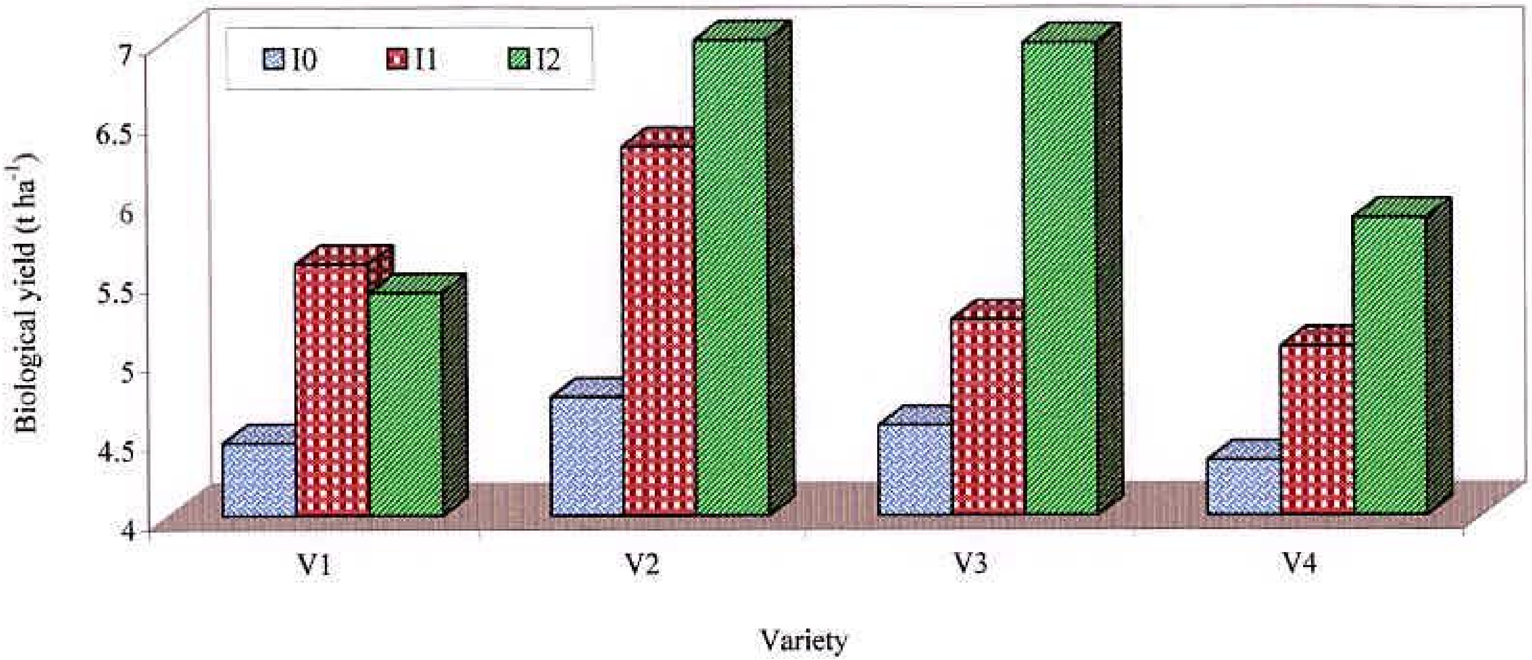

$I_0$: No irrigation
$I_1$: One irrigation (crown root initiation stage)
$I_2$: Two irrigations (crown root initiation and grain filling stage)

Figure 8. Effect of irrigation on the biological yield of wheat




$V_1$: Bijoy　　$V_2$: Prodip
$V_3$: Sufi　　$V_4$: BAW1064

Figure 9. Effect of variety on the biological yield of wheat




$I_0$: No irrigation
$I_1$: One irrigation (crown root initiation stage)
$I_2$: Two irrigations (crown root initiation and grain filling stage)

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Figure 10. Interaction effect of irrigation and variety on the biological yield of wheat

Differences were noticed due to the interaction effect of irrigation and variety for harvest index of wheat (Table 7). The minimum harvest index (38.59%) was recorded from the treatment combination of $I_2V_3$ which was statistically similar to $I_2V_2$ (38.66%) and $I_2V_2$ and the maximum harvest index (46.62%) was recorded from the treatment combination of $I_0V_2$ that similar to $I_0V_3$, $I_0V_4$ and $I_0V_1$.

# CHAPTER V

## SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2007 to March 2008 to study the effect of irrigation on the growth and yield of different wheat varieties. The experiment comprised as two factors. Irrigation: 3 levels ($I_0$: Control, $I_1$: one irrigation at crown root initiation stage, $I_2$: two irrigations one at crown root initiation stage and other at grain filling stage) and variety: 4 wheat varieties ($V_1$: Bijoy, $V_2$: Prodip, $V_3$: Sufi and $V_4$: BAW1064). There were all together 12 (3 × 4) treatment combinations. The experiment was laid out in split plot design with three replications. Data on different growth parameters, yield attributes and yield were recorded.

At harvest, the longest plant (79.99 cm) and the maximum number of total tilers plant$^{-1}$ (4.89) was recorded from $I_2$. The highest spike length (11.30 cm) was obtained from $I_2$. The maximum number of spikelets spike$^{-1}$ (19.25) was found from $I_2$. The maximum number of grains spikelets$^{-1}$ (2.78) was found from $I_2$. The maximum number of filled grains spike$^{-1}$ (49.21) was obtained from $I_2$. The minimum number of unfilled grains spike$^{-1}$ (4.14) was found from $I_2$. The maximum number of total grains spike$^{-1}$ (53.35) was recorded from $I_2$. The highest weight of 1000 seeds (46.98 g) was found from $I_2$. The highest grain yield (2.54 t ha$^{-1}$) was recorded from $I_2$. The highest straw yield (3.80 t ha$^{-1}$) was observed from $I_2$. The highest biological yield (6.35 t ha$^{-1}$) was found from .. The minimum harvest index (40.27%) was obtained from $I_2$ and the maximum (46.28%) was recorded from $I_0$.

At harvest, the longest plant (80.03 cm) and the maximum number of total tillers plant$^{-1}$ (4.87) was recorded from $V_2$. The highest spike length (10.90 cm) was found from $V_2$. The maximum number of spikelets spike$^{-1}$ (18.31) was recorded from $V_3$. The maximum number of grains spikelets$^{-1}$ (2.65) was observed from $V_2$. The maximum number of filled grains spike$^{-1}$ (42.87) was recorded from $V_2$. The minimum number of unfilled grains spike$^{-1}$ (4.58) was observed from $V_2$. The maximum number of total grains spike$^{-1}$ (47.44) was found from $V_2$. The highest weight of 1000 seeds (46.35 g) was observed from $V_2$. The highest grain yield (2.50 t ha$^{-1}$) was recorded from $V_2$. The highest straw yield (3.56 t ha$^{-1}$) was observed from $V_2$. The highest biological yield (6.06 t ha$^{-1}$) was recorded from $V_2$. The minimum harvest index (41.82%) was recorded from $V_2$, while the maximum (44.00%) was found from $V_1$.

At harvest, the longest plant (83.79 cm) and the maximum number of total tillers plant$^{-1}$ (5.27) was obtained from the treatment combination of $I_2V_2$. The highest spike length (11.96 cm) was obtained from the treatment combination of $I_2V_3$. The maximum number of spikelets spike$^{-1}$ (19.77) was observed from $I_1V_3$. The maximum number of grains spikelets$^{-1}$ (2.97) was recorded from $I_2V$. The maximum number of filled grains spike$^{-1}$ (54.03) was found from $I_2V_2$. The minimum number of unfilled grains spike$^{-1}$ (3.63) was found from $I_2V_2$. The maximum number of total grains spike$^{-1}$ (57.67) was observed from $I_2V_2$. The highest weight of 1000 seeds (49.33 g) was observed from $I_2V_2$. The highest grain yield (2.75 t $ha^{-1}$) was obtained from $I_2V_2$. The highest straw yield (4.36 t $ha^{-1}$) was recorded from the treatment combination of $I_2V_2$. The highest biological yield (7.11 t $ha^{-1}$) was found from $I_2V_2$. The minimum harvest index (38.59%) was recorded from $I_2V_3$ and the maximum (46.62%) was recorded from $I_0V_2$.

Considering the results of the present experiment, further studies in the following areas are suggested:

1. Studies of similar nature be carried out in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability;
2. In this study, two irrigations, one at CRI and another at grain filling stage, were tested. The reviewed works suggested that another irrigation should also be tested at anthesis stage in the future study.

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## APPENDICES

**Appendix I. Monthly air temperature, relative humidity, rainfall and sunshine of the experimental site during the period from December 2007 to March 2008**

| Month | *Air temperature (°c) | | *Relative humidity (%) | *Rainfall (mm) (total) | *Sunshine (hr) |
|---|---|---|---|---|---|
| | Maximum | Minimum | | | |
| December, 2007 | 22.4 | 13.5 | 74 | 00 | 6.3 |
| January, 2008 | 24.5 | 12.4 | 68 | 00 | 5.7 |
| February, 2008 | 27.1 | 16.7 | 67 | 30 | 6.7 |
| March, 2008 | 31.4 | 19.6 | 54 | 11 | 8.2 |

* Monthly average,

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

**Appendix II. Characteristics of experimental site**

**A. Morphological characteristics of the experimental field**

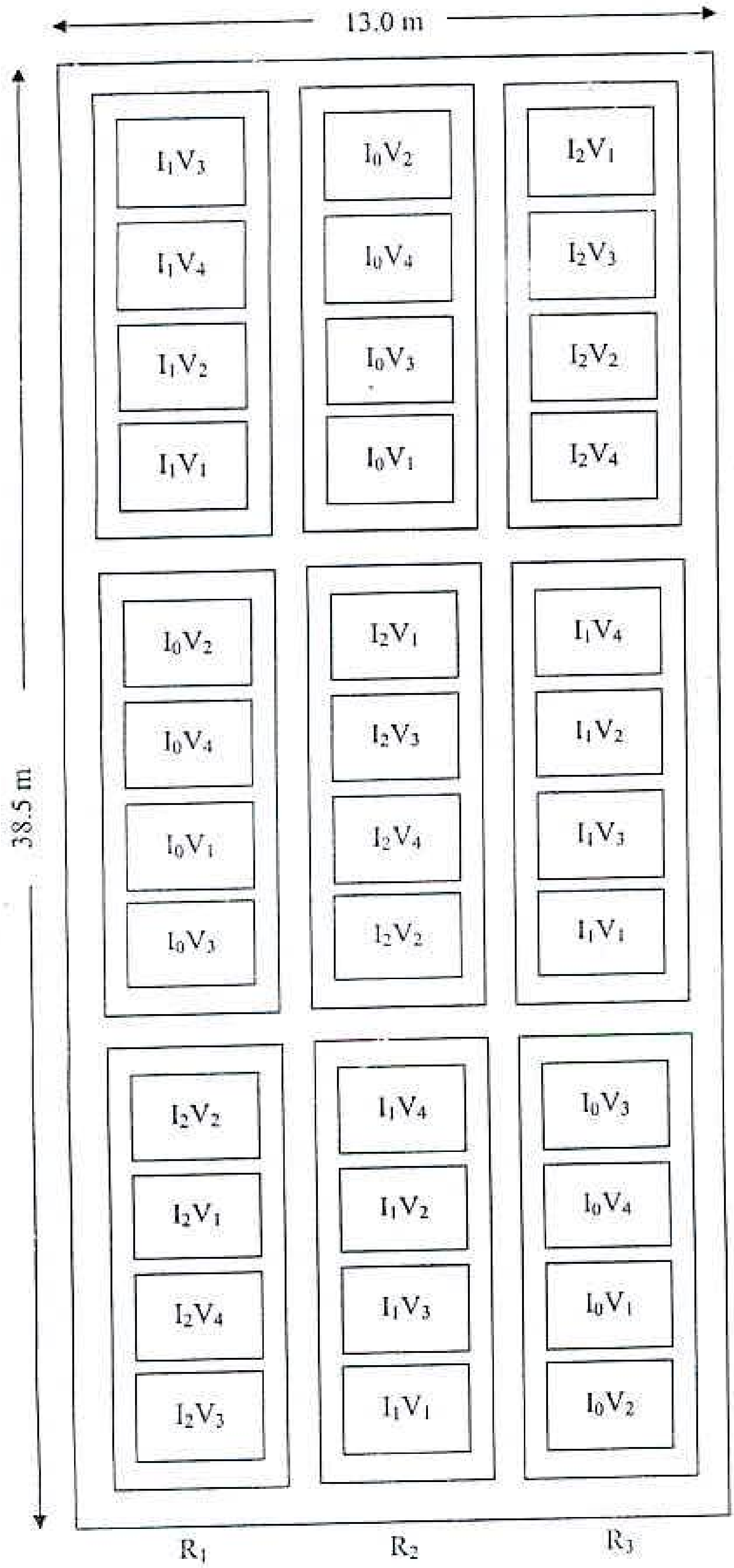
| Morphological features | Characteristics |
|---|---|
| Location | Agronomy field , SAU, Dhaka |
| AEZ | Madhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |

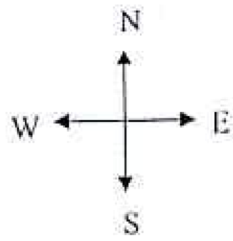
**B. Physical and chemical properties of the initial soil**

| 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 |

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

## Appendix III. Layout of the experimental plot




Plot size: 3 m × 2.5 m
Plot to plot spacing: 50 cm
Between replication: 1.0 m

**Factors A: Irrigation**

$I_0$: Control
$I_1$: One irrigation at crown root initiation stage
$I_2$: Two irrigations one at crown root initiation stage and other at grain filling stage

**Factors B: Variety**

$V_1$: Bijoy
$V_2$: Prodip
$V_3$: Sufi
$V_4$: BAW1064

Appendix IV. Analysis of variance of the data on plant height as influenced by irrigation and variety of wheat

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Plant height (cm) at | | | | |
| | | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| Replication | 2 | 0.126 | 1.649 | 2.255 | 2.264 | 1.599 |
| Irrigation (I) | 2 | 22.389** | 82.890** | 141.380** | 271.430** | 386.149** |
| Error | 4 | 0.309 | 0.411 | 0.927 | 3.924 | 5.212 |
| Variety (V) | 3 | 13.634** | 49.849** | 102.002** | 198.002** | 198.626** |
| Interaction (I×V) | 6 | 1.295** | 8.622** | 8.358** | 15.381** | 19.530** |
| Error | 18 | 0.227 | 0.873 | 1.110 | 4.532 | 4.570 |

**: Significant at 0.01 level of probability;

Appendix V. Analysis of variance of the data on number of total tillers plant$^{-1}$ at as influenced by irrigation and variety of wheat

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Number of total tillers per plant at | | | | |
| | | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| Replication | 2 | 0.002 | 0.0001 | 0.0001 | 0.018 | 0.056 |
| Irrigation (I) | 2 | 0.661** | 0.439** | 0.939** | 2.258** | 2.036** |
| Error | 4 | 0.016 | 0.003 | 0.004 | 0.019 | 0.029 |
| Variety (V) | 3 | 1.006** | 0.215** | 0.455** | 0.958** | 1.312** |
| Interaction (I×V) | 6 | 0.073** | 0.005** | 0.059** | 0.068* | 0.122** |
| Error | 18 | 0.013 | 0.005 | 0.002 | 0.023 | 0.032 |

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

Appendix VI. Analysis of variance of the data on yield contributing characters as influenced by irrigation and variety of wheat

| Source of variation | Degrees of freedom | Mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spike length (cm) | Number of spikelets spike$^{-1}$ | Number of grains spikelet$^{-1}$ | Number of filled grains spike$^{-1}$ | Number of unfilled grains spike$^{-1}$ | Number of total grains spike$^{-1}$ |
| Replication | 2 | 0.057 | 0.043 | 0.002 | 1.170 | 0.250 | 0.627 |
| Irrigation (I) | 2 | 15.630** | 59.747** | 1.208** | 1516.356** | 4.947** | 1353.909** |
| Error | 4 | 0.118 | 0.113 | 0.012 | 2.667 | 0.082 | 3.431 |
| Variety (V) | 3 | 4.037** | 1.855** | 0.151** | 68.644** | 0.430** | 58.310** |
| Interaction (I×V) | 6 | 1.112** | 0.979** | 0.062** | 30.160** | 0.259** | 30.258** |
| Error | 18 | 0.167 | 0.333 | 0.008 | 3.698 | 0.074 | 3.842 |

**: Significant at 0.01 level of probability:

Appendix VII. Analysis of variance of the data on yield contributing characters and yield as influenced by irrigation and variety of wheat

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Weight of 1000 seeds (g) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
| Replication | 2 | 0.494 | 0.0001 | 0.002 | 0.0001 | 0.002 |
| Irrigation (I) | 2 | 195.194** | 0.604** | 5.645** | 0.604** | 5.645** |
| Error | 4 | 1.273 | 0.015 | 0.020 | 0.015 | 0.020 |
| Variety (V) | 3 | 34.354** | 0.145** | 0.935** | 0.145** | 0.935** |
| Interaction (I×V) | 6 | 5.958** | 0.028* | 0.411** | 0.028* | 0.411** |
| Error | 18 | 1.478 | 0.008 | 0.035 | 0.008 | 0.035 |

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