# EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON YIELD OF WHEAT GROWN UNDER WATER STRESS CONDITION

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**December, 2015**

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**REGISTRATION NO. : 14-06324**

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**
**IN**
**SOIL SCIENCE**

**SEMESTER: July-December, 2015**

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Dedicated to
My
Beloved Parents

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# CERTIFICATE

This is to certify that thesis entitled **“EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON YIELD OF WHEAT GROWN UNDER WATER STRESS CONDITION”** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN SOIL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **SURVI AKTAR, Registration no. 1406324** under my supervision and guidance. No part of the thesis has been submitted earlier for any other degree or diploma.

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

**Dated: December, 2015**
**Place: Dhaka, Bangladesh**

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# *ACKNOWLEDGEMENT*

*All the praises due to the Almighty Allah, who enabled the author to pursue his education in Agriculture discipline and to complete this thesis for the degree of Master of Science (M.S.) in Soil Science.*

*I would like to express my heartiest respect, deepest sense of gratitude, profound appreciation to my supervisor,* ***Prof. Dr. Alok Kumar Paul,*** *Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

*I would like to express my heartiest respect and profound appreciation to my co-supervisor,* ***Prof. Mst. Afrose Jahan,*** *Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation, constructive suggestions to conduct the research work as well as preparation of the thesis.*

*I express my sincere respect to the Chairman,* ***Assoc. Prof. Md.Mosharraf Hossain,*** *and all the teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

*I thank all of my course mates to cooperate and help me during the entire time of experimentation.*

*Mere diction is not enough to express my profound gratitude and deepest appreciation to my brothers, brothers' wife, sisters, and friends for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate me to this level.*

**The Author**

# EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON YIELD OF WHEAT GROWN UNDER WATER STRESS CONDITIOON

## Abstract

An experiment was carried out to know the effect of irrigation, soil and foliar application of zinc on the growth and yield contributing characteristics of wheat. In this experiment, irrigation viz $T_1$- Regular irrigation, $T_2$- Skipping irrigation at CRI stage, $T_3$- Skipping irrigation at booting stage, $T_4$- Skipping irrigation at flowering and heading stage and foliar spray of zinc viz $Zn_0$ - Control, $Zn_1$ – 0.02%, $Zn_2$ – 0.04% and $Zn_3$ – 2.5kg Zn/ha into soil were studied. Data of field experiment were recorded on plant height, spike length, number of grains spike$^{-1}$, number of spikelet spike$^{-1}$, 1000 grain-weight and total yield of wheat. Results revealed that individual effect of irrigation was significant on all selected parameters. The effect of zinc application was found significant while the higher dose of foliar application of zinc increased the yield of wheat compared with the application of zinc in soil. Results showed that the highest number of grains per spike (48.20) was achieved from both $T_1Zn_2$ and $T_4Zn_2$ treatments while $T_2Zn_0$ produced the lowest number of grains spike$^{-1}$ (36.12). It was found that the highest 1000-grain weight (54.10g) was exerted by $T_4Zn_2$ treatment and the lowest yield of 1000-grain weight (46.67g) was produced from $T_2Zn_0$ treatment. However, the highest yield of wheat (3.82 t/ha) was exerted by $T_4Zn_2$ treatment, whereas the lowest yield (1.80t/ha) was found for $T_2Zn_0$ treatment. From this study, it was revealed that foliar application of zinc was more effective than the application in soil. In addition, skipping irrigation at flowering and heading stage with foliar application of zinc (0.04%) could be recommended for higher yield of wheat.

# Contents

## List of contents (Cont'd)

**List of contents (Cont'd)**

## List of Tables

## List of Figures

# List of Appendices

# LIST OF ABBREVIATIONS

BARI = Bangladesh Agricultural Research Institute  
BCR = Cost Benefit Ratio  
cm = Centimeter  
$^{0}$C = Degree Centigrade  
DAS = Days after sowing  
*et al.* = and others *(at elli)*  
kg = Kilogram  
kg/ha = Kilogram/hectare  
g = gram (s)  
LER = Land Equivalent Ratio  
LSD = Least Significant Difference  
MoP = Muriate of Potash  
m = Meter  
pH = Hydrogen ion conc.  
TSP = Triple Super Phosphate  
t/ha = ton/hectare  
% = Percent

# CHAPTER I

# INTRODUCTION

Wheat (*Triticum aestivum L.)* is an important cereal crop and serves as a staple food in many countries of the world. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. In Bangladesh, the amount of rice production is not enough for feeding a large number of its hungry people. Moreover, wheat constitutes 15 to 20 per cent of the staple cereal food of Bangladesh which stands on the second position considering the relative importance of all food crops (Rahman, 1980). Bangladesh produces 1302998 Mt of wheat per annum from 1061602 acres of land with an average yield of 3.03 t ha$^{-1}$ (BBS, 2014). Major yield limiting factors includes delayed sowing, high weeds infestations, water shortage at critical growth stages and imbalance and non-judicious fertilizers use. Several studies reveal that drought stress along with Zn deficiency is the major causes of yield declining of wheat in our country.

Zinc is an essential component of various enzyme systems for energy production, protein synthesis and growth regulation. It also helps in the reproduction of plants. Zn is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Hence, application of Zn fertilizer is a promising short-term approach to improve Zn concentrations in seeds and can also contribute to alleviation of Zn deficiency related health problems in the developing world (Aslam *et al*., 2014). As well documented by plant physiologists, zinc exerts a great influence on basis plant life process, such as (a) nitrogen metabolism-uptake of nitrogen and protein quality; (b) photosynthesis-chlorophyll synthesis, carbon anhydrase activity; (c) resistance to abiotic and biotic stress-protections against oxidative damage (Cakmak, 2008). Zinc also plays an important role in the production of biomass and grain yield (Kaya and Higgs, 2002 and Cakmak, 2008).

Most of the wheat growing areas in the world suffer from low water supply and irregular distribution of rainfall during the growing season (Bagci *et al*., 2007). Water stress and nutritional deficiency are serious abiotic stress factor that limit plant production in Bangladesh. The intensity of the effects of water stress on plants is variable according to the timing, duration and magnitude of the deficit (Pandey *et al*., 2001). Depending on the time, amount and distribution of the precipitations, drought stress results in substantial yield losses and in combination with zinc deficiency the decrease in yield become more severe (Ekiz, *et al.,* 1998). However, one of the most important effects of moisture shortage is that mobility of some elements such as zinc will be reduced in the soil solution causing plants to encounter deficiency of the elements because of restricted root growth (kafi and Rostami, 2007). So, when considering a water regime for a crop, it is wise to understand the sensitive growth stages for water and the water requirements of the crops in order to achieve maximum yield and maintaining adequate soil moisture conditions during moisture-sensitive stages of growth. Bangladesh is a small country with large population and its population has an increasing trend. So, cereal crop production like wheat should be increased to meet the demand of the escalating population in this country where per capita requirement of cereal food is more than 400g. There is also a great prospect of wheat cultivation in Bangladesh as it is cultivated in winter season, when it is more or less free from climatic hazards and diseases. Thus wheat may solve to a considerable extent the food problem and save huge foreign currency of the country as well.

Application of Zinc in shoot and in soil corresponding with its foliar application caused as increasing yield, dry matter and number of tiller per square meter (Yilmaz *et al*., 1997) . Furthermore, Zinc concentration in shoot and grains have increased under influence of Zinc application (Yilmaz *et al*., 1997). Drought stress represents as oxidative stress and kills plants by inducing production of ROS (Reactive Oxygen Species), especially during photosynthesis *(*Selote *et al.,* 2004, Goodman and Newton, 2005). It's therefore, likely that drought stress-related production of ROS and sensivity of plants of photooxidative damage in chloroplast are additionally accentuated when plants would simultaneously suffer from zinc-deficiency stress.

Drought is one of the factors, which threatens the agricultural products in most parts of the world (Abolhasani and Saeidi, 2004). Drought stress is a serious abiotic stress factor limiting crop production in Bangladesh. Zinc plays a more important role in adjusting stomata and ionic balance in plant system to decrease stresses caused by water shortage (Karam *et al*., 2007; Babaeian *et al*., 2010). Moreover, zinc by its participation in the action of superoxide dismutase (SOD) enzyme, may contribute to drought stress tolerance ((Bakalova *et al*., 2004; Csiszar *et al*., 2005). Under drought stress, plant roots cannot absorb micronutrients (Heidarian *et al*., 2011), and foliar spraying of micronutrients is useful and more influential as compared to soil application (Narimani *et al*., 2010). It is besides very useful, when roots are unable to absorb the zinc from soil due to the several factors including; soil reaction, organic matter, low soil temperature, high soil moisture and loss of zinc by leaching. So, foliar application of zinc can be considered as the helpful apply for the production of wheat.

Considering above issues, the present research work has been undertaken in order to fulfilling the following objectives:

(a) to study the effect of foliar application of zinc on growth and yield of wheat under water stress condition.
(b) to find out the optimum dose of foliar applied zinc for higher yield of wheat under water stress condition; and
**(c)** to compare the effect of soil and foliar application of zinc under water stress condition.

grain mass. The magnitude of each component is determined by processes such as tillering, ear development and grain filling, occurring at different stages of crop development.

Raghuwansh (1989) conducted an experiment to know the effect of irrigation on wheat yield and found that irrigation with cumulative pan evaporation of 0.8, and 1.0 or 1.2 (6, 9 and 10 irrigation, respectively) gave average grain yields of 0.99, 1.12 and 1.23 t ha$^{-1}$ respectively. According to Gill (1992) irrigation depth based on evaporation ratios of 0.75 to 0.90 produced the highest grain yields.

Walia and Cheema (1992) found that grain yield, root weight and water use of wheat were highest with irrigation at four weeks after sowing + subsequent irrigations at 80 mm cumulative pan evaporation with 120 kg N ha$^{-1}$ and with weed control.

Hundal and Rajwant (1993) found that wheat irrigated at irrigation water (IW) : calculated pan evaporation (CPE) ratio of 0.5, IW:CPE ratio of 1.0 up to booting followed by IW : CPE ratio of 0.5 up to maturity produced grain yield of 3.45, 3.80 and4.10 t ha$^{-1}$, respectively, compared with 2.63 t ha$^{-1}$ from the rainfed crop.

Deshmukh and Padole (1993) conducted field experiment on wheat cultivation on a clay loam soil. They applied irrigation process at cumulative pan evaporation (CPE) of 50, 75, 100 or 125 mm. Grain yield increased from 2.07 t ha$^{-1}$ to with irrigation at 125mm CPE to 3.23 t with irrigation at 50 mm CPE. Parsad (1993) in the field trial conducted on silty loam found that combination of manual weed control + irrigation at 150 mm CPE + 150 kg N resulted in the greatest wheat grain yields.

Abd El-Gawad *et al*. (1994) found that increasing number of irrigation from two to four increased wheat growth and seed index, while Ibrahim *et al*. (1996) and Khatun *et al*. (2007) reported higher yield with the increase of irrigation frequency.

Alderfasi *et al*. (1999) observed a significant increase of plant height, fertile tillering, thousand kernel weight and grain and biological yields with increased amount of irrigation.

Bunyolo (2000) found that water use by wheat increased with shorter irrigation intervals, while Munyindaa and Bunyoloa (2000) applied irrigations at tillering either on a weekly, every two weeks, or every three weeks basis and obtained maximum yields with weekly irrigation.

Karim *et al*. (2000) investigated the effect of water stress at reproductive stage on grain growth pattern and yield responses of wheat and found that 94% of tillers of irrigated plants produced ears, compared to 79% of the stressed plants. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated plants.

Wajid *et al*. (2002) reported that the highest grain yield of wheat was obtained by applying irrigation at all definable growth stages. He pointed out that irrigation is an expensive input therefore; farmer, agronomist, economist and engineer need to know the response of yield to irrigation.

Shaozhong *et al*. (2002) carried out a field experiment for winter wheat (*Triticum aestivum L*.) to evaluate the effects of limited irrigation on crop yield and water use efficiency (WUE). The results showed that evapotranspiration, grain yield, biomass, WUE and harvest index depended on soil water content. The effect of irrigation on yield varied considerably due to differences in soil moisture content and irrigation scheduling between seasons. High moisture treatment gave the greatest evapotranspiration and biomass, but did not produce the highest grain yield and gave relatively low WUE. Appropriately controlled soil water content could improve grain yield, WUE and harvest index. Consistently high values of grain yield, WUE, and harvest index were obtained under conditions of mild water deficit at the seedling and start of regrowth to stem-elongation stages, with further soil drying at the physiological maturity to harvest stage.

Li *et al.* (2004) observed that under recommended complete irrigation conditions and supplementary irrigation programs, plants would have higher yields compared to those without any irrigation. Water unavailability and unfavorable moisture distribution during the growing period can lead to a high variability in yield and in protein content of wheat affecting the bread-making quality (Bonfil *et al.*, 2004).

Kumar *et al.* (2005) carried out an experiment under drought and rainfed condition to know the environmental effect on growth and yield contributing traits. Significant correlation of grain yield with leaf area index, plant height, spikelets per spike, 1000-grain weight, and biological yield under both environments (drought stress and rainfed condition) was revealed in this study.

Haj *et al.* (2005) studied the effect of irrigation regimes on wheat and reported significant differences were noted regarding these parameters due to irrigation regimes. Significant effects of the water regime were found on all measured traits by Ibrahim *et al.* (2007) and number of grain per spike, thousand grain weight, the grains were highest when the crop was irrigated five times at 25 days interval, rather than four times at 30 days intervals.

Onyibe (2005) studied to know the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Sietecerros and Pavon 76). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Pavon 76 produced superior grain yield than Siete ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m$^2$ and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the highest water use efficiency of 4.0-4.8 kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Hong *et al*. (2006) conducted an experiment on winter wheat (*Triticum aestivum L.*) to identify suitable irrigation schedules for winter wheat. A comparison of irrigation schedules for wheat suggested that for maximum yield in the NCP, 300 mm is an optimal amount of irrigation, corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

Khan *et al*. (2007) studied to know the effect of different irrigation schedules on yield of wheat cultivated on clay loam soil. Experiments were conducted with one wheat variety, four irrigation intervals i.e. three weeks ($W_3$), four weeks ($W_4$), five weeks ($W_5$) and six weeks ($W_6$). Maximum yield was obtained when plots were irrigated after five weeks interval. Same was the case with number of grains per spike and grain weight per spike. But in case of number of tillers and lodging percentage, the result showed that more moisture favours greater number of tillers and lodging percentage. The highest water use efficiency (8.01 kg $ha^{-1}$ $mm^{-1}$) was obtained when crop was irrigated after five weeks interval. It is concluded that for maximum yield of wheat the crop may be irrigated after five weeks interval. Excessive and earlier than five weeks irrigation interval could be harmful for the optimum yield of wheat if seasonal rainfall is 330 mm.

Khan *et al*. (2007) reported that the highest water use efficiency was obtained when crop was irrigated after at one week interval; while Lin *et al*. (2007) found that higher yield and greater water use efficiency in wheat appear to be associated with smaller root systems and higher harvest index irrespective of irrigation.

Saleem *et al.* (2007) conducted a field experiment to appraise the effect of water regime at various growth stages on the performance of wheat production. It was found that irrigations significantly affected spikes $m^{-2}$, spikes weight, 1000 grain weight, days to maturity and biological yield. The result revealed that maximum dry matter at maturity was achieved by irrigating to 94% and maximum grain yield to 84% of seasonal full evapotranspiration (ET). A positive relationship was also found between harvest index (HI) and dry matter mobilization efficiency (DMME) during grain filling. Moderate water deficit during grain filling was found to increase mobilization of assimilate stored in vegetative tissue to grain, resulting in greater grain yield and water use efficiency (WUE).

Shao *et al*. (2009) reported that good soil moisture conditions at sowing also played an important role in achieving high yields of wheat under limited water supply. The proper irrigation schedule could save considerable amount of irrigation with low yield losses. The present study will be carried out to examine the effect of irrigation scheduling on the growth and harvest index of wheat varieties.

Akbar *et al.* (2010) conducted an experiment to study the performance of wheat in relation to yield and yield component under different water deficit conditions. The number of spikes per meter square, number of kernels per spike, 1000-grain weight, plant height, days to maturity, maturity duration, harvest index and grain yield were significantly affected by water deficit conditions. It was observed that water limitation during double ridge to anthesis reduced the number of spikelets per meter square and number of kernels per spike. Moreover, water deficit condition at post-anthesis decreased the number of days to maturity, maturity duration, 1000-grain weight, harvest index and grain yield.

Huifang *et al.* (2010) conducted an experiment to study the irrigation frequency on grain yield, water use efficiency and protein yield of wheat. The results showed that irrigation at jointing, heading and milking stage were in favor of increase in grain yield, dry matter accumulation and 1000-grain weight respectively. The highest grain yield was obtained in case of the treatment irrigated 60 mm at jointing and heading stage respectively.

Khokhar *et al.* (2010) conducted an experiment to know the effect of different irrigation levels on growth and yield of different wheat genotypes. It was stated that tillering in wheat plants improved significantly with an additional irrigation applied during tillering stage in $I_4$ (irrigations at crown root stage, tillering stage, booting stage and milky stage), $I_5$ (irrigations at crown root stage, tillering stage, booting stage, anthesis stage and milky stage) and $I_6$ (irrigations at crown root stage, tillering stage, booting stage, anthesis stage, milky stage and dough stage) as compared to irrigation applied only at the time of crown root initiation stage in $I_3$ (irrigation at crown root stage , booting stage and dough stage).

Sarwar *et al.* (2010) conducted a field experiment to check the effect of different levels of irrigation on yield and yield components of wheat cultivars. Treatments were three cultivars (AS-2002, SH-2002, Aqab-2000), 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). The highest grain yield (5696.8 kg ha$^{-1}$) was recorded for $I_5$ treatment, which was significantly higher than all the other irrigation levels.

Abro (2012) investigated the effect of different water regimes on the growth and yield of wheat varieties and stated that to get the maximum grain yield of wheat, the crop would require five irrigations because there was significant decrease ingrain yield with decreasing the number of irrigations.

Ngwako and Mashiqa (2013) designed an experiment to know the effect of irrigation on the growth and development of winter wheat cultivars. Significant difference in the cultivars was observed in the days to emergence, days to anthesis, number of tillers and number of grains per spike. Cultivar 14SAWYT306 took long to emerge and flower but matured at the same time as cultivar Baviaans. Cultivar Baviaans produced higher leaf area index, leaf dry mass, stem dry mass and more tillers than 14SAWYT306. More grains per spike, grain yield, harvesting index and grain protein were recorded in cultivar 14SAWYT306. Irrigation significantly affected days to maturity, number of tillers, grains per spike and grain yield. Irrigation throughout the growth stages increased number of tillers, number of grains per spike, grain yield, harvesting index and grain protein by 20.58%, 26.07%, 42.72%, 16.71% and 3.31% respectively over no irrigation.

Aslam *et al*. (2014) conducted a field experiment to investigate the effect of different irrigation scheduling on the growth and harvest index of wheat varieties. Tillers, spike length, grains spike$^{-1}$, Biological yield and grain yield significantly affected by irrigation scheduling. The wheat crop irrigated five times (1st 25 DAS and subsequent irrigations at 15 days interval) resulted maximum plant height (86.206 cm), tillers m$^{-2}$ (402.11), spike length (12.040 cm) spikelets spike$^{-1}$ (18.979), grains spike$^{-1}$ (47.099), seed index (44.580g), biological yield, (13732 kg ha$^{-1}$), grain yield (6999.30 kg ha$^{-1}$) and harvest index (50.95%) as compared to four irrigations (1st 30 DAS and subsequent irrigations at 20 days interval) and three irrigations (1st 35 DAS and subsequent irrigations at 25 days interval). Among varieties SKD-1 ranked 1st in all traits studied particularly grain yield (5818.80 kg ha$^{-1}$) followed by TD-1 5407.4 kg ha$^{-1}$) and Imdad (5014 kg ha$^{-1}$). However, it is concluded that interaction of five irrigations (1st 25 DAS and subsequent irrigations at 15 days interval) and wheat variety SKD$^{-1}$ proved optimum for obtaining maximum grain yield (7444.70 kg ha$^{-1}$).

Tabassam *et al.* (2014) stated that water shortage was one of the main factors that reduced the total production. It was revealed that shortage of water during maturity resulted in about 10% decrease in the total yield, while there was no effect on the yield due to moderate stress at early growing stage. Shortage of water brought unaffordable changes in plants resulted in growth and photosynthesis inhibition affecting yield components adversely.

## 2.2 Effect of Zinc

The micronutrients are reducing in soil with time due to more dependence on synthetic fertilizers and increase in cropping intensity with high yielding (Dewal and Pareek, 2004). According to World Health Report (2002), the fifth major cause of diseases and deaths in human beings is due to Zn deficiency in developing countries. By the foliar application of micronutrients, its concentration can be increased by the process of bio fortification. Several studies stated that zinc fertilization not only increased wheat and oil seed rape yield, but also enhanced grain zinc contents (Grewal *et al.*, 1997 and Torun *et al.*, 2001).

Zinc deficiency is one of the worldwide nutritional constraints for crop production, as Zn removed by crops is usually not fully replenished by fertilization in agricultural soils. Again, Zinc deficiency is widespread in wheat grown on alkaline calcareous soils; therefore, a large population of the world as result of this also lacks adequate Zn nutrition (Maqsood *et al.*, 2009).

Foliar fertilization is a moderately new and touchy technique of feeding plants by applying liquid fertilizer directly to their leaves, which is one of the safest and most effective approaches to enrich essential micronutrients in crop grain. Uptake and transport of micronutrients to the edible parts of plants could be increased by foliar application to leaf (Nasiri *et al.*, 2010). Foliar application is suggested to alleviate micronutrient deficiencies, and presently most of the studies have been focused on uptake and distribution of single micronutrient in fruit tree, corn, and wheat (16 to 20) (Kaya and Higgs, 2002; Godsey *et al.*, 2003; Elmer *et al.*, 2007).

Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Asad and Rafique, 2000). Several reports indicate that either soil or foliar application of micronutrients have positive correlation with wheat yield (Habib, 2009; Wroble, 2009). Foliar application of Zn at growth and reproductive stage enhanced grain yield of wheat (Wroble, 2009).

Ziaeian and Malakouti (2001) reported that Fe, Mn, Zn and Cu fertilization significantly increased grain yield, straw yield, 1000-grain weight, and the number of grains per spikelet. They also found that application of Zn significantly increased the concentration and total uptake of Zn in grain, flag leaves grain protein contents as well.

Asad and Rafique (2002) found that application micronutrients increased wheat dry matter, grain yield, and straw yield significantly over an unfertilized control. Foliar application of micronutrients (Fe, Mn, Zn, Cu and B) at different growth stages of wheat increased plants height, grains per spike, 1000-grain weight, biological yield, harvest index, straw and grain yield (Khan *et al*., 2010).

A field experiment was conducted by Arshad *et al*. (2016) to find out the “interactive effect of phosphorus and zinc on wheat crop” at New Developmental farm, the University of Agriculture Peshawar, Pakistan. Four zinc levels (0, 5, 10 and 15 kg ha$^{-1}$) were applied to plots with three different levels of phosphorus (45, 90 and 135 kg ha$^{-1}$). Zn application had significantly increased wheat spike length (10.78 cm), 1000 grains weight (49.36 g) total dry matter (8200 kg ha$^{-1}$) and grain yield (4426 kg ha$^{-1}$) in the plots which were treated with 10 kg Zn ha$^{-1}$, while the maximum straw yield (4000 kg ha$^{-1}$) was recorded at 5 kg Zn ha$^{-1}$. These results indicated that agronomic characteristics of wheat crop showed more significant response in plots which were treated with 10 kg Zn ha$^{-1}$.

Ahmadi and David (2016) conducted a field experiment during *Rabi* season to study the effect of Nitrogen and Zinc on Yield of Wheat *(Triticum aestivitm* L.) at the research farm of department of Soil Science. Three levels of nitrogen [0, 60 and 120] kg ha$^{-1}$], three levels of zinc [0, 15 and 30 kg ha$^{-1}$], respectively were applied. The treatment combination T8 - [@ 120 kg Nitrogen ha$^{-1}$ +@ 30 kg Zinc ha$^{-1}$] gave the best results with respect to plant height 101.2 cm, it gave highest yield 5.600 t ha$^{-1}$, straw yield 7.570 t ha$^{-1}$.

A field experiment was carried out by Singh *et al*. (2015) to evaluate the effect of zinc levels and methods of application of boron on the growth, yield and protein content of wheat (*Triticum aestivum* L.) during the winter (Rabi) season in two consecutive years at the Allahabad agricultural Institute – Deemed University, Allahabad. The treatments comprised three levels of zinc (0, 3.5 and 7 kg ha$^{-1}$) through zinc sulphate and four methods of application of boron (0, soil application @ 0.5 kg ha$^{-1}$, foliar spray @ 0.5kg ha$^{-1}$ at 45 and 60 days after sowing and soil application @ 0.25 kg ha$^{-1}$ + foliar spray @ 0.25 kg ha$^{-1}$ at 45, 60 DAS) as borax, making 12 treatment combinations, each replicated three times. On the basis of the findings of the experiment, zinc @ 7 kg ha$^{-1}$, soil application of boron @ 0.25 kg ha$^{-1}$ + foliar application of boron @ 0.25 kg ha$^{-1}$ and their combination (i.e., 7 kg ha$^{-1}$ zinc + soil application of boron @ 0.25 kg ha$^{-1}$ + foliar application of boron @ 0.25 kg ha$^{-1}$) was found superior over all other treatments in relation to plant height, dry weight, effective tillers yield and yield attributes and protein content in grains, of wheat crop.

To assess the possible role of micronutrients in improving wheat yield, an experiment was conducted by Zain *et al.* (2015) to evaluate the wheat performance by foliar application of micronutrients. Treatments consist of $T_1$ = No spray, $T_2$ = Spraying plants with tube well water (control), $T_3$ = Spraying plants with 1.6 kg FeSO4/100 L water/acre, $T_4$= Spraying plants with 3 kg $ZnSO_4$ (21%)/100 L water/acre, $T_5$ = Spraying plants with 1 kg $MnSO_4$/100 L water/acre, $T_6$ = Spraying plants with ($FeSO_4$ + $MnSO_4$), $T_7$ = Spraying plants with ($FeSO_4$ + $ZnSO_4$), $T_8$ = Spraying plants with ($ZnSO_4$ + $MnSO_4$), and $T_9$ = Spraying plants with ($FeSO_4$ + $ZnSO_4$ + $MnSO_4$). Results showed that foliar application of micronutrients substantially improved plant height, spike length cm, spikelets/spike, grains/spike, test weight, Tillers m$^{-2}$, grain and biological as well as harvest index of wheat.

Bybordi and Malakouti (2003) reported that wheat is sensitive to zinc deficiency followed by iron and copper deficiencies. Wheat production is inherently low when grown on Zn-deficient soils. Based on a range of reports and survey studies, the average concentration of Zn in whole grain of wheat in various countries is between 20 to 35 mg kg$^{-1}$ (Rengel *et al*., 1999; Cakmak *et al*., 2004; Seilsepour, 2007).

A field experiment was conducted by Singh *et al*. (2013) for rabi season at the cultivator field in order to find out the effect of zinc on wheat crop. A field experiment was undertaken to evaluate the effect of graded levels of zinc sulphate (0, 7.5, 15.0, 22.5 and 30.0 kg/ha) on the flag leaf, yield content and uptake of nutrient in wheat. Application of 22.5 kg Zn ha$^{-1}$ gave significantly higher flag leaf and yield.

Fertilizer studies focusing specifically on increasing Zn concentration of grain (or other edible parts) are, however, very rare, although a large number of studies are available on the role of soil and foliar applied Zn fertilizers in correction of Zn deficiency and increasing plant growth and yield (Martens and Westermann, 1991; Seilsepour, 2007). Depending on the application method, Zn fertilizers can increase grain Zn concentration up to three- or four fold (Yilmaz *et al*., 1997). The most effective method for increasing Zn in grain was the soil + foliar application method that resulted in about 3.5-fold increase in the grain Zn concentration. The highest increase in grain yield was obtained with soil, soil + foliar and seed + foliar applications.

Ozturk *et al*. (2006) studied the changes in Zn concentration in wheat during the reproductive stage and found that the highest concentration of Zn in grain occurs during the milk stage of the grain development. Results show a high potential of Zn fertilizer strategy for rapid improvement of grain Zn concentrations, especially in the case of late foliar Zn application. In practical agriculture, it is known that foliar uptake of Zn is stimulated when Zn fertilizer is mixed with urea (Mortvedt and Gilkes, 1993).

Shaheen *et al*. (2007) carried out a pot experiment to study the yield and yield contributing characters, zinc concentrations and its uptake by wheat. Six different locations of Bangladesh were collected. The effect of applied zinc was more pronounced in Khulna, BAU Farm, Maskanda and Modhupur soils than in the highly acidic Sylhet soil or calcareous soil of Ishurdi. It is evident that for obtaining increased yield of wheat, zinc status of the soils should be improved and for this zinc fertilization and seems imperative and care should be taken while a zinc fertilizer to the soil. Higher rates of zinc may be required for acid and calcareous soils.

Potarzycki and Grzebisz (2009) revealed that among many growth factors zinc was recognized as one of main limiting factors of maize crop growth and yielding. The optimal rate of zinc foliar spray for achieving significant grain yield response was in the range from1.0 to 1.5 kg Zn/ha. Grain yield increase was 18% (mean of three years) as compared to the treatment fertilized only with NPK.

Ali *et al.* (2009) evaluated the effect of foliar application of zinc and boron on yield and yield components of wheat. Solutions of zinc, boron and zinc plus boron were used as foliar spray and each solution was applied at tillering, jointing and boot stage. They recorded significant increase in number of spikes $m^{-2}$, grains $spike^{-1}$, thousand grain weight, biological yield and grain yield for foliar application of zinc and boron compared to control treatments.

Habib (2009) stated that the appearance of micronutrient deficiency in crops reduced quality of grain and production. He conducted a field experiment on clay-loam soil to investigate the effect of foliar application of zinc and iron on wheat yield and quality at tillering and heading stage. Results showed that foliar application of Zn and Fe increased seed yield and its quality compared to control. Among treatments, application of (Fe + Zn) obtained highest seed yield and quality.

Field experiments were carried out to study the response of wheat crop cultivar (AS-2002) to Zn as Zinc sulphate. It was found that maximum grain yield was observed with each incremental zinc dose reaching the threshold level of zinc sulphate at 22.5 kg/ ha (Abbas *et al*., 2010).

A field experiment was conducted by Cao *et al*. (2010) to investigate the effects of different Zn application methods (soil application or foliar spray) on grain Zn concentration and Zn bioavailability of 5 winter wheat cultivars in potentially zinc (Zn)-deficient calcareous soil. Compared with the control treatment (no Zn application), the grain Zn concentrations are increased by 6.1%, 63.9% and 82.6% under the methods of soil application, foliar spray and soil+foliar application of Zn fertilizers, and the grain Zn uptakes are increased by 3.6%, 69% and 83%, respectively.

Bameri *et al.* (2012) investigated the response of growth and yield of wheat to foliar application of micronutrients. It was revealed that foliar application of micronutrient significantly improved the height of plant, number of spike plant$^{-1}$, number of grain spike$^{-1}$, grain yield, 1000 grain weight, biological yield and harvest index. Treatment (Mn + Fe) had the maximum optimistic effect on yield characters and grain yield.

Khan *et al.* (2010) designed a field experiment to check the response of wheat to market available micronutrient application “Shelter” (Zinc = 2%, Iron = 1%, Mangenese = 2%, Copper = 1%, Boron = 1%). Shelter treatment significantly enhanced the number of grains spike$^{-1}$, weight of 1000 grains, straw yield, grain yield, biological yield and harvest index at different growth stages of wheat. They suggested that commercially available foliar application might be useful to improve the wheat crop.

Gul *et al*. (2011) designed an experimental trail to quantify the response of yield and yield component of wheat toward foliar spray of nitrogen, potassium and zinc. Maximum biological yield (8999 kg ha$^{-1}$),number of grains (52) spike$^{-1}$ and straw yield (6074 kg ha$^{-1}$) were produced in plots under the effect of foliar spray of 0.5% N + 0.5% K + 0.5% Zn solution (once), while control plots produced minimum biological yield (5447 kg ha$^{-1}$),number of grains (29) spike$^{-1}$ and straw yield (3997 kg ha$^{-1}$). Similarly maximum thousand grain weight (46 g) and grain yield (2950 kg ha$^{-1}$) were recorded in plots sprayed with 0.5% N + 0.5% K + 0.5% Zn solution (twice), followed by lowest values (36 g) and (1450 kg ha$^{-1}$) in plots having no spray (control). Among the treatment of 0.5% N + 0.5% K + 0.5% Zn solution applied either one or two times, gave best response towards yield and yield components of wheat in irrigated area of Peshawar valley.

Jatoi *et al.* (2011) reported that any increase or decrease in agronomic traits is caused by variable response of wheat genotypes via physiological changes. Thus, the development of cultivars for water limited environments would involve selection and incorporation of both physiological and morphological mechanisms of drought resistance through traditional breeding programmers.

Nadim et al. (2012) designed an experiment to know the growth and yield response of wheat variety Gomal-8 to different micronutrients and their application methods. It was revealed that different micronutrients had significant interaction with application methods for physiological and agronomic traits including number of tillers, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) and grain yield. In addition, higher leaf area index and crop growth rate were obtained with the application of zinc at 10 kg ha$^{-1}$.

Ghafoor *et al*. (2014) studied to know the effect of four levels of Zinc as Zn-EDTA ( 0, 20, 40, 60 kg Zn ha$^{-1}$) on growth traits and yield of wheat variety ‘ovanto’ at two different agricultural locations. The results showed that the increase in rates of Zn causes an increase in grain yield, grain zinc content and zinc uptake by plant, from both of locations. However, the results showed that the relative yield was decreased with increasing of zinc application rate from both of locations.

Gomaa *et al.* (2015) found that the foliar application of mixture nutrients (Zn+Fe) gave the highest grain and yield components and quality of wheat grain. Foliar application of B and Zn had positive effect on yield and yield component of wheat (Ali *et al*., 2009; Moghadam *et al*., 2012).

## 2.3 Interaction effect of irrigation and Zn

Rahimi *et al.* (2012) carried out an experiment to know the effects of wastewater and zinc fertilizer on quantitative traits of wheat (*Triticum aestivum* L.). Results indicated that wheat plants irrigated with wastewater showed an increase in all recorded parameters including grain yield, straw yield, 1000-grain weight, spike length, plant height and number of tillers compared to well water. Use of zinc micronutrient also led to improvement in all of these traits. The highest amounts were recorded from the application of zinc sulfate at a rate of 75 kg/ha. Wastewater irrigation of wheat crops with an application of 75 kg $ZnSO_4$ ha$^{-1}$ could be recommended for an enhanced yield and yield components.

Teimouri *et al.* (2014) conducted an experiment to know the effect of selenium spraying under drought stress condition on yield and growth indices of wheat. Results revealed that the interaction effect of irrigation and selenium was significant regarding yield contributing characteristics of wheat. They also reported the highest grain yield (16.894 tha$^{-1}$) for normal irrigation with selenium spraying.

Abdel-Motagally *et al.* (2016) reported that interaction of irrigation and foliar application of boron significantly affected different growth and yield parameters of wheat. The highest plant height (99.42cm), spike length (11.86cm), number of spikelets m$^{-2}$ (332.65), grain yield plant$^{-1}$ (21.56g), 1000-grain weight (37.4 g) and grain yield (1.87 tonha$^{-1}$), which were recorded at normal irrigation level (100% from the amount of water consumption for wheat) with boron spraying at booting stage ($B_1$).

A field experiment was carried out by Sultana *et al.* (2016) at micronutrient experimental field of Soil Science Division, BARI, Joydebpur, Gazipur to study the effect of foliar application of zinc on yield of wheat (BARI gom-25) grown by skipping irrigation at different growth stages of the crop. The experiment was designed in a split plot design on sixteen treatments comprising four irrigation treatments (regular irrigation, skipped irrigation at crown root initiation, skipped irrigation at booting stage and skipped irrigation at grain filling stages of wheat growth) and four foliar application of zinc (0.0%, 0.02%, 0.04% and 0.06% of zinc). Zinc Sulphate Monohydrate ($ZnSO_4.H_2O$) was used as a source of Zn. The highest yield (5.59 t $ha^{-1}$) was recorded in normal irrigation which was identical with skipping irrigation at flowering and heading stage with 0.06% foliar application of zinc. Skipping irrigation at crown root initiation stage had the most negative effect on growth and yield. Skipping irrigation at flowering and heading stage of wheat with 0.04% foliar application of zinc gave the identical yield in regular irrigation with 0.04% and 0.06% foliar application of zinc. Thus, foliar application of zinc played a major role on yield and yield components of wheat at later stages of growth. The response of foliar application of Zn was positive and quadrate in nature. The optimum dose was appeared as 0.04% foliar application of zinc for grain yield of wheat in the study area of Joydebpur, Gazipur (AEZ-28).

Aghtape *et al.* (2011) carried out an experiment to observe the effects of treated wastewater, with complete fertilizer sprayed on some forage quantitative and qualitative characteristics of foxtail millet (*Setaria italica*). Among the irrigation treatments, irrigation with wastewater for all growing stages cause increase of grain yield and forage quality characteristics such as soluble carbohydrate, crude protein, ash, dry matter digestibility and significant decrease in cell wall, cell wall without hemicellulose and lignin percentage. The highest grain yield and dry matter digestibility were obtained from 1200 g of fertilizer sprayed in comparison with sprayed with 600 g of complete fertilizer and control treatments.

Pourgholam *et al.* (2013) conducted an experiment to evaluate the beneficial impact of zinc and iron foliar application and plant irrigation on rapeseed. Some yield characters were investigated. In this respect, the experimental unit had designed by achieved treatments in split plot on the basis completely randomized block design with three replications. Certain factors including three levels of irrigation ($I_1$: normal (control) $I_2$: Irrigation at stem elongation $I_3$: Irrigation at flowering stage) and zinc and iron foliar application ($S_1$: control, $S_2$: zinc spraying, $S_3$: spraying iron $S_4$: iron and zinc spraying) were studied. The results showed that grain yield is directly related to the rise and fall of each of the components, the yield will be affected. Grain yield of the control treatment with foliar iron concentration was 3484 kg $ha^{-1}$. The results of this experiment showed that the Zn and Fe foliar application increased all features in rapeseed. The results can be used in agronomy and increase the quantitative and qualitative features for achieve to the sustainable agriculture.

Thalooth *et al.* (2006) carried out two field to study the effect of foliar application of zinc, potassium or magnesium on growth, yield and yield components and some chemical constituents of mungbean plants grown under water stress conditions (missing one irrigation at vegetative, flowering and pod formation growth stages). The results revealed that missing one irrigation at any of the three studied stages significantly reduced all the tested growth parameters, yield and yield components as well as photosynthetic pigments content as compared with unstressed plants (control). However, subjecting mungbean plants to moisture stress at vegetative stage had the most negative effect on growth parameters. Meanwhile, stress at a pod formation stage produced the least yield and yield components’ values. On the other hand, water stress had a stimulating effect on proline and crude protein contents. The present study also indicate that foliar application of Zn, K or Mg had a positive effect on growth parameters, yield and yield components but K application surpassed the two other nutrients.

# CHAPTER III

# MATERIALS AND METHODS

This chapter deals with the materials and methods used in the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate and materials used for the experiment. The details of the experiment are given below.

## 3.1 Experimental site

The research work was carried out at the experimental field of Sher-e- Bangla Agricultural University, Dhaka during the period from November 2014 to march 2015. The field was located at the southeast part of the main academic building. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28).

## 3.2 Soil

The experiment was carried out in a typical wheat growing soil of the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka, during *robi* season of 2014. The farm belongs to the General soil type, "Deep Red Brown Terrace Soil" under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of initial soil are presented in Tables 1 and 2.

## 3.3 Climate

The experimental area is under the subtropical climate. Usually the rainfall was heavy during Kharif season and scanty in Rabi season. The atmospheric temperatures increased as the growing period proceeded towards Kharif season. The weather conditions of crop growth period such as monthly mean rainfall (mm), mean temperature ($^oC$), sunshine hours and humidity (%) are presented in Appendix 2.

### 3.4 Planting material

The variety of wheat used for the present study was BARI gom-25. The seeds of this variety were collected from the Wheat Research Centre of Bangladesh Agricultural Research Institute (BARI), Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristics of these varieties are mentioned below:

**BARI Ghom-25:** Plants are of average 85-90 cm height. Leaves are darker green. Maximum yield is 3.5 - 4 ton ha$^{-1}$. Seeds contain 60 - 65% carbohydrate.

**Table 1. Morphological characteristics of the experimental field**

| Morphological features | Characteristics |
|---|---|
| Location | Sher-e-Bangla Agricultural University Farm, Dhaka |
| AEZ | Madhupur Tract |
| General Soil Type | Deep Red Brown Terrace Soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |
| Flood level | Above flood level |
| Drainage | Well drained |

**Table 2. Physical and chemical properties of the initial soil sample**

| Characteristics | Value |
|---|---|
| % Sand | 29 |
| % Silt | 41 |
| % Clay | 30 |
| Textural class | Clay loam |
| Consistency | Granular and friable when dry |
| CEC(c mol/kg) | 17.9 |
| pH | 5.6 |
| Bulk Density (g/cc) | 1.45 |
| Particle Density (g/cc) | 2.52 |
| Organic carbon (%) | 0.68 |
| Organic matter (%) | 1.18 |
| Total N (%) | 0.06 |
| Available P (ppm) | 19.85 |
| Exchangeable K (meq/100g soil) | 0.12 |

### 3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds were removed. The first ploughing and the final land preparation were done 1 November and 7 November, respectively. Experimental land was divided into unit plots following the design of the experiment. The plots were spaded one day before seed sowing and the basal dose of fertilizers was incorporated thoroughly before seed sowing.

### 3.6 Fertilizer application

Urea, triple super phosphate (TSP) and muriate of potash (MoP) and gypsum were used as source of nitrogen, phosphorus and potassium and sulphur respectively. As micro nutrient, Zinc (Zn) was applied as zinc sulphate monohydrate(gram) as per treatments illustrated later. The rate of N, P , K and s was 150 kg, 125 kg ,67 kg, 80 kg ha$^{-1}$ respectively.

### 3.7. **Treatment of the experiment**

The experiment was two factorials with four levels of irrigation, soil

and 3 level of foliar application of zn.

### 3.7.1 Factor A: Irrigation levels

The following irrigation levels were imposed in the experiment

$T_1$: Regular irrigation ; unstressed; irrigation at crown root initiation stage, booting stage , flowering and heading stage,

$T_2$: Skipping irrigation at CRI stage; stressed by skipping one irrigation at crown root initiation stage;

$T_3$: Skipping irrigation at booting stage; stressed by skipping one irrigation at booting stage;

$T_4$: Skipping irrigation at flowering and heading stage; stressed by skipping one irrigation at flowering and heading stage

### 3.7.2 Factor B: Foliar application of Zn levels

The following foliar application of Zn levels were imposed in the experiment
$Zn_0$: Control (No Zn application)
$Zn_1$: 0.02% foliar application of Zn
$Zn_2$: 0.04% foliar application of Zn
$Zn_3$: Application of Zn solution into the soil as per recommended dose (2.5kg/ha)

### 3.7.3 Combining two factors, 16 treatment combinations were obtained

| | | | |
|---|---|---|---|
| $T_1Zn_0$ | $T_2Zn_0$ | $T_3Zn_0$ | $T_4Zn_0$ |
| $T_1Zn_1$ | $T_2Zn_1$ | $T_3Zn_1$ | $T_4Zn_1$ |
| $T_1Zn_3$ | $T_2Zn_2$ | $T_3Zn_2$ | $T_4Zn_3$ |
| $T_1Zn_4$ | $T_2Zn_3$ | $T_3Zn_3$ | $T_4Zn_4$ |

### 3.8 Experimental design and lay out

The experiment was laid out in split plot Design (factorial). Each treatment was replicated three times. The size of a unit plot was 2m × 2m. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m. The inter block and inter row spaces were used as footpath and irrigation/ drainage channels.

### 3.9 Germination test

Germination test was performed before sowing the seeds in the field using petridishes. Three layers of filter paper were placed on petridishes and the filter papers were softened with water. Seeds were distributed at random in four petridishes. Each petridish contained 100 seeds. Germination percentage was calculated by using the following formula:

$$\text{Germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds taken for germination}} \times 100$$

### 3.10 Application of fertilizers and manure

Fertilizer was applied based on BARC fertilizer recommendation guide-2012. The fertilizers N, P, K, S and Zn in the form of Urea, TSP, MoP, Gypsum and Zinc, respectively were applied. Cowdung was applied 15 days before seeds sowing. The entire amount of TSP, MoP and Gypsum and 1/3rd of urea were applied at final land preparation. Rest of urea was top dressed in two splits after 1st &2ndirrigation at 21& 45 days after sowing (DAS). Zinc Sulphate Monohydrate ($ZnSO_4.H_2O$) was used as a source of Zn.

### 3.11 Sowing of seeds in the field

The seeds of wheat were sown in rows made by hand plough on 16 November 2014.The seeds were sown in solid rows in the furrows having a depth of 2-3 cm from the soil surface. Row to row distance was 20 cm.

### 3.12 Intercultural operations

#### 3.12.1 Irrigation and weeding

Four types of irrigations were done according to the treatments during the entire growing period. The crop field was weeded twice; first weeding was done at 25 DAS (Days after sowing) and second weeding at 40 DAS. Demarcation boundaries and drainage channels were also kept weed free.

#### 3.12.2 Protection against insect and pest

At early stage of growth, few worms (*Agrotis ipsilon*) and virus vectors (Jassid) attacked the young plants. To control these pests, Dimacron 50 EC was sprayed at the rate of 1L per ha.

### 3.13 Preparation and application of foliar and soil Zn spray

Four level of Zn concentration was applied in experimental field. The mixture of 200 g Zn in 10 liter water is called 0.02% Zn. Similarly 400 g Zn in 10 liter water is called 0.04% Zn and 2.5kg/ha zinc was applied in soil. Foliar application of zinc was done during the skipping irrigation at respective days. Zinc Sulphate Monohydrate ($ZNSO_{4.}H_2O$) was used as a source of Zn.

### 3.14 Crop sampling and data collection

The crop sampling was done at the time of harvest. Harvesting date was 3rd march, 2015. At each harvest, five plants were selected randomly from each plot. The selected plants of each plot were cut carefully at the soil surface level. The plant heights, spike length, number of grain Spike$^{-1}$, number of spikelet spike$^{-1}$, 1000 grain weight and yield were recorded separately.

### 3.15 Harvest and post harvest operations

Harvesting was done when 90% of the crops became brown in color. The matured crop were cut and collected manually from a pre demarcated area of 1 $m^2$ at the centre of each plot. After harvesting, the samples were sun dried.

### 3.16 Data collection

The data on the following parameters of five plants were recorded at each harvest.

1) Plant height (cm)
2) Spike length (cm)
3) Number of grain spike$^{-1}$
4) Number of spikelet spike$^{-1}$
5) 1000 grain weight (g)
6) yield (t ha$^{-1}$)

### 3.17 Procedure of data collection

#### 3.17.1 Plant height

The heights of five plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

#### 3.17.2 Spike length (cm)

Spike length were counted from five plants and then averaged. This was taken at the time of harvest and it was expressed in cm.

#### 3.17.3 Number of grain spike$^{-1}$

Total number of grains were counted from total spike that was obtained from preselected five plants. After that it was averaged and expressed as number of grain spike$^{-1}$.

### 3.17.3 Number of spikelet per spike

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

### 3.17.5 Weight of 1000 seeds (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and the mean weight was expressed in gram.

### 3.17.6 Grain yield (t ha$^{-1}$)

Weight of grains of the demarcated area (1 m$^{2)}$ at the centre of each plot was taken and then converted to the yield in t ha$^{-1}$.

## 3.18 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-computer package program developed by Russel (1986). 5% level of significance (Gomez and Gomez, 1984) was used to compare the mean differences among the treatments.

## 3.19 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

### 3.20 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil Resource Development Institute (SRDI), Farmgate, Dhaka. The properties studied included soil texture, pH, and organic matter, total N, available P, and exchangeable K. The physical and chemical properties of post harvest soil have been presented in Appendix-1. The soil was analyzed by standard methods as follow:

#### 3.20.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the “Marshall’s Textural Triangular Coordinate” according to the USDA system.

#### 3.20.2 Soil pH

Soil pH was measured with the help of a Glass electrode pH meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

#### 3.20.3 Organic carbon

Organic carbon in soil was determined by Walkley and Black (1934) Wet Oxidation Method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. $H_2SO_4$ and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

#### 3.20.4 Total nitrogen

Total nitrogenof soil was determined by Micro Kjeldahl method where soil was digested with 30% $H_2O_2$, conc. $H_2SO_4$ and catalyst mixture ($K_2SO_4$: $CuSO_4.5H_2O$: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in $H_3BO_3$ with 0.01N $H_2SO_4$ (Bremner and Mulvaney, 1982).

### 3.20.5 Available phosphorus

Available phosphoruswas extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.*, 1954). The phosphorus in the extract was then determined by developing blue colour using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 *n*m wave length by Spectrophotometer and available P was calculated with the help of standard curve.

### 3.20.6 Exchangeable potassium

Exchangeable potassium was determined by 1N $NH_4OAc$ (pH 7.0) extract of the soil by using Flame photometer (Black, 1965).

## 3.20 Statistical Analysis

Data on yield and other parameters were compiled, tabulated and analyzed statistically using the analysis of variance technique. Analysis of variance was done and the mean differences were adjudged by Least Significant Difference Test (LSD) at 5% level of probability using Statistical Program MSTAT-C.

# CHAPTER IV

# RESULTS AND DISCUSSION

Data on different growth parameters and yield attributes were recorded. The results have been presented in graphs and table and possible interpretations given under the following headings:

## 4.1 Main effect of irrigation on the growth and yield of wheat

### 4.1.1 Plant height

Plant height is one of important morphological characters and potent indicator of availability of growth resources in its vicinity. Main effect of irrigation in respect of plant height of wheat was found significant (Table 3). Plant height of wheat under different irrigation treatments are presented in Figure 1.

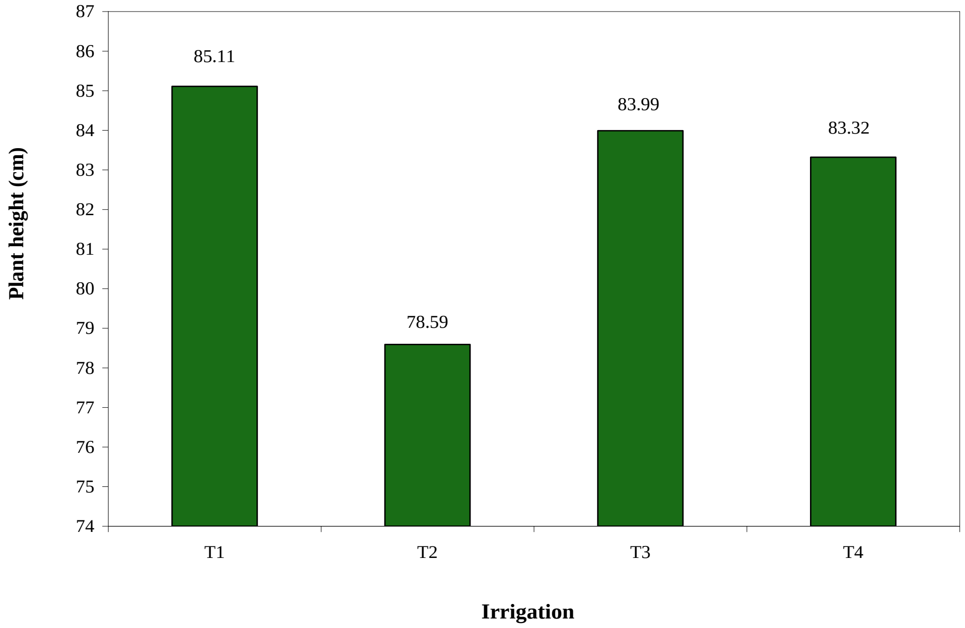

**Figure 1: Effect of irrigation on plant height of wheat; $T_1$-unstressed, $T_2$-skipping irrigation at crown root irrigation stage, $T_3$- skipping irrigation at booting stage, $T_4$- skipping irrigation at flowering and heading stage**

The highest plant height (85.11cm) was recorded in unstressed treatment ($T_1$), which was statistically similar with that of 83.99 cm from skipping irrigation at booting stage ($T_3$) treatment. On the other hand, the lowest height (78.59 cm) of wheat plant was recorded in stressed by skipping irrigation at crown root irrigation stage ($T_2$) treatment. Zhu *et al.* (2004) and Baek *et al.* (2005) reported reduced rate of cell division, expansion and enlargement by increasing stiffness of cell wall as inhibitory effect of water stress on plant growth. Similarly, Thalooth *et al.* (2006) observed reduced plant height from skipping irrigation at the different stages of growth compared to regular irrigation.

### 4.1.2 Spike length

The main effect of irrigation was remained significant on spike length of wheat (Table 3). Figure 2 shows spike length of wheat under different stressed conditions.

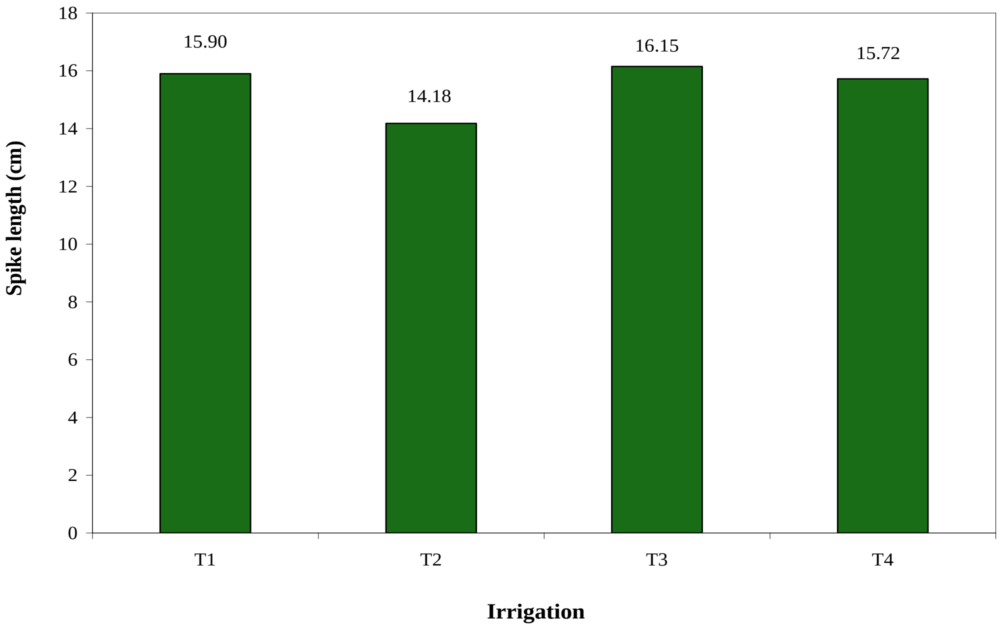

**Figure 2: Effect of irrigation on spike length of wheat; see ligand to Figure 1**

Skipping irrigation at booting stage ($T_3$) treatment produced the highest spike length (16.15cm) which was statistically similar to 15.90 cm and 15.72cm in control and skipping irrigation at flowering and booting stage ($T_4$) respectively. However, the lowest spike length (14.18cm) was found from skipping irrigation at crown root irrigation (CRI) stage ($T_2$) treatment. From this study it is clear that irrigation skipping at CRI stage may have negative effect on wheat yield. Similar finding was reported by Aslam *et al.* (2014) who observed that spike length significantly ($P<0.01$) affected by irrigation scheduling.

### 4.1.3 Number of grains spike$^{-1}$

Results revealed that number of grains per spike significantly affected by skipping irrigation at different growth stage of wheat plant; although significant difference in grains per spike was not found among $T_1$ (control), $T_3$ (skipping irrigation at flowering and heading stage) and $T_4$ treatment (skipping irrigation at booting stage) (Table 3). Figure 3 presents variation in grains per spike of wheat because of skipping irrigation at growth stage.

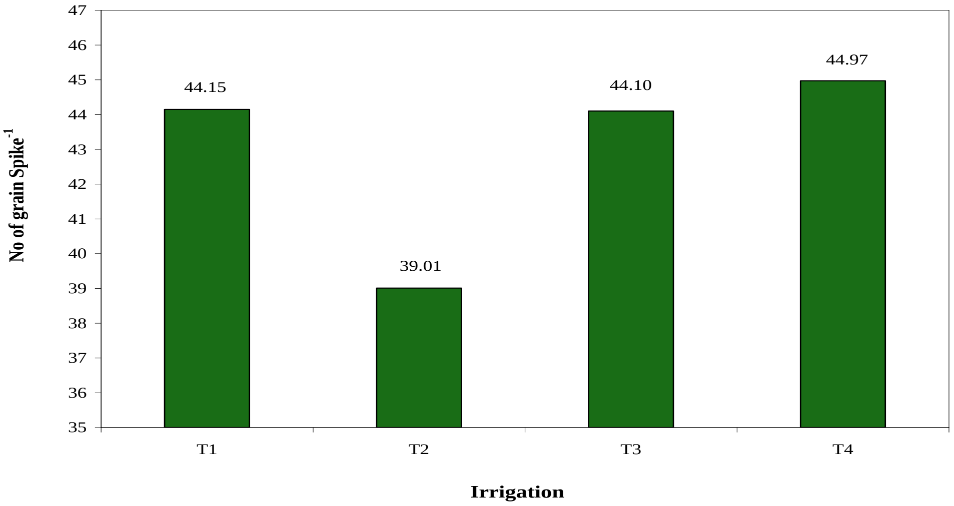

**Figure 3: Effect of irrigation on number of grains per spikelet; see ligand to Figure 1**

However, the highest number of grains per spike was 44.97 for $T_4$ treatment and the lowest number was 39.01 for $T_2$. Khan *et al.* (2007) observed significant effect of irrigation intervals on the number of grain per spike. Ngwako and Mashiqa (2013) evaluated that irrigation significantly affected number of grains per spike. On the other hand, Abdel-Motagally and El-Zohri (2016) recorded the highest number of grains per spikelet because of normal irrigation.

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

Variation in number of spikelet due to irrigation is presented in Figure 4. Results revealed that there was significant effect of skipping irrigation on number of spikelet per spike(Table 3). Maximum number of spikelet (23.47 no.) was produced from skipping irrigation at flowering and heading stage, followed by 22.55 number from control and 21.75 number from skipping irrigation at booting stage. However, minimum number of spikelet (20.63) spike$^{-1}$ was recorded for skipping irrigation at CRI stage. Abdel-Motagally and El-Zohri (2016) observed highest number of spikelet by adding normal irrigation level.

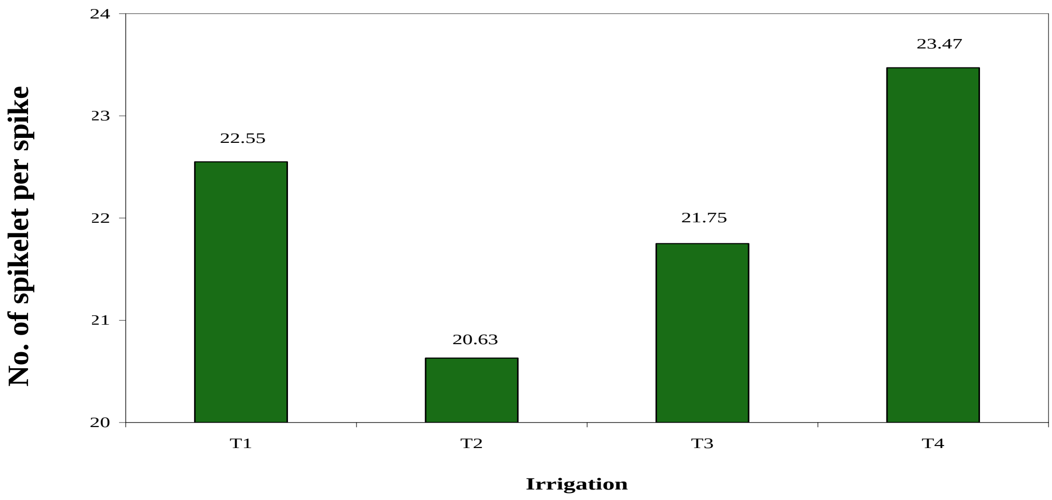

**Figure 4: Effect of irrigation on number of spikelet per spike; see ligand to Figure 1**

### 4.1.5 1000-Grain weight

The **e**ffect of irrigation skipping on 1000-grain weight was observed significant ($p<0.05$) (Table 3). Variation in 1000-grain weight as a result of irrigation skipping at different growth stages is shown in Figure 5. Results showed that the highest 1000-grain weight (52.62g) was resulted for skipping irrigation at flowering and heading stage ($T_4$) that was not statistically differed from 52.06g for $T_1$ treatment. On the other hand, skipping irrigation at CRI stage exerted the lowest 1000 grain yield (50.41g). This result was supported by Thalooth *et al.* (2006) who reported that missing one irrigation at any stages of growth significantly reduced yield components as well as photosynthetic pigments content as compared with regular irrigation. In earlier, Eskandari and Kazemi (2010) evaluated the response of irrigation to yield contributing characteristics and reported that limiting water decreased 1000 grain weight grain yield. Again, Huifang *et al.* (2010) noted that irrigation at jointing, heading and milking stage significantly increased 1000-grain weight.

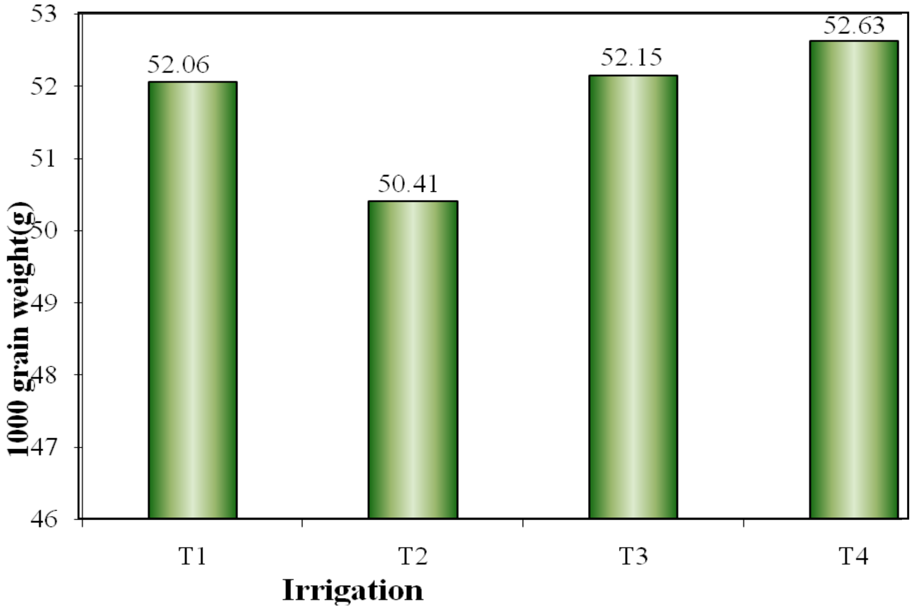

**Figure 5: Effect of irrigation on number of 1000 grain yield; see ligand to Figure 1**

### 4.1.6 Total yield

Total yield of wheat for variation in irrigation is shown in Figure 6. Irrigation skipping at various stages was remained significant in respect of total yield of wheat (Table 3). It was found that the highest yield (3.36 t/ha) of wheat was achieved for skipping irrigation at flowering and heading stage ($T_4$), followed by 2.91 t/ha and 3.05 t/ha for skipping irrigation at booting stage ($T_3$) and control. However, skipping irrigation at CRI stage ($T_2$) produced lowest yield (2.00 t/ha). From this study, it is clear that crown root irrigation stage is important because water stress at this stage may result in less tillering and great reduction in total yield. Irrigation interval at critical growth stage drastically reduces the number of grains per spike (Akram, 2000) and the total grain yield (Chauhan *et al.*, 2010). On the other hand, Wisal *et al.* (2006) reported that excess irrigation may lead to decrease in total yield instead of increasing yield.

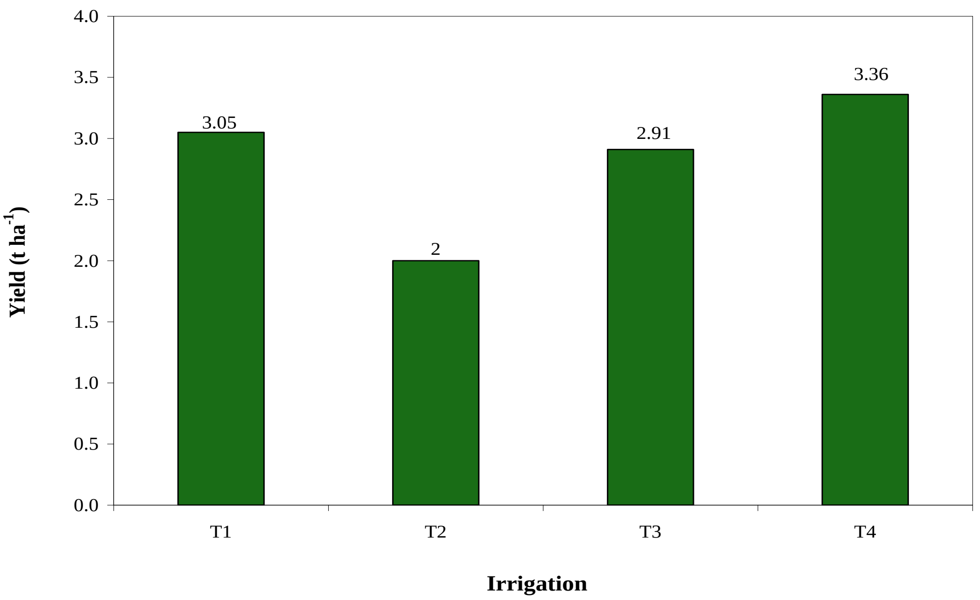

**Figure 6: Effect of irrigation on total yield of wheat; see ligand to Figure 1**

**Table 3: Effect of skipping irrigation on growth and yield parameters of wheat**

| Treatment combination | Plant height(cm) | Spike length(cm) | No of grain Spike$^{-1}$ | N0. of spikelet spike$^{-1}$ | 1000 grain weight (g) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1$ | 85.11$^{a}$ | 15.90$^{a}$ | 44.15$^{a}$ | 22.55$^{b}$ | 52.06$^{ab}$ | 3.05$^{b}$ |
| $T_2$ | 78.59$^{c}$ | 14.18$^{b}$ | 39.01$^{b}$ | 20.63$^{c}$ | 50.41$^{c}$ | 2.00$^{c}$ |
| $T_3$ | 83.99$^{ab}$ | 16.15$^{a}$ | 44.10$^{a}$ | 21.75$^{b}$ | 52.15$^{bc}$ | 2.91$^{b}$ |
| $T_4$ | 83.32$^{b}$ | 15.72$^{a}$ | 44.97$^{a}$ | 23.47$^{a}$ | 52.62$^{a}$ | 3.36$^{a}$ |
| Level of significance | ** | ** | ** | ** | * | ** |
| CV (%) | **11.31** | **07.21** | **10.54** | **7.51** | **3.25** | **5.60** |

Values in a column followed by a common letter are not significantly different at $p<0.05$; ** = Significant at 1% level of probability, * = Significant at 5% level of probability

## 4.2. Main effect of soil and foliar application of zinc on the growth and yield of wheat

### 4.2.1 Plant height

The effect of foliar application of zinc on plant height was significant at 1% level of significance (Table 4). Plant height of wheat affected by foliar application is shown in Figure 7. The highest plant height (86.10 cm) was achieved from $Zn_2$ treatment and the lowest height (77.93 cm) was found from control. This result was in line with Mekkei and El-Haggan (2014) who reported that foliar application of zinc with combination of micronutrients produced the highest plant height of wheat. Gul *et al.* (2011) also observed significant effect and maximum plant height of wheat from foliar application of zinc with potassium.

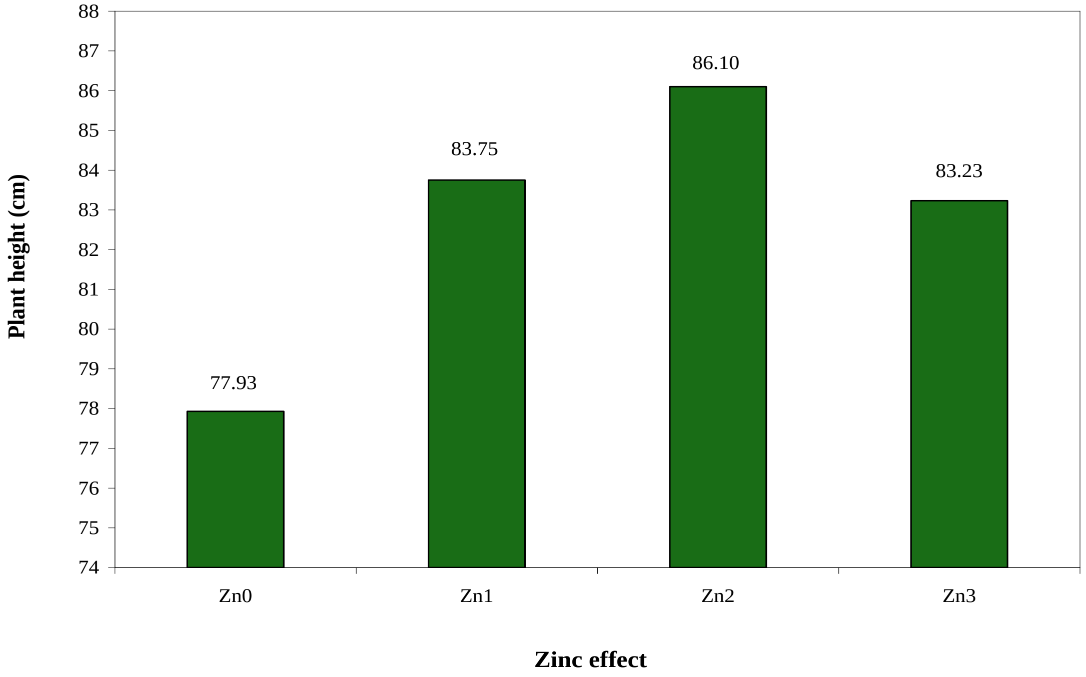

**Figure 7: Effect of soil and foliar application of zinc on plant height of wheat; $Zn_0$-control, $Zn_1$- 0.02% zinc solution, $Zn_2$-0.04% zinc solution and $Zn_3$- application of Zn solution (2.5 kg/ha) into soil**

### 4.2.2 Spike length

Variation in spike length as effect of foliar application of zinc is exerted in Figure 8 and foliar application had significant effect at 1% level of significance (Table 4). Application of zinc (0.04%) produced maximum spike length (16.15cm), which was statistically higher than that of 15.53cm for $Zn_3$ and 15.46 cm for $Zn_1$ treatment. On the other hand, control treatment produced the lowest spike length of 14.81cm. Zinc application may increase the spike length because it helps in cell division during the growth stage of plant. It was supported by Potarzycki and Grzebisz (2009) who observed that zinc treatment significantly affected the cob length, grain size and the final grain yield of maize.

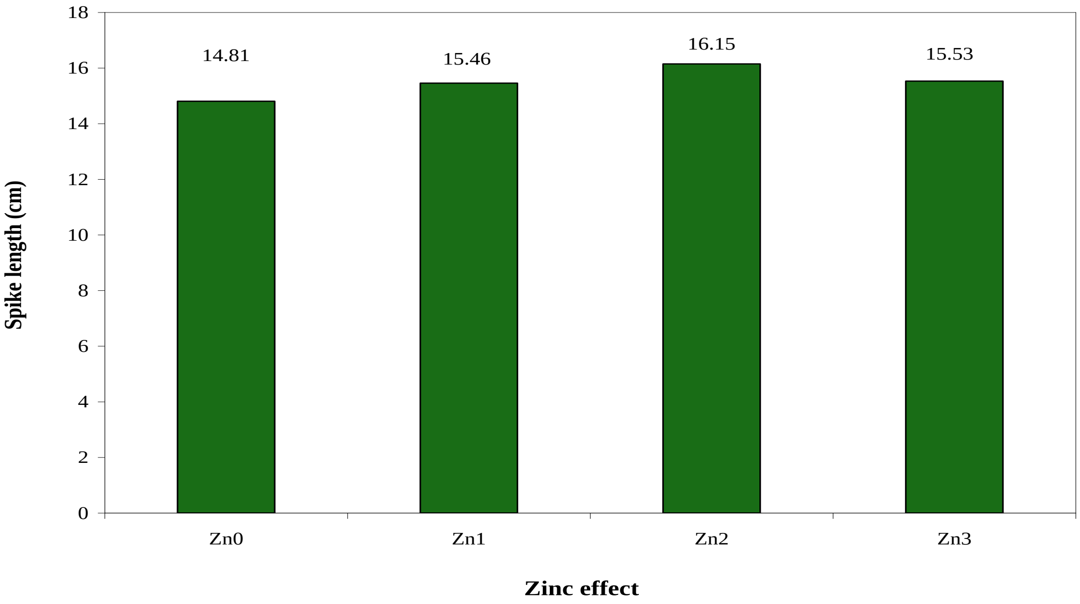

**Figure 8: Effect of soil and foliar application of zinc on spike length of wheat; see ligand to Figure 7**

### 4.2.3 Number of grains spike$^{-1}$

Number of grains per spike is exerted in Figure 9, was significantly affected by foliar application of zinc (Table 4). Results showed that there was significant (1%) difference among treatment in respect of grains per spike. It was found that zinc application into soil was less effective compared to foliar spray. However, maximum grains per spike was recorded 45.95 number from $Zn_2$ treatment, whereas $Zn_0$ treatment produced the lowest grains per spike (39.48 no.). This result was in agreement with Ali *et al.* (2009) who recorded that foliar spray of zinc with boron significantly increased the grains per spike. Soleimani (2006) also achieved increased number of grains spike$^{-1}$ for foliar application of zinc. Khan *et al*. (2010) observed higher grains per spike as foliar application of zinc, iron, manganese, copper and boron. Gul *et al*. (2011) also reported that foliar spray of 0.5% N + 0.5% K + 0.5% Zn solution produced maximum number of grains spike$^{-1}$ (52) while control treatment produced minimum number of grains spike$^{-1}$(29).

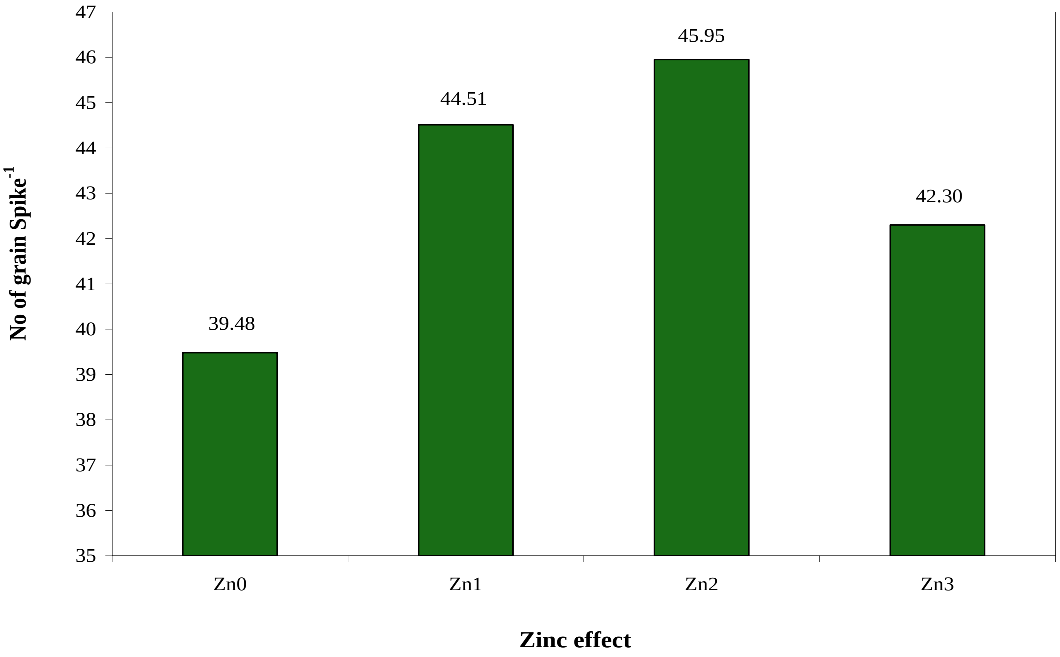

**Figure 9: Effect of soil and foliar application of zinc on grains per spikelet; see ligand to Figure 7**

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

Number of spikelet per spike of wheat is presented in Figure 10 and effect of foliar application of zinc in respect of spikelet number was found significant (Table 4). However, maximum number of spikelet (24.08) was achieved from $Zn_2$ treatment, followed by 22.40 number from $Zn_1$ and 22.10 number from $Zn_3$ treatment while control treatment exerted the lowest number of spikelet (19.82) spike$^{-1}$. Gul *et al.* (2011) reported that foliar spray of 0.5% N + 0.5% K + 0.5% Zn solutions had significant effect on the number of spikes m$^{-2}$.

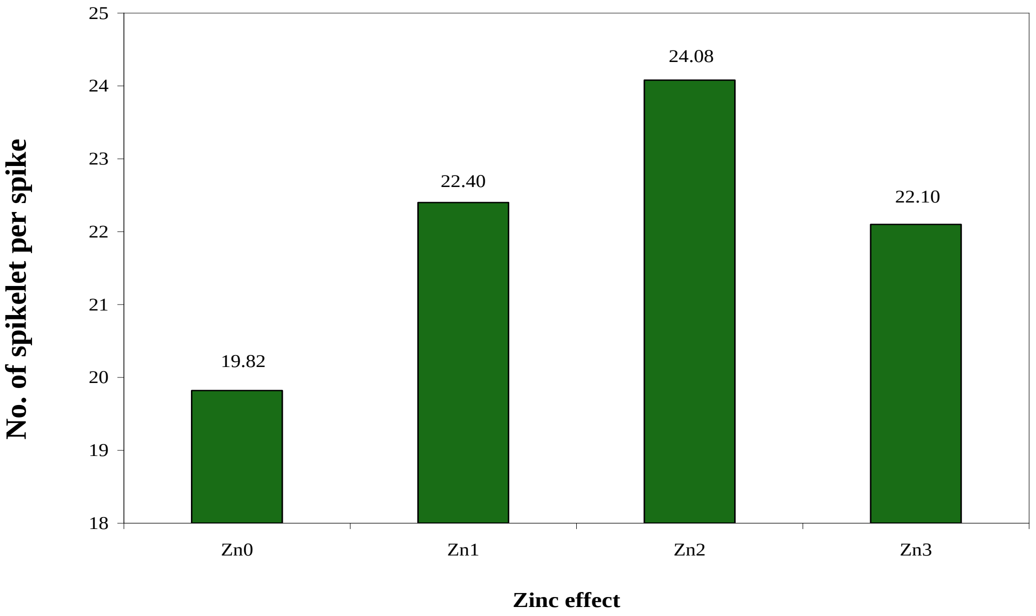

**Figure 10: Effect of soil and foliar application of zinc on number of spikelet per spike; see ligand to Figure 7**

### 4.2.5 1000-Grain weight

Results showed that foliar application of zinc significantly ($p<0.01$) affected 1000 grain weight (Table 4). Application of zinc increased 1000 grain weight compared with control treatment (Figure 11). Results revealed that foliar application of zinc produced higher 1000-grain weights than application of zinc in soil. The highest 1000-grain weight was found 53.53g for zinc application at 0.04% and followed by 52.83g for $Zn_1$ treatment while the lowest 1000-grain weight (49.64g) was found for control treatment. This result was in agreement with the finding of Sultana *et al.* (2016) who reported higher 1000-grain weight from higher dose of foliar application of zinc. In previous studies, Kaya and Higgs (2002) and Cakmak (2008) also reported that zinc plays an important role in the production of biomass.

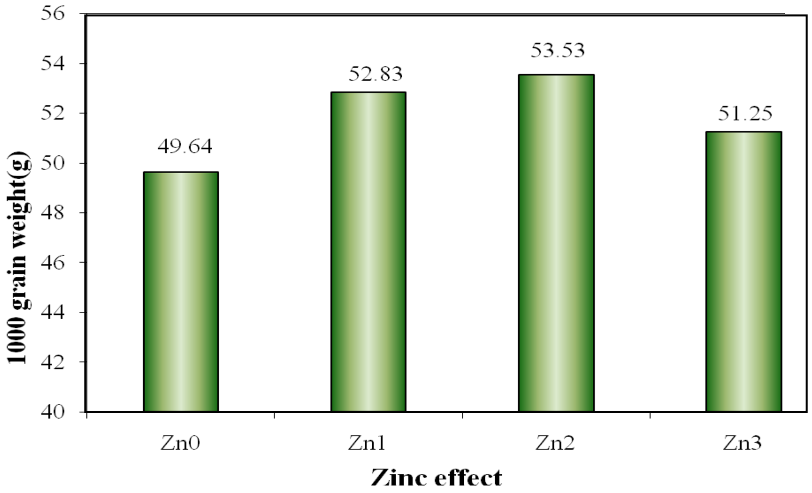

**Figure 11: Effect of soil and foliar application of zinc on number of 1000 grain weight; see ligand to Figure 7**

### 4.2.6 Total yield

Foliar application of zinc had significant effect on total yield of wheat (Table 4). Figure 12 shows that $Zn_2$ resulted maximum wheat yield (3.25 t/ha) followed by 2.87 t/ha and 2.84 t/ha for both $Zn_1$ and $Zn_3$ treatments. The lowest yield of wheat (2.36 t/ha) was found for control treatment. Similar finding was reported by Torun *et al.* (2001) and Grewal *et al.* (1997) who reported increased wheat production with the application of zinc over control. Zinc is essential for carbonic enzyme which presents in photosynthetic tissues and helps in chlorophyll biosynthesis (Ali *et al.*, 2008 and Graham *et al.*, 2001). Khan *et al.* (2010) stated that foliar application of zinc with other micronutrients increased the grain yield of wheat.

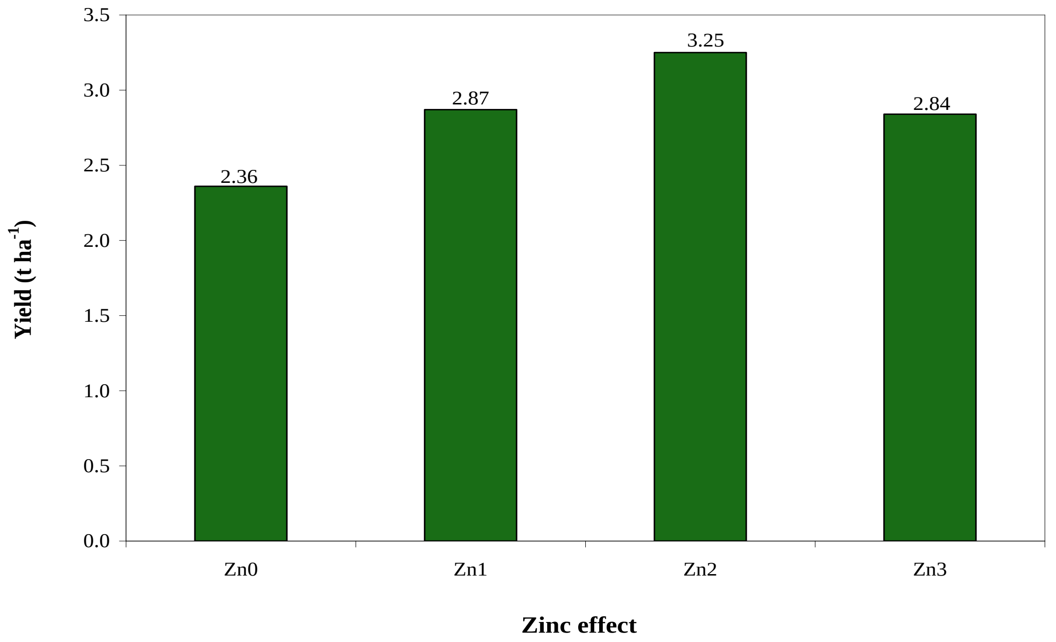

**Figure 12: Effect of soil and foliar application of zinc on total yield of wheat; see ligand to Figure 7**

**Table 4: Effect of soil and foliar application of zinc on growth and yield parameters of wheat**

| **Zinc application** | **Plant height(cm)** | **Spike length(cm)** | **No of grain Spike$^{-1}$** | **N0. of spikelet spike$^{-1}$** | **1000 grain weight (g)** | **Yield (t ha$^{-1}$)** |
|---|---|---|---|---|---|---|
| $Zn_0$ | 77.93$^{c}$ | 14.81$^{c}$ | 39.48$^{d}$ | 19.82$^{c}$ | 49.64$^{c}$ | 2.36$^{c}$ |
| $Zn_1$ | 83.75$^{b}$ | 15.46$^{b}$ | 44.51$^{b}$ | 22.40$^{b}$ | 52.83$^{ab}$ | 2.87$^{b}$ |
| $Zn_2$ | 86.10$^{a}$ | 16.15$^{a}$ | 45.95$^{a}$ | 24.08$^{a}$ | 53.53$^{a}$ | 3.25$^{a}$ |
| $Zn_3$ | 83.23$^{b}$ | 15.53$^{b}$ | 42.30$^{c}$ | 22.10$^{b}$ | 51.25$^{b}$ | 2.84$^{b}$ |
| Level of significance | ** | ** | ** | ** | * | ** |
| CV (%) | 10.09 | 7.22 | 13.11 | 10.03 | 3.25 | 5.60 |

Values in a column followed by a common letter are not significantly different at $p<0.05$; ** = Significant at 1% level of probability, * = Significant at 5% level of probability

## 4.3 Interaction effect of irrigation, soil and foliar application of zinc on the growth and yield of wheat

### 4.3.1 Plant height

Interaction of irrigation and foliar application of zinc had significant effect on plant height of wheat (Table 5). In general, regular irrigation with zinc solution application produced the higher plant height of wheat. Results revealed that the highest plant height (89.17cm) was achieved from $T_1Zn_2$ treatment, which was statistically similar to $T_3Zn_2$ (87.68cm). On the other hand, the lowest plant height of wheat was recorded 73.64 cm for $T_2Zn_0$, which was statistically similar to $T_1Zn_0$ (78.43cm), $T_2Zn_3$ (79.24cm) and $T_3Zn_0$ (79.12cm) treatment. From this study, it was clear that only irrigation without foliar application of zinc was not sufficient to enhance the plant height of wheat. Gul *et al.* (2011) noted that foliar application of N, K and Zn solution at boot stage was found to increase the stem length, which produced maximum plant height.

### 4.3.2 Spike length

It was found that spike length of wheat significantly affected by the combined effect of irrigation skipping and foliar application of zinc. Table 5 shows that skipping irrigation at flowering and heading stage with foliar application of zinc produced comparatively higher spike length. The highest spike length (16.98cm) was resulted in $T_4Zn_2$ treatment, whereas the lowest spike length (13.54cm) was found for $T_2Zn_0$ treatment. This result clearly reveled that both irrigation and foliar application at CRI stage are important for higher spike length of wheat. In a recent study, Sultana *et al.* (2016) reported that skipping irrigation at booting stage with zinc (0.02%) gave maximum spike length of wheat.

### 4.3.3 Number of grains spike$^{-1}$

Interaction between water stress and foliar application of zinc was remained significant on number of grains per spike (Table 5). It was found that the highest number of grains spike$^{-1}$ (48.20) was achieved from both regular irrigation with 0.04% zinc application ($T_1Zn_2$) and water stressed at flowering and heading stage with 0.04% zinc application ($T_4Zn_2$) treatments. On the other hand, second lowest grains per spike (46.00 no) was recorded from $T_1Zn_1$, which was not significantly differed from $T_3Zn_1$ (45.87 no), $T_4Zn_1$ (45.47 no), $T_4Zn_3$ (45.20 no) and $T_3Zn_3$ (44.27 no). However, water stressed with no zinc application resulted in the lowest number of grains per spike (36.12). This result was in line with Thalooth *et al.* (2006) who stated that missing of irrigation at any stage of growth significantly reduced yield and yield components as well as photosynthetic pigments content as compared with regular irrigation.

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

Interaction between water stress and foliar application of zinc had significant effect on number of spikelet spike$^{-1}$ (Table 5). The highest number of spikelet spike$^{-1}$ was recorded 26.20 for $T_4Zn_2$ treatment, which was followed by 24.40 number of spikelet spike$^{-1}$ for $T_1Zn_2$ treatment. However, the lowest spikelet per spike (16.80 no) was recorded for water stressed at CRI stage with no foliar spray of zinc ($T_2Zn_0$).

### 4.3.5 1000-Grain weight

Interaction effect of water stress and foliar application of zinc on 1000-grain weight was found significant ($p<0.05$) (Table 5). The highest 1000-grain weight (54.10g) was exerted by $T_4Zn_2$ treatment, which was followed by 54.00 g from $T_1Zn_2$. On the other hand, the lowest yield of 1000-grain weight (46.67g) was produced from water stressed at CRI stage with no foliar spray of zinc ($T_2Zn_0$) treatment. This result showed that water stress at CRI stage with no foliar application would have negative impact on the yield of wheat. Similar finding was reported by Sultana *et al.* (2016) who reported that skipping irrigation at flowering and heading stage of wheat with 0.04% foliar application of zinc gave the identical 1000-grain weight compared to regular irrigation with 0.04% and 0.06% foliar application of zinc.

### 4.3.6 Total yield

Result presented in (Table 5) shows that total yield of wheat was significantly affected by interaction effect between water stress and foliar application of zinc. It was found that water stress at different growth stage with foliar application of zinc increased total yield of wheat. Table 5 shows that the highest yield (3.82 t/ha) was achieved from $T_4Zn_2$ treatment, which was significantly different from other treatments. In addition, water stress at CRI stage with foliar application was found unable to increase the yield of wheat significantly and the lowest yield (1.80 t/ha) of wheat was found for $T_2Zn_0$ treatment. On the other hand, Sultana *et al.* (2016) reported that the highest grain yield of wheat (3.59 t/ha) was recorded in regular irrigation with 0.04% foliar application of zinc.

**Table 5: Effect of irrigation, soil and foliar application of zinc on growth and yield parameters of wheat**

| Treatment combination | | Plant height(cm) | Spike length(cm) | No of grain spike$^{-1}$ | No. Of spikelet panicle$^{-1}$ | 1000 grain weight (g) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Irrigation | Soil and Foliar application | | | | | | |
| $T_1$=Control (regular irrigation) | $Zn_0$ = Control | $78.43^{h}$ | $14.95^{ef}$ | $40.80^{c}$ | $21.40^{d}$ | $49.60^{h}$ | $2.37^{f}$ |
| | $Zn_1$ = 0.02% | $86.87^{bc}$ | $16.38^{abc}$ | $46.00^{b}$ | $22.40^{cd}$ | $53.33^{bc}$ | $3.20^{cde}$ |
| | $Zn_2$ = 0.04% | $89.17^{a}$ | $16.20^{abc}$ | $48.20^{a}$ | $24.40^{b}$ | $54.00^{b}$ | $3.55^{ab}$ |
| | $Zn_3$ = 2.5kg zn/ha | $85.96^{bcd}$ | $16.06^{bc}$ | $41.60^{c}$ | $22.00^{cd}$ | $51.33^{ef}$ | $3.10^{cde}$ |
| $T_2$ = skipping irrigation at CRI stage | $Zn_0$ = Control | $73.64^{i}$ | $13.54^{g}$ | $36.12^{e}$ | $16.80^{f}$ | $46.67^{i}$ | $1.80^{h}$ |
| | $Zn_1$ = 0.02% | $79.75^{gh}$ | $14.20^{fg}$ | $40.69^{c}$ | $21.87^{cd}$ | $51.67^{def}$ | $2.00^{gh}$ |
| | $Zn_2$ = 0.04% | $81.74^{fg}$ | $14.80^{ef}$ | $41.12^{c}$ | $22.53^{cd}$ | $53.00^{bcd}$ | $2.30^{fg}$ |
| | $Zn_3$ = 2.5kg zn/ha | $79.24^{h}$ | $14.18^{fg}$ | $38.12^{d}$ | $21.33^{d}$ | $50.33^{f}$ | $1.90^{h}$ |
| $T_3$ = skipping irrigation at booting stage | $Zn_0$ = Control | $79.12^{h}$ | $15.75^{cd}$ | $40.00^{cd}$ | $19.60^{e}$ | $51.60^{g}$ | $2.35^{f}$ |
| | $Zn_1$ = 0.02% | $84.56^{cde}$ | $16.15^{bc}$ | $45.87^{b}$ | $22.20^{cd}$ | $53.00^{bcd}$ | $2.90^{e}$ |
| | $Zn_2$ = 0.04% | $87.68^{ab}$ | $16.61^{ab}$ | $46.27^{ab}$ | $23.20^{c}$ | $53.00^{bcd}$ | $3.36^{bcd}$ |
| | $Zn_3$ = 2.5kg zn/ha | $84.60^{de}$ | $16.10^{bc}$ | $44.27^{b}$ | $22.00^{cd}$ | $51.00^{ef}$ | $3.06^{de}$ |
| $T_4$ = skipping irrigation at flowering and heading stage | $Zn_0$ = Control | $80.52^{gh}$ | $15.01^{de}$ | $41.00^{c}$ | $21.47^{d}$ | $50.70^{g}$ | $2.92^{e}$ |
| | $Zn_1$ = 0.02% | $83.84^{def}$ | $15.10^{de}$ | $45.47^{b}$ | $23.13^{c}$ | $53.33^{bc}$ | $3.40^{bc}$ |
| | $Zn_2$ = 0.04% | $85.82^{bcd}$ | $16.98^{a}$ | $48.20^{a}$ | $26.20^{a}$ | $54.10^{a}$ | $3.82^{a}$ |
| | $Zn_3$ = 2.5kg zn/ha | $83.11^{ef}$ | $15.80^{bcd}$ | $45.20^{b}$ | $23.07^{c}$ | $52.33^{cde}$ | $3.30^{bcd}$ |
| Level of significance | | * | * | * | ** | * | * |
| CV (%) | | **11.43** | **10.07** | **12.23** | **9.34** | **3.67** | **5.60** |

Values in a column followed by a common letter are not significantly different at $p<0.05$; ** = Significant at 1% level of probability, * = Significant at 5% level probability, NS = Not significant

### 4.4. Analytical value of post harvest soil

Post harvest soil was collected and analyzed following the established analytical methods.The data were presented in appendix-1.

# CHAPTER V

# SUMMARY AND CONCLUSION

The experiment was conducted at the Central Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2014 to march 2015 to know the effect of irrigation and foliar application of zinc on plant height, spike length, number of grains per spike, number of spikelet per spike, 1000 grain weight and total yield of wheat. This experiment comprised as two factors, Factor A: irrigation viz $T_1$- Regular irrigation, $T_2$- Skipping irrigation at CRI stage, $T_3$- Skipping irrigation at booting stage, $T_4$- Skipping irrigation at flowering and heading stage and factor B: foliar spray of zinc viz $Zn_0$ - Control, $Zn_1$ – 0.02%, $Zn_2$ – 0.04% and $Zn_3$ – 2.5kg Zn/ha into the soil.

The data on growth and yield characters like plant height, spike length, number of grains per spike, number of spikelet per spike, 1000 grain weight, and total yield of wheat were recorded and the analyses were carried out using MSTATC statistical package program. The mean differences were compared by least significant difference test (LSD) at 5% level of significance.

Results revealed that individual effect of irrigation was significant on all selected parameters. Effect of foliar application of zinc was also observed significant. However, interaction of variety and sowing date significantly affected all growth and yield contributing characteristics of wheat.

The highest plant height (85.11cm) was recorded for regular irrigation ($T_1$) and the lowest height (78.59cm) of wheat plant was recorded in stressed by skipping irrigation at crown root irrigation stage ($T_2$) treatment. On the other hand, skipping irrigation at booting stage ($T_3$) treatment produced the highest spike length (16.15cm), whereas the lowest spike length (14.18cm) was found from skipping irrigation at crown root irrigation (CRI) stage. The highest number of grains per spike (44.97) for $T_4$ treatment and the lowest number of grains per spike (39.01) were recorded for $T_2$. Maximum spikelet (23.47 no) was produced from skipping irrigation at flowering and heading stage while minimum number of spikelet (20.63) spike$^{-1}$ was recorded for skipping irrigation at CRI stage. Results showed that the highest 1000-grain weight (52.62g) was resulted for skipping irrigation at flowering and heading stage ($T_4$), whereas skipping irrigation at CRI stage exerted the lowest 1000-grain yield (50.41g). However, the highest yield (3.36 t/ha) was revealed for $T_4$ treatment while skipping irrigation at CRI stage ($T_2$) produced the lowest yield (2.00 t/ha).

Plant height of wheat was affected by foliar application while the highest plant height (86.10cm) and the lowest height (77.93cm) were achieved from $Zn_2$ and control treatment respectively. Again, application of zinc (0.04%) produced maximum spike length (16.15cm) and control treatment produced the lowest spike length of 14.81cm. Zinc application into soil was found less effective compared to foliar spray and the highest grains per spike (45.95 no) from $Zn_2$ treatment, whereas the lowest grains per spike (39.48 no) was found for $Zn_0$ treatment. However, maximum number of spikelet (24.08) was achieved from $Zn_2$ treatment, while control treatment exerted the lowest number of spikelet (19.82) spike$^{-1}$. The highest 1000-grain weight was found 53.53g for zinc application at 0.04% and the lowest 1000 grain weight (49.64g) was found for control treatment. Results showed that $Zn_2$ produced maximum yield (3.25 t/ha), whereas the lowest yield of wheat (2.36 t/ha) was found from control treatment.

Results revealed that the highest plant height (89.17cm) was achieved from $T_1Zn_2$ treatment whereas, the lowest plant height of wheat was recorded 73.64cm for $T_2Zn_0$, which was not statistically differed from $T_1Zn_0$ (78.43cm), $T_2Zn_3$ (79.24cm) and $T_3Zn_0$ (79.12cm) treatment. It was found that water stressed at flowering and heading stage with foliar application of zinc produced comparatively higher spike length. The highest spike length (16.98cm) and the lowest spike length (13.54cm) were resulted from $T_4Zn_2$ and $T_2Zn_0$ treatments. Results showed that the highest number of grains spike$^{-1}$ (48.20) was achieved from both $T_1Zn_2$ and $T_4Zn_2$ treatments. However, water stressed with no zinc application resulted the lowest number of grains per spike (36.12). Skipping irrigation at flowering and heading stage with foliar application of zinc (0.04%) produced the highest number of spikelet spike$^{-1}$(26.20) and the lowest spikelet spike$^{-1}$ (16.80 no) was recorded for water stressed at CRI stage with no foliar spray of zinc ($T_2Zn_0$). The highest 1000-grain weight (54.10g) was exerted by $T_4Zn_2$ treatment and the lowest yield of 1000-grain weight (46.67g) was produced from water stressed at CRI stage with no foliar spray of zinc ($T_2Zn_0$) treatment. The $T_4Zn_2$ treatment exerted the highest yield of wheat (3.82 t/ha), whereas the lowest yield (1.80 t/ha) was found for $T_2Zn_0$ treatment.

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

1. Studies of similar nature could be carried out in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability.
2. Higher dose of zinc with different management practices might be included in further studies.

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# APPENDICES

## Appendices-I. Physical and chemical Properties of Post harvest soil

| Treatment combination | | **pH** | **Total N%** | **Available p (ppm)** | ***K(meq/ 100g)*** | **OM%** |
|---|---|---|---|---|---|---|
| *irrigation* | *Soil and foliar application zn* | | | | | |
| *$T_1$=regular irrigation* | *Zn0=control* | 5.2 | 0.080 | 24.2 | *0.29* | 1.24 |
| | *$Zn_1$= 0.02%* | 5.5 | 0.050 | 22.6 | *0.20* | 1.35 |
| | *$Zn_2$= 0.04%* | 5.6 | 0.070 | 20.7 | *0.35* | 1.45 |
| | *$Zn_3$=2.5kg/ha* | 5.5 | 0.065 | 23.2 | *0.22* | 1.25 |
| *$T_1$= skiping irrigation at CRI stage* | *Zn0=control* | 5.4 | 0.069 | 23.6 | *0.21* | 1.45 |
| | *$Zn_1$= 0.02%* | 5.3 | 0.067 | 24.8 | *0.25* | 1.19 |
| | *$Zn_2$= 0.04%* | 5.1 | 0.060 | 26.0 | *0.25* | 1.27 |
| | *$Zn_3$=2.5kg/ha* | 5.4 | 0.073 | 23.0 | *0.24* | 1.19 |
| *$T_3$ = skiping irrigation at booting stage* | *Zn0=control* | 5.7 | 0.075 | 20.7 | *0.22* | 1.34 |
| | *$Zn_1$= 0.02%* | 5.5 | 0.083 | 23.3 | *0.25* | 1.38 |
| | *$Zn_2$= 0.04%* | 5.3 | 0.075 | 27.3 | *0.25* | 1.43 |
| | *$Zn_3$=2.5kg/ha* | 5.4 | 0.076 | 26.0 | *0.27* | 1.29 |
| $T_4$ = skiping irrigation at flowering and heading stage | *Zn0=control* | 5.4 | 0.065 | 22.9 | *0.30* | 1.30 |
| | *$Zn_1$= 0.02%* | 5.5 | 0.052 | 20.2 | *0.25* | 1.40 |
| | *$Zn_2$= 0.04%* | 5.3 | 0.050 | 23.6 | *0.32* | 1.45 |
| | *$Zn_3$=2.5kg/ha* | 5.5 | 0.055 | 19.0 | *0.22* | 1.29 |

# APPENDICES

## Appendix 11. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2014 to March 2015

| Month | *Air temperature (°c) | | *Relative humidity (%) | Total Rainfall (mm) | *Sunshine (hr) |
|---|---|---|---|---|---|
| | Maximum | Minimum | | | |
| November, 2014 | 25.8 | 16.0 | 78 | 00 | 6.8 |
| December, 2014 | 22.4 | 13.5 | 74 | 00 | 6.3 |
| January, 2015 | 24.5 | 12.4 | 68 | 00 | 5.7 |
| February, 2015 | 27.1 | 16.7 | 67 | 30 | 6.7 |
| March, 2015 | 28.1 | 19.5 | 68 | 00 | 6.8 |

* Monthly average,

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

Photographs showing different stages of wheat in experimental plot