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

BY

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CERTIFICATE

This is to certify that thesis entitled **"EFFECT OF 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 **MD. HASIBUR RAHAMAN HERA, Registration no. 13-05750** 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: June, 2014
Place: Dhaka, Bangladesh

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Dedicated to
My
Beloved Parents

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Abstract

A field experiment was carried out to study the effect of foliar application of zinc on growth and yield of wheat (BARI gom-25) grown under water stress condition in the research farm of the Sher-e-Bangla Agricultural University (SAU), during October 2013 to February 2014. The experiment was designed in randomized complete block with factor A (representing irrigation) and factor B (as foliar Zn application). There were in total 16 treatments comprising 4 irrigation treatments (regular irrigation, skipped irrigation at crown root initiation, skipped irrigation at booting stage and skipped irrigation at heading and flowering stage of growth) and four foliar application of zinc (control, 0.02%, 0.04% and 0.06% of zinc). Zinc Sulphate Monohydrate ($ZnSO_4.H_2O$) was used as a source of Zn. The interaction effect of irrigation and foliar application of zinc on yield components of wheat was significant. The highest yield (2.90 t ha^{-1}) was recorded in skipping irrigation at flowering and heading stage with 0.06% foliar application of zinc. Water stress at crown root initiation stage had the most negative effect on growth and yield. Skipping irrigation at booting stage and skipping irrigation at flowering and heading stage with 0.04% foliar application of zinc gave the identical yield in regular with control 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 optimum dose was appeared as 0.04% foliar application of zinc for grain yield of wheat.

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LIST OF ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Cost Benefit Ratio
cm	=	Centimeter
^0C	=	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
p^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Wheat is an important cereal crop and serves as a staple food in many countries of the world. It is the major source of plant based human nutrition and a part of daily dietary need in one form or the other. Besides its tremendous significance, average yield is far below than developed countries (FAO, 2010). 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.

Water deficit is frequently the primary limiting factor for crop production under arid and semi-arid conditions (Hussain, *et al.* 2004). It affects nearly all the plant growth processes. However, the stress response depends upon the intensity, rate and duration of exposure and the stage of crop growth (Wajid, *et al.* 2004). When considering a watering regime for a crop, it is wise to understand the sensitive growth stages for water stress and the water requirements of the crop in order to achieve maximum yield and maintaining adequate soil moisture conditions during moisture-sensitive stages of growth, so irrigation water may be saved if soil water could be depleted to a greater extent during certain growth stages without affecting yield.

Grain yield in wheat and other cereals is the end result of a number of contributing and inter-related components such as number of grains per ear, number of ear per unit area and mean 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. 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 (Karim *et al.* 2000).

Wajid *et al.* (2002) reported that wheat crop produced highest grain yield 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.

The impact of soil moisture deficit on crop yield depends on the particular phenological stage of the crop, and the most sensitive stage can show region-by-region variations (Singh *et al.,* 1991). These differences relate to regional variability in environment and information specific to a region is needed for developing and refining limited irrigation schemes. Applying water to crops at critical growth stages where the crop may utilize the water efficiently can save water.

Zn plays a pivotal role in the yield improvement of wheat (Rehm and Sims, 2006). Nearly 50% of the cereal-grown areas in the world have soils with low plant availability of Zn (Graham and Welch 1996; Cakmak 2002). Their lack greatly influences both the quantity and the quality of plant products (Ahmadikhah *et al.,* 2010). They are needed in trace amounts but their adequate supply improves nutrients availability and positively affects the cell physiology that is reflected in yield as well (Taiwo *et al.,* 2001; Adediran *et al.,* 2004). Potarzycki and Grzebisz (2009) reported that zinc exerts a great influence on basic plant life processes, such as (a) nitrogen metabolism– uptake of nitrogen and protein quality; (b) photosynthesis– chlorophyll synthesis, silt carbon anhydrase activity; reported that Zn-deficient 5.8%, plants reduce the rate of protein synthesis and protein content drastically. Zinc is important to membrane integrity and phytochrome activities (Shkoinik, 1984).

Foliar application of Zn leads to increase the grain yield and protein percentage in seed of wheat (Jiang and Huang 2002). Many researchers reported that increasing in agronomic traits is caused by foliar application of Zn. Jiang and Huang (2002) reported that the yield and its components of wheat are increased due to the effects of zinc on the amount of chlorophyll and concentration of abscisic acid. The increase of chlorophyll increases yield through the increase of photosynthesis. Although plants need a little amount of zinc, if sufficient amount of this element is not available, plants suffer physiological stresses resulted from inefficiency of various enzyme systems and other metabolic functions related to zinc (Baydar and Erbas, 2005; Ehdaie *et al.,* 2008). Zinc is also involved in key metabolic processes such as respiration, photosynthesis and assimilation of some major nutrients. Zinc plays an important role in enzymes activation as well.

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). Although plants need a little amount of zinc, if sufficient amount of this element is not available, plants suffer physiological stresses resulted from in efficiency of various enzyme systems and other metabolic functions related to zinc (Baydar and Erbas, 2005; Ehdaie *et al*., 2008).

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

Objectives

(1) To study the effective stage of applying irrigation water for wheat production.

(2) To find out the optimum dose of zinc for sustainable yield of wheat under water stress condition.

(3) To study the efficiency of foliar application of zinc to the harmful effect of water stress on growth and yield of wheat plants.

CHAPTER II

REVIEW OF LITERATURE

Wheat (*Triticum aestivum*) is the most important and strategic crop in the world and also in our country, so for sustainable production its requirements precise managements and special attention to wheat nutrition. Water is one of the most important factors that are necessary for proper growth, balanced development and higher yield of all crops. Wheat is also very sensitive to water stress and it is urgently needed for production. The role of macro and micronutrients are crucial in wheat production in order to achieve higher yields (Arif *et al*., 2006). Micronutrients deficiency has became a major constraint for wheat productivity in many countries of the world. The deficiency of micronutrients may be due to their low total contents or decreasing availability of them by soil aggregate fixation (Jafarimoghadam, 2008; Ranjbar and Bahmaniar, 2007). Among micronutrients, Zinc (Zn) plays a key role in pollination and seed set processes; so that their deficiency can cause to decrease in seed formation and subsequent yield reduction (Ziaeyan and Rajaiea 2009). Zinc as a micronutrient in wheat production has been clearly proved. Wheat (*Triticum aestivum* L.) is primary grown across exceptionally diverse range of environments in the world. It is classified into spring or winter wheat referring to the season during which the crop is grown. Under the present study, winter wheat was cultivated. An attempt has been made in this chapter to present a brief review of research in relation to foliar application of zinc on yield of wheat grown under water stress condition.

2.1 Effect of Irrigation

Bangladesh is although counted as an extensive irrigated country along with United States, Indonesia, Soviet Union, Mexico and Egypt, yet in its dry regions water is not sufficient even to provide initial requirements of agricultural crops. This deficiency retards not only the growth of the plants but also results in poor harvests thereby causing a great financial loss to the poor tiller of the soil. Even in the regions where irrigation water is available throughout the year, the cultivators fail to provide the optimum requirements because lack of knowledge about the quantities and timings of irrigation.

The irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper irrigation scheduling is essential for the efficient use of water, energy and other production inputs. Three major considerations influencing irrigation schedule are: (a) water needs of crop; (b) availability of water for irrigation; and (c) capacity of the root zone to store water. Water needs of crop are of paramount importance in determining the time of irrigation during the crop-growing season. The available research works on irrigation of wheat are presented below as review of literature:

Raghuwansh (1989) 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.

Patel and Upadhyay (1993) conducted experiment on wheat that was irrigated at irrigation water : cumulative pan evaporation (IW : CPE) ratio of 0.8. 1.2 or 1.6 and was given 90, 120 or 150 kg N and 45, 60 or 75 kg P_2O_5 per ha. They found that yield increased significantly with increasing irrigation up to 1.2 IW: CPE and N fertilizer rate up to 120 kg ha^{-1} but was not significantly affected by P rates. 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 and 4.10 t ha^{-1}, respectively, compared with 2.63 t ha^{-1} from the rainfed crop.

According to Deshmukh and Padole (1993), in a field trial on a clay loam soil, wheat was irrigated 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.

Khan *et al*. (2007) conducted a research work on clay loam soil to study the effect of different irrigation schedules on water use and yield of wheat. 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). Results of yield and its components indicated that there was significant effect of irrigation intervals on grain yield, number of grain per spike, grain weight per spike, number of tillers per plant and visual lodging percentage. There was no difference in yield and yield components when the crop was irrigated according to the full evaporation and half pan evaporation. 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 favors 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 can be harmful for the optimum yield of wheat if seasonal rainfall is 330 mm.

Wheat is produced under irrigated conditions in the country; but low rainfall and late heat stress conditions are the constraints to achieve the desired results. 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 yield increase 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. Dawood and Kheiralla, (1994) and Bankar *et al.* (2008) observed that five irrigations at crown root initiation, (tillering, jointing, flowering and milking stages, led to the highest yield. 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.

Haj *et al.* (2005) studied effects 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.

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.

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.

Abro (2012) concluded from the study of keeping in view the facts stated above a study was carried out to investigate the effect of different water regimes on the growth and yield of wheat varieties that for obtaining maximum grain yield in wheat, the crop will need five irrigations because there was significant decrease ingrain yield with decreasing the number of irrigations.

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. Three wheat varieties i.e. SKD-1, TD-1 and Imdad were evaluated for their performance against three irrigation scheduling i.e. five irrigations (1st 25 DAS and subsequent irrigations at 15 days interval), 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). The results showed that plant height, differed highly significantly ($P<0.01$) for irrigation scheduling, and non- significantly ($P>0.05$) for varieties and interaction. Spikelet's spike^{-1} and seed index highly significant ($P<0.01$) for irrigation and varieties where as non- significantly ($P>0.05$) for interaction. Tillers, spike length, grains spike^{-1}, Biological yield and grain yield showed highly significant ($P<0.01$) effects for irrigation scheduling, varieties and their interaction where as harvest index was influenced highly significantly ($P<0.01$) between irrigation scheduling and varieties and significantly ($P<0.05$) for their interaction. 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) spikelet's 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}).

Shaozhong *et al*. (2002) conducted 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. We therefore suggest that for winter wheat periods of mild soil drying in the early vegetative growth period together with severe soil drying in the maturity stage is an optimum limited-irrigation regime in this region.

Water is one of the most important factors that are necessary for proper growth, balanced development and higher yield of all crops. Water deficiency affects plant growth and grain yield (Hussain *et al*. 2004; Wajid *et al*. (2004). Grain yield in wheat and other cereals is the end result of a number of contributing and inter-related components such as number of grains per ear, number of ear per unit area and mean 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. 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 (Karim *et al*. 2000). Wajid *et al*. (2002) reported that wheat crop produced highest grain yield 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.

Ngwako and Mashiqa (2013) studied the effect of irrigation on the growth and development of winter wheat cultivars. The experiment comprised of two cultivars of wheat, namely Baviaans, and 14SAWYT306; four levels of irrigation namely: I_0 = no irrigation, I_1 = irrigation up to stem extension, I_2 = irrigation from stem extension up to physiological maturity, and I_3 = irrigation throughout the growth stages. 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, harvest index and grain protein were recorded in cultivar 14SAWYT306. Irrigation significantly affected days to maturity, number of tillers, number of grains per spike and grain yield. Irrigation throughout the growth stages increased number of tillers, number of grains per spike, grain yield, harvest index and grain protein by 20.58%, 26.07%, 42.72%, 16.71% and 3.31% respectively over no irrigation.

Onyibe (2005) conducted field trials to study 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. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. 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 a Irrigation experiments were conducted during different growing stages of winter wheat (*Triticum aestivum L.*) to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between seasonal amounts of irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). 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.

2.2 Effect of Zinc

The micronutrients play an important role in increasing crop yield. Micronutrients have prominent affects 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 spray of micronutrients is more effective to control deficiency problem than soil application (Torun *et al.*, 2001). Foliar application of Zn at growth and reproductive stage enhanced grain yield of wheat (Wroble, 2009). Many research work on effect of foliar application of zinc in wheat and also other crop on yield and yield contributing characters are presented below:

The regions with Zn-deficient soils are the regions where Zn deficiency in human beings is widespread, for example in India, Pakistan, China, Iran and

Turkey (Cakmak *et al.* 1999; Alloway, 2004). Zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries (Seilsepour, 2007). Nearly 50% of the cereal-grown areas in the world have soils with low plant availability of Zn (Graham and Welch, 1996).

Bybordi and Malakouti (2003) reported that wheat is sensitive to zinc deficiency, but less sensitive to Iron and copper deficiencies. Wheat is inherently low in concentrations of Zn in grain, particularly 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).

There are several examples demonstrating that applying Zn fertilizers to cereal crops improve not only productivity, but also grain Zn concentration of plants. Depending on the soil conditions and application form, Zn fertilizers can increase grain Zn concentration up to four fold under field conditions (Bansal *et al.*, 1990; Seilsepour, 2007).

Cultivated wheat contains very low levels of Zn and shows a narrow genetic ariation for Zn. Compared to cultivated wheat, wild and primitive wheat represent a better and more promising genetic resource for high Zn concentrations. Little information is, however, available about the genetic control and molecular physiological mechanisms contributing to high accumulation of Zn and other micronutrients in grain of different genetic materials (White and Broadley, 2005; Lucca *et al.*, 2006).

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 (Yilmaz *et al.*, 1997).

Timing of foliar Zn application is an important factor determining the effectiveness of the foliar applied Zn fertilizers in increasing grain Zn concentration. It is expected that large increases in loading of Zn into grain can be achieved when foliar Zn fertilizers are applied to plants at a late growth stage. Ozturk *et al.* (2006) studied changes in grain concentration of Zn 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).

Results showed that grain yield is dependent to available-Fe and available-Zn in soil. So use of Fe and Zn had not any effects in soils which had available-Fe and available-Zn more than 4.7 and 0.8 mg kg^{-1}, respectively. Maximum increasing of grain yield by Fe application was 1100 kg ha^{-1} in soils which contain 2 mg kg^{-1} available Fe and by Zn application, grain yield increase received to 1200 mg kg^{-1} in soils which contain 0.5 mg kg^{-1} available Zn. There was a positive correlation between grain yield and available soil Fe or available soil Zn. The average grain yield increased by using of Fe and Zn were 317 and 330 mg kg^{-1}, respectively. Yield increased 868 mg kg^{-1} by using of Fe and Zn. So the critical levels of Fe and Zn in soils were determined 4.7and 0.8 mg kg^{-1}, respectively. In this way, 54 and 46% of soils under wheat cultivation had deficiency in Fe and Zn, respectively. So the use of Zn and Fe fertilizers is highly recommended for yield increase in these soils (El- Majid *et al.*, 2000; Seilsepour, 2007).

As a plant nutrient the role of zinc in crop production, including wheat cultivation, has been well established (Kanwar and Randhawa, 1974).

Deficiency of and response to zinc in wheat have been reported from various parts of the world. Bangladesh soils are not exception to this. Zinc, a micro nutrient element, is required for plant growth relatively to a smaller amount. The total zinc content of soil ranges from less than 10 to 1000 ppm. Plant root absorbs zinc in the form of Zn++. Zinc involves in a diverse range of enzymatic activities. The functional role of zinc includes auxin metabolism. It influences the activities of hydrogenase and carbonic anhydrase, synthesis of cytochrome and the stabilization of ribosomal fractions (Tisdale *et al*., 1984). Due to the deficiency of zinc, plants show symptoms such as little leaf, mottle rosette, die-back, browning, yellowing, brown spot. The visual symptoms of zinc deficiency vary with the species, variety, soil, water regime, fertilizer use, planting method, growth stage and season. In general, zinc deficient plants make poor growth and interveinal leaf chlorosis and necrosis of lower leaves. Reddish or brownish spot often occurs on the older leaves and seed production is strikingly reduced due to its deficiency (Throne, 1957).

Shaheen *et al*. (2007) conducted 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 results obtained indicated the number of tillers per hill, grain and straw yield of wheat, zinc concentrations and zinc uptake both in grain and straw and zinc concentrations of pre-sowing and post—harvest soils were significantly increased with the application of zinc. But 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.

Zeidan *et al*. (2010) carried out two field experiments for increasing wheat yield and improve grain quality by increasing Zn and Fe in grains for human food in the developing country and to investigate the effect of micronutrient foliar application on wheat yield and quality of wheat grains. Results indicated that grain yield, straw yield, 1000-grain weight and number of grains/spike, Fe, Mn and Zn concentration in flag leaves and grains as well as, protein content in grain were significantly increased by application of these elements.

Potarzycki and Grzebisz (2009) reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism– uptake of nitrogen and protein quality; (ii) photosynthesis– chlorophyll synthesis, carbon anhydrase activity; reported that Zn-deficient plants reduce the rate of protein synthesis and protein content drastically Mn is required for biological redosystem, enzyme activation, oxygen carrier in nitrogen fixation (Romheld *et al.*, 1995). Gurmani *et al.* (1988) studied the effect of Fe, Mn, Zn and Cu on the yield and yield components of rice; they concluded that Zn alone, Mn alone and combined application of Mn and Cu increased the yield significantly over NPK. Zinc, Mn and Cu increased yield by 15, 11 and 10% over NPK, respectively.

Lutcher and Petrie (2005) conducted nine Zn fertilization experiments in low and intermediate precipitation. Treatments consisted of a factorial combination of P and Zn. Phosphorus was applied at 0 and 15 lb P_2O_5/ac (low precipitation zone) or 0 and 40 lb P_2O_5/ac (intermediate precipitation zone) and Zn was applied at 0 and 5 lb Zn/ac. Significant treatment-induced differences in tissue Zn concentration and uptake were measured in plant samples collected from the low precipitation zone. Treatments had no effect on grain yield or test weight.

Ghafoor *et al.* (2014) conducted this study during growing season of 2010 - 2011, to study 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 (Bakrajow and Kanypanka). 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.

Mekkei and El-Haggan Eman (2014) conducted two field experiments to study the effect of Cu, Fe, Mn, Zn foliar application on yield and quality of four wheat cultivars (Sids 13, Sakha 94, Misr 1 and Gemeiza 7). Results showed that foliar application by all micronutrients gave significant effect on yield traits and protein content in both seasons compared with control treatment. Moreover, foliar application with combination of micronutrients (Cu+Fe+Mn+Zn) produced the highest values of plant height (85.03 and 87.17 cm), tillers number m-2 (318.4 and 329.3), spikes number m-2 (279.33 and 282.9), spike length (9.32 and 9.56 cm), number of spikelet's spike^{-1} (16.26 and 16.37), number of grains spike^{-1} (39.73 and 40.98), 1000-grain weight (42.50 and 43.26 g), grain yield (6.270 and 6.400 ton ha^{-1}), straw yield (12.58 and 12.77 ton ha^{-1}), biological yield (18.84 and 19.17 ton ha^{-1}) and harvest index (33.21 and 33.36 %), respectively, in both seasons followed by Zn foliar application followed by Mn foliar application followed by Fe foliar application then Cu foliar application. Among wheat cultivars Sids 13 cultivar ranked 1st in all yield traits and protein content in both seasons followed by Misr 1 followed by Gemeiza 7 cultivar. However, Sakha 94 gave the lowest values of yield traits and protein content. It concluded that sowing Sids 13 cultivar with foliar application micronutrients (Cu+Fe+Mn+Zn) produce high grain yield and greatest grain protein content.

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. This hypothesis has been verified within a three-year field study, where zinc fertilizer was applied to maize plants at the 5th leaf stage. The optimal rate of zinc foliar spray for achieving significant grain yield response was in the range from 1.0 to 1.5 kg Zn/ha. Grain yield increase was circa 18% (mean of three years) as compared to the treatment fertilized only with NPK. Plants fertilized with 1.0 kg Zn/ha significantly increased both total N uptake and grain yield. Yield forming effect of zinc fertilizer revealed via improvement of yield structure elements. The number of kernels per plant showed the highest response (+17.8% as compared to the NPK plot) and simultaneously the highest dependence on N uptake (R2 = 0.79). For this particular zinc treatment, however, the length of cob can also be applied as a component of yield structure significantly shaping the final grain yield.

Mohsen *et al.* (2013) conducted a study to know the effect of foliar application of Zn and Mn on yield and yield components of safflower. Factors were foliar application with four levels (control water spraying), Zn spraying, Mn spraying and Zn + Mn spraying) and three cultivars of safflower (Sina, Sofeh and Li-111). Spraying was done at 50% flowering. Results showed that in the cultivars, there was significant difference ($p<0.01$) for 1000 -grain weight, stem diameter, number of seeds per plant, number of bolls, plant height and harvest index. Sofeh had stem diameter and plant height higher than other cultivars and the minimum number of boll per plant. It seems that in Sofeh reduced capability of boll production, because of assimilates using for more thickness stem and plant height. The highest harvest index obtained in Li-111 (44.05%). Sofeh had more number of seeds per plant than other cultivars. Sina had more 1000- seeds weight (48.28 g) than others. Mn spraying and Zn + Mn spraying had maximum grain yield, biological yield, 1000- seeds weight, stem diameter, number of seeds per plant and plant height.

Habib (2009) stated that the appearance of micronutrient deficiency in crops reduced quality of grain and production. He conducted afield 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. The treatments were control (no Zn and Fe Application), 150 g $Zn.ha^{-1}$ as ZnSO4, 150 g $Fe.ha^{-1}$as Fe2O3, and a combination of both Zn and Fe. In this study, parameters such as wheat grain yield, seed-Zn and Fe concentration were evaluated. Results showed that foliar application of Zn and Fe increased seed yield and its quality compared with control. Among treatments, application of (Fe + Zn) obtained highest seed yield and quality.

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. Yield and yield component of wheat showed significant response towards 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 (no spray) 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.

2.3 Interaction effect of irrigation and Zinc

Rahimi *et al.* (2012) conducted afield study to determine the effects of wastewater and zinc fertilizer on quantitative traits of wheat (*Triticum aestivum* L.) during the 2010/2011 growing season. The experiment was performed as a randomized complete block design in a factorial scheme with three replications. These factors were three levels of irrigation water (W_1: irrigation with well water, W_2: irrigation with waste water and well water alternately and W_3: irrigation with waste water at the whole growth period) and three levels of zinc fertilizer (F_1: control, F_2: application of 50 kg/ha $ZnSO_4$ and F_3: application of 75 kg/ha $ZnSO_4$). Results indicated that wheat plants irrigated with waste water 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. In conclusion, this research suggests that waste water irrigation of wheat crops with an application of 75 kg $ZnSO_4$ ha^{-1} could be recommended for an enhanced yield and yield components.

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.

Aghtape *et al* (2011) carried out an experiment to study the effects of treated wastewater, with complete fertilizer sprayed on some forage quantitative and qualitative characteristics of foxtail millet (*Setaria italica*), A split plot experiment based on randomized complete block design (R.C.B design) with three replicates was followed. Treatments included three levels of irrigation namely, irrigation with tap water at all stages of grows (control), irrigation with wastewater and tap water alternately, irrigation with wastewater for all growing stages, as the main plot and sprayed with three levels of complete fertilizer (NATBA-LIB): non-spraying (control), Sprayed with 600 g of complete fertilizer in each hectare, sprayed with 1200 g of complete fertilizer in each hectare, as were the subplots. According to the results, the irrigation with waste water and complete fertilizer sprayed had a significant effect on yield and forage quality characteristics. Among the irrigation treatments, irrigation with waste water 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. Also 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. Therefore, in order to achieve the desired quantitative and qualitative characteristics of forage millet, using the treated waste water and complete fertilizer has recommended.

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.

CHAPTER III

MATERIALS AND METHODS

In this chapter, the details of different materials used and methodology followed during the experimental period are described.

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 October 2013 to February 2014. 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 2013. 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 (°C), 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
Particle size analysis	
% Sand	30
% Silt	40
% 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
Available S (ppm)	22
Available Calcium	3.60 meq/100g soil
Available Magnesium	1.00 meq/100g soil
Available Boron	0.48 μg/g soil
Available Copper	3.54 μg /g soil
Available Iron	262.6 μg/g soil
Available Manganese	164 μg/g soil
Available Zinc	3.32 μg/g soil

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 on 18 October and 22 October 2013, respectively. Experimental land was divided into unit plots following the design of 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) were used as source of nitrogen, phosphorus and potassium respectively. As micro nutrient, Zinc (Zn) was applied as per treatments illustrated later. The rate of N, P and K was 150 kg, 125 kg and 67 kg ha^{-1} respectively.

3.7 Treatments of the experiment

The experiment was two factorials with four levels of irrigation and four levels 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

3.7.2Factor B : Foliar application 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 Zn
Zn_2	:	0.04% foliar application Zn
Zn_3	:	0.06% foliar application Zn

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_2	T_2Zn_2	T_3Zn_2	T_4Zn_2
T_1Zn_3	T_2Zn_3	T_3Zn_3	T_4Zn_3

3.8 Experimental design and lay out

The experiment was laid out in a Randomized Complete Block 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 Fertilizer application

Fertilizer was applied based on BARC fertilizer recommendation guide-2012. Urea, TSP. MoP, Gypsum and Boric acid was used as a source of N, P, K, S and B, respectively. All P, K, S, B and half of N was applied at the final land preparation and the remaining half of N was applied before booting stage.

3.11 Sowing of seeds in the field

The seeds of wheat were sown in rows made by hand plough on October 25, 2013. 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 1litre per ha.

3.13 Preparation and application of foliar 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 and 600 g Zn in 10 liter water is called 0.04% Zn and 0.06% Zn respectively. 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 22/2/2014. 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}, 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 predemarcated 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
3) Number of grain spike^{-1}
4) 1000 grain weight (g)
5) Seed 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 is 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}.

3.17.4 Weight of 1000 seeds

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.

3.17.5 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, organic matter, total N, available P, exchangeable K and available S. The physical and chemical properties of post harvest soil have been presented in Appendix-1. The soil was analyzed by standard methods:

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 nitrogen of 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 phosphorus was 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).

3.20.7 Available sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page *et al.*, 1982). The S content in the extract was determined turbidmetrically and the intensity of turbid was measured by Spectrophotometer at 420 *n*m wave length.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from present study for different crop characters, yields and other analyses have been presented and discussed in this chapter.

4.1 Effect of irrigation on the growth and yield of wheat

4.1.1 Plant height

Plant height is an important growth character of a crop. Under the present study, plant height was significantly influenced by irrigation treatment (Table 3). It was observed that the highest plant height (83.30 cm) was achieved from treatment T_1 (regular irrigation) where as the lowest plant height (76.40 cm) was obtained from T_2 (skipping irrigation at CRI stage) (Fig. 1). The results obtained from T_3 (skipping irrigation at booting stage) and T_4 (skipping irrigation at flowering and heading stage) were statistically similar with treatment T_1. Here, it can be stated that regular irrigation is essential for higher plant growth and next to at flowering and heading stage including CRI stage and booting stage. Alderfasi *et al.* (1999) observed a significant increase of plant height, with increased amount of irrigation. Aslam *et al.* (2014) also observed that plant height, differed highly significantly for irrigation scheduling.

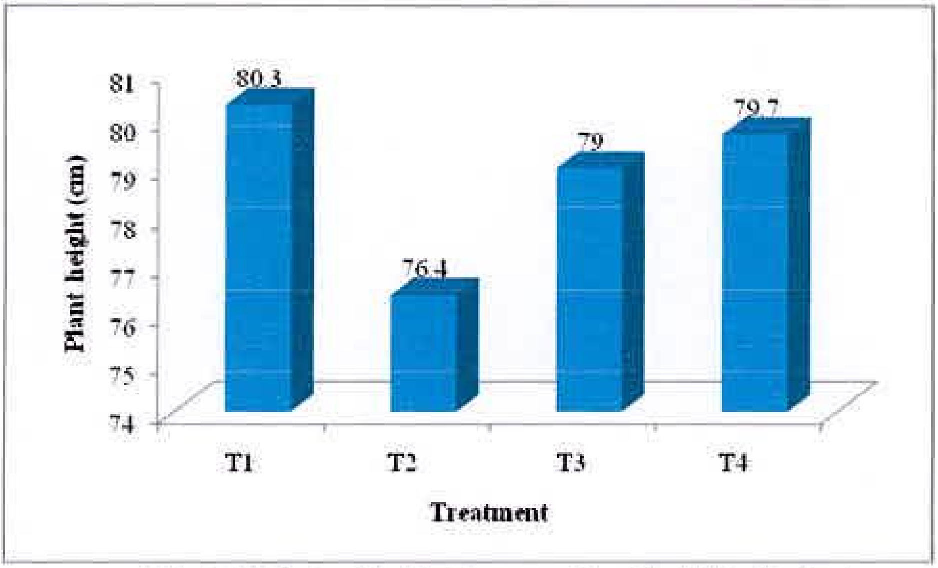

Fig.1: Effect of irrigation on plant height of wheat

Here,

T_1 = Control (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

4.1.2 Spike length

Spike length is also an important growth character of a crop. Under the present study, spike length was significantly influenced by irrigation treatment (Fig. 2). It was observed that the highest spike length (13.54 cm) was achieved from skipping irrigation at flowering and heading stage (T_4) which was statistically identical with Control (T_1) and skipping irrigation at booting stage (T_3) (Table 3). Again, the lowest spike length (10.35 cm) was obtained from T_2 (skipping irrigation at CRI stage). Here, it can be stated that regular irrigation or skipping irrigation at booting stage and/or also skipping irrigation at flowering and heading stage is essential for higher yield contributing characters. Similar result was obtained by Aslam *et al.* (2014) and he observed that spike length showed highly significant ($P<0.01$) effects for irrigation scheduling. Mekkei and El-

Haggan Eman (2014) also showed foliar application with combination of micronutrients (Zn) produced the highest values spike.

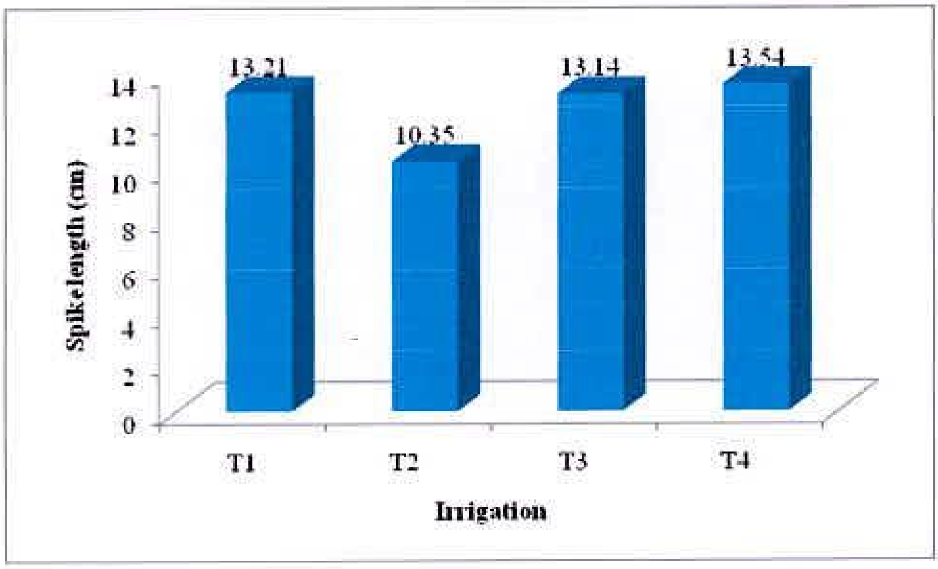

Fig.2: Effect of irrigation on spike length of wheat

Here,

T_1 = Control (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

4.1.3 Number of grain spike^{-1}

Signification variation was observed in terms of number of grain spike^{-1}. Under the present study, number of grain spike^{-1} was significantly influenced by irrigation treatment (Table 3). It was experimented that the highest number of grain spike^{-1} (44.90) was achieved from skipping irrigation at flowering and heading stage (T_4) which was statistically identical with control treatment (T_1) and skipping irrigation at booting stage (T_3) (Fig. 3). Again, the lowest number of grain spike^{-1} (39.10) was obtained from T_2 (skipping irrigation at CRI stage) which was significantly different from all other treatments. Here, it can be stated that regular irrigation or skipping irrigation at booting stage and/or also skipping irrigation at flowering and heading stage is essential for higher yield contributing characters like number of grain spike^{-1}. Khan *et al.* (2007) observed that there was significant effect of irrigation intervals by number of grain per spike. 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. Ngwako and Mashiqa (2013) evaluated that irrigation significantly affected number of grains per spike and grain yield. Irrigation throughout the growth stages increased number of grains per spike over no irrigation.

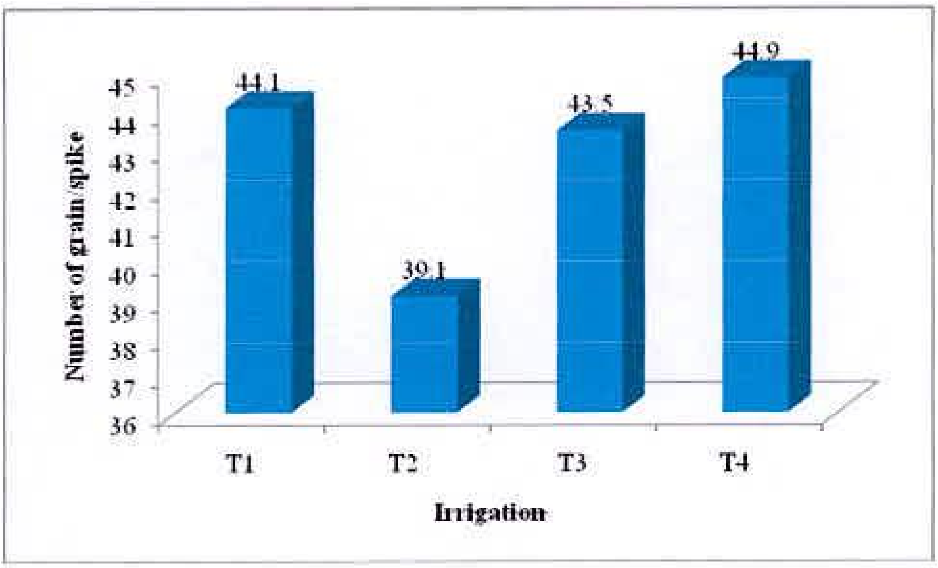

Fig.3: Effect of irrigation on number of grain spike^{-1} of wheat

Here,

T_1 = Control (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

4.1.4 Weight of 1000 grains

Generally increased 1000 grain weight resulted higher grain yield ha^{-1}. Here, irrigation at different stages to the crops was not significant (Table 3). But the highest 1000 grain weight (52.05 g) was observed with skipping irrigation at flowering and heading stage (T_4) where the lowest (50.40 g) was with skipping irrigation at CRI stage (T_2) (Fig. 4). The results obtained by Ibrahim *et al.* (2007) was not similar and they observed that thousand grain weight was highest when the crop was irrigated five times at 25 days interval, rather than four times at 30 days intervals.

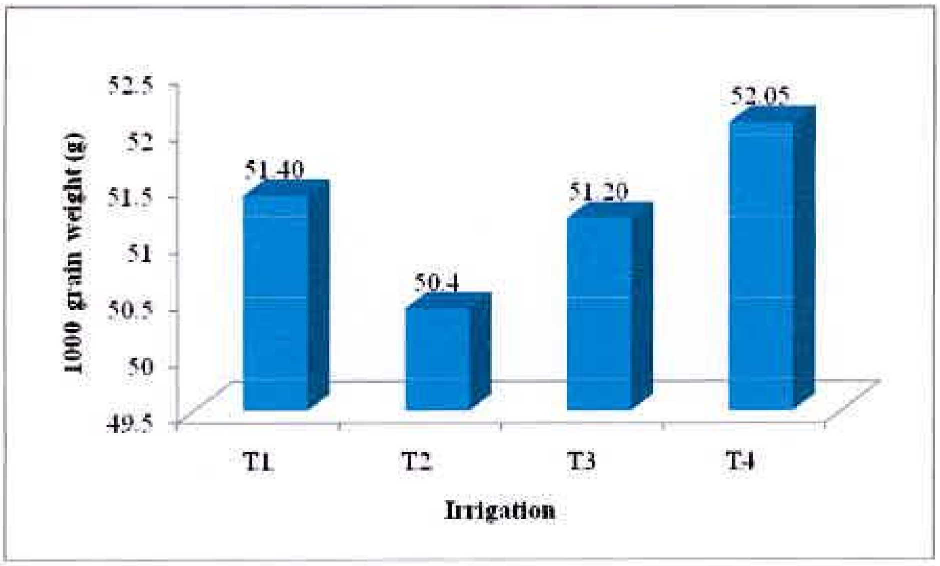

Fig.4: Effect of irrigation on 1000 grain weight (g) of wheat

Here,

T_1 = Control (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

4.1.5 Yield ha^{-1}

Generally yield is the ultimate goal of a crop production. More yield encourage more production and causes higher return and also meet higher demand of food. Under the present study, yield was significantly influence by irrigation that was applied at different condition according to the experiment. The effect of irrigation on the grain yield and yield components of wheat has been shown in (Table 3). The highest grain yield (2.55 t ha^{-1}) was obtained with skipping irrigation at heading and flowering stage (T_4), which is followed by T_1 treatment (Fig. 5). The lowest yield (1.65 t ha^{-1}) was obtained from skipping irrigation at crown root initiation stage (T_2) which was significantly lower than other treatments. This finding revealed that crown root initiation stage was the most critical stage for irrigation and its omission at this stage reduced the grain yield of 33 to 42%. Here, it can be stated that irrigation at flowering and heading stage is more effective than regular irrigation and also more cost effective. Memon *et al.*, (1999) also concluded that early growing period of wheat (crown root initiation and tillering stages) was most sensitive to water stress followed by milky and booting stages. Irrigation missing at some critical growth stage sometimes drastically reduces grain yield (Chauhan *et al.*, 2008), due to lower 1000-grain weight (Bajwa *et al.*, 1993) and lesser number of grains per spike (Hussain, 1996; Akram, 2000). Wisal *et al* (2006) reported that over irrigation also sometimes leads to decrease in grain yield instead of increasing yield (Kahlown and Azam, 2002). CRI stage is the most critical for irrigation in wheat, because any shortage of moisture at this stage results in less tillering and great reduction in yield.

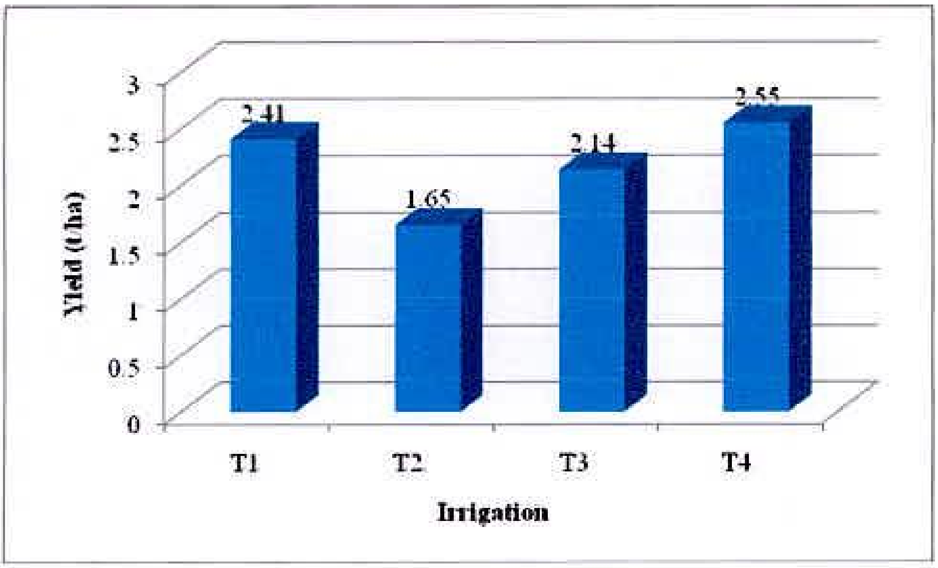

Fig.5: Effect of irrigation on Yield (t ha^{-1}) of wheat

Here,

T_1	=	Control (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

Table 3: Effect of irrigation on the growth and yield of wheat

Treatment combination	Plant height(cm)	Spike length(cm)	No of grain $Spike^{-1}$	1000 grain weight (g)	Yield ($t\ ha^{-1}$)
T_1=Control (regular irrigation)	80.3^{a}	13.21^{a}	44.1^{a}	51.40^{a}	2.41^{a}
T_2= Skipping irrigation at CRI stage	76.4^{b}	10.35^{b}	39.1^{b}	50.40^{a}	1.65^{c}
T_3= Skipping irrigation at booting stage	79.0^{ab}	13.14^{a}	43.5^{a}	51.20^{a}	2.14^{b}
T_4= Skipping irrigation at flowering and heading stage	79.7^{ab}	13.54^{a}	44.9^{a}	52.05^{a}	2.55^{a}

Values in a column followed by a common letter are not significantly different at $p<0.05$

4.2 Effect of foliar application of zinc on the growth and yield of wheat

4.2.1 Plant height

Under the present study, plant height was significantly influenced by foliar application of zinc (Fig. 6). Results revealed that the highest plant height (82.70 cm) was achieved from Zn_2 (0.04%) where the lowest plant height (78.00 cm) was obtained from Zn_0 (control) (Table 4). The results obtained from Zn_1 (0.02%) and Zn_3 (0.06%) was statistically similar with Zn_2 (0.04%) treatment. Here, it was also observed that zinc had a contribution for higher plant growth and Zn_2 =0.04% showed the best result where no application of zinc treatment showed lowest plant height. Mekkei and El-Haggan Eman (2014) obtained similar results and they observed that foliar application with combination of micronutrients (Zn) produced the highest values of plant height.

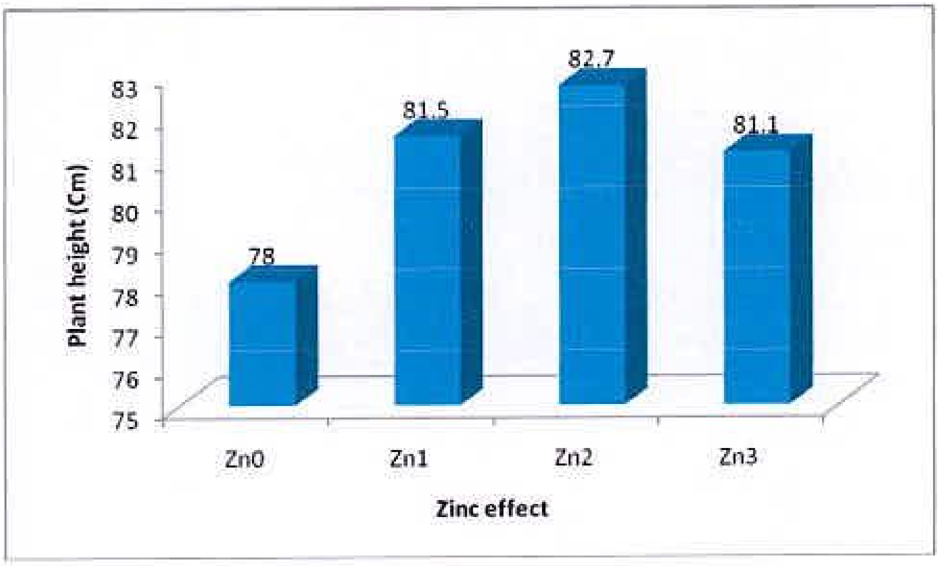

Fig.6: Effect of foliar application of zinc on plant height of wheat

Here,

Zn_0	=	Control (No Zn application)
Zn_1	=	0.02% foliar application Zn
Zn_2	=	0.04% foliar application Zn
Zn_3	=	0.06% foliar application Zn

4.2.2 Spike length

Significant variation was observed for spike length influenced by foliar application of zinc (Fig. 7). Results revealed that the highest spike length (13.30 cm) was achieved from Zn_2 (0.04%) which was statistically same with Zn_3 (0.06%). The results obtained from Zn_1 (0.02%) was statistically similar with Zn_2 (0.04%) treatment. The lowest spike length (12.67 cm) was obtained from Zn_0 (control) treatment which was significantly different from all other treatments (Table 4). Here, it can be stated that zinc had a contribution for higher spike length and Zn_2 @ 0.04% showed the best result where no application of zinc (Zn_0) showed lowest spike length. Mekkei and El-Haggan Eman (2014) observed that foliar application with combination of micronutrients (Cu+Fe+Mn+Zn) produced the highest values of spikes number m^{-2}, number of grains $spike^{-1}$. Another research conduted by Potarzycki and Grzebisz (2009) found that particular zinc treatment, however, the length of cob can also be applied as a component of yield structure significantly shaping the final grain yield of maize.

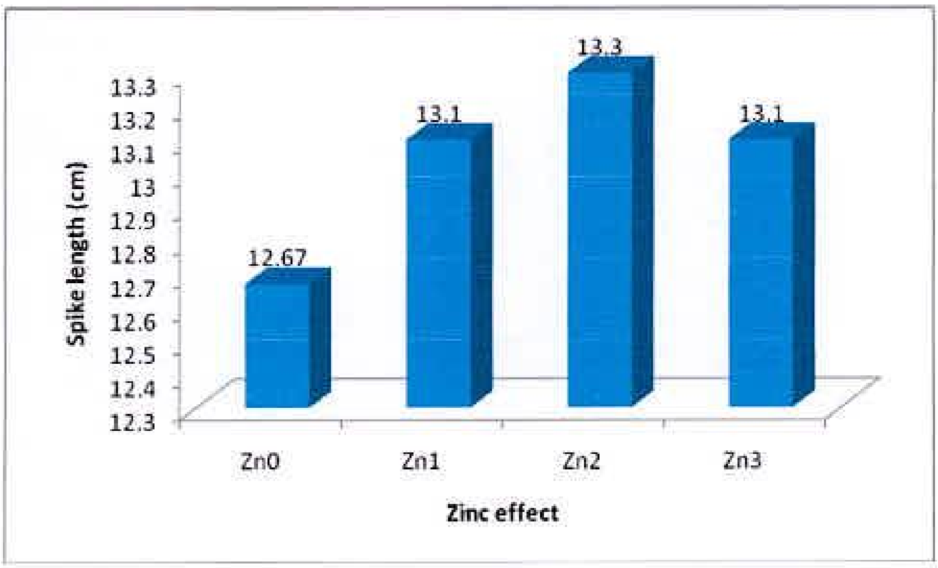

Fig.7: Effect of foliar application of zinc on spike length of wheat

Here,

Zn_0	=	Control (No Zn application)
Zn_1	=	0.02% foliar application Zn
Zn_2	=	0.04% foliar application Zn
Zn_3	=	0.06% foliar application Zn

4.2.3 Number of grain spike^{-1}

Significant variation was observed in terms of number of grain spike^{-1} (Fig. 8). Under the present study, number of grain spike^{-1} was significantly influenced by foliar application of zinc at different doses (Table 4). It was examined that the highest number of grain spike^{-1} (46.70) was achieved from Zn_2 which was statistically similar with Zn_1 and Zn_3. Again, the lowest number of grain spike^{-1} (35.20) was obtained from Zn_0 (control) which was significantly different from all other treatments. Here, it can be declared that definite doses of Zn contribute more effective number of grain spike^{-1}. Mekkei and El-Haggan Eman (2014) evaluated that foliar application with combination of micronutrients (Cu+Fe+Mn+Zn) produced the highest values of number of grains spike^{-1}. Gul *et al.* (2011) also reported that maximum number of grains (52) spike^{-1} was produced in plots under the effect of foliar spray of 0.5% N +

0.5% K + 0.5% Zn solution (once), while control (no spray) plots produced minimum number of grains (29) $spike^{-1}$.

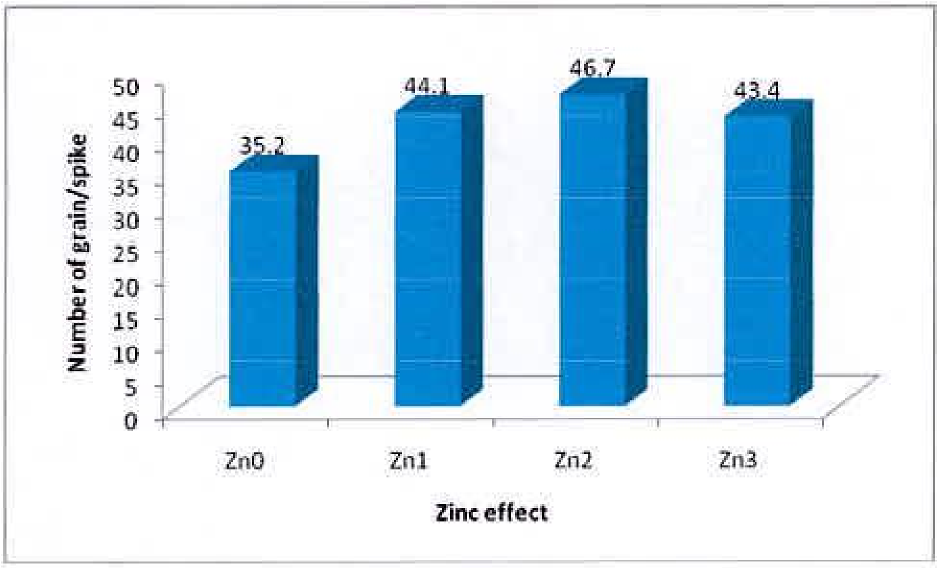

Fig.8: Effect of foliar application of zinc on number of grain $spike^{-1}$ of wheat

Here,

Zn_0	=	Control (No Zn application)
Zn_1	=	0.02% foliar application Zn
Zn_2	=	0.04% foliar application Zn
Zn_3	=	0.06% foliar application Zn

4.2.4 Weight of 1000 grains

Weight of 1000 grains is an important yield contributing character. Higher 1000 grain weight indicates more healthy seeds and resulted higher grain yield ha^{-1}. Here, foliar application of zinc to the crops was significant (Table 4). The highest 1000 grain weight (54.00 g) was observed with Zn_2 where the lowest (52.00 g) was with control treatment (Zn_0) (Fig. 9). But significant influence was observed in wheat by foliar application of Zn by Zeidan *et al.* (2010) and they showed that 1000-grain weight was significantly increased with application of foliar application of Zn. Mekkei and El-Haggan Eman (2014) also showed similar results with Zeidan *et al.* (2010).

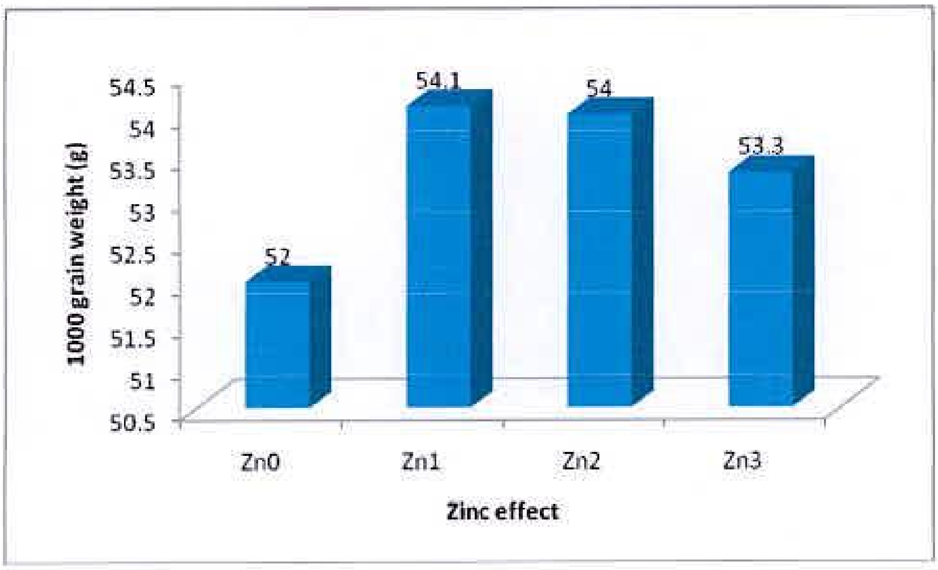

Fig.9: Effect of foliar application of zinc on 1000 grain weight plot^{-1} (g)

Here,

Zn_0	=	Control (No Zn application)
Zn_1	=	0.02% foliar application Zn
Zn_2	=	0.04% foliar application Zn
Zn_3	=	0.06% foliar application Zn

4.2.5 Yield ha^{-1}

Grain yield is the main achievement of a crop production. Foliar application of zinc played a significant role in the yield and yield components of wheat (Table 4). Yield components were influenced significantly due to foliar application of zinc. The grain yield of wheat increased significantly due to added zinc up to 0.04%. The highest grain yield (2.42 t ha^{-1}) was achieved from Zn_2 (0.04% Zn) which was not statistically different from Zn_1 (0.02% Zn) and Zn_3 (0.06% Zn). Here, it can be stated that foliar application of zinc @ 0.04% was more effective than other doses that was applied under the present study and also more cost effective (Fig.9). The lowest grain yield (1.82 t ha^{-1}) was obtained from Zn_0 (control; no Zn application) which was significantly different from all other treatments. Zinc is essential element for crop production and optimal size of grain, also it required in the carbonic enzyme which present in all photosynthetic tissues, and required for chlorophyll biosynthesis (Ali *et al.*, 2008; Graham *et al.*, 2000). Zinc was described to its role in maintenance of the structural integrity of the plasma membrane and thus controlling the uptake of toxic ion (Welch *et al.*, 1982; Cakmak and Marschner, 1988b) also help plant from damaging attack of ROS. The highest yield (2.42 t ha^{1}) was found with 0.04% foliar application of zinc which was higher over rest of the doses. These results agree with Torun *et al.*, (2001) and Grewal *et al.*, (1997) who reported increased wheat production with application of zinc over control. In conformity, Soylu *et al.* (2005), Guenis *et al.* (2003) and Hussian *et al.* (2002) reported significant increase in 1000-grains weight of wheat with foliar application of Zn. Our results are in line with that of Soleimani (2006) who also reported increase in number of grains $spike^{-1}$ for foliar application of zinc. There was no significant difference among 0.02% and 0.06% foliar application of zinc.

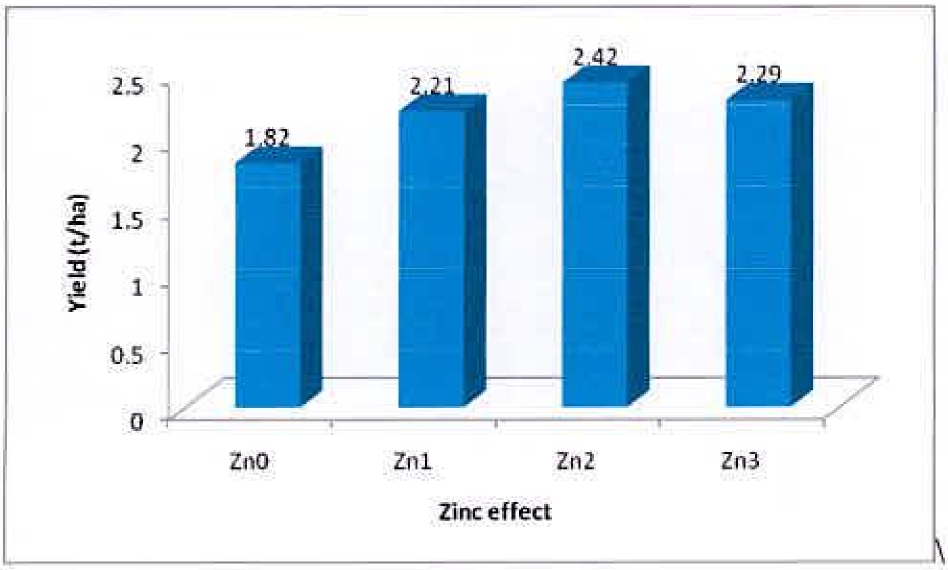

Fig.10: Effect of foliar application of zinc on Yield (t ha^{-1})

Here,

Zn_0	=	Control (No Zn application)
Zn_1	=	0.02% foliar application Zn
Zn_2	=	0.04% foliar application Zn
Zn_3	=	0.06% foliar application Zn

Table 4. Effect of foliar application of zinc on the growth and yield of wheat.

Treatment combination	Plant height(cm)	Spike length(cm)	No of grain Spike^{-1}	1000 grain weight (g)	Yield (t ha^{-1})
Zn_0=control	78.0^{b}	12.67^{b}	35.2^{b}	52.00^{a}	1.82^{b}
Zn_1 =0.02%	81.5^{ab}	13.1^{ab}	44.1^{ab}	54.10^{a}	2.21^{a}
Zn_2 =0.04%	82.7^{a}	13.3^{a}	46.7^{a}	54.00^{a}	2.42^{a}
Zn_3 =0.06%	81.1^{ab}	13.1^{a}	43.4^{ab}	53.30^{a}	2.29^{a}

Values in a column followed by a common letter are not significantly different at $p<0.05$

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

4.3.1 Plant height

Significant variation was found from the interaction effect of irrigation and foliar application of zinc on the growth and yield of wheat (Table 5). Results indicated that the highest plant height (81.00 cm) was achieved from the treatment combination of T_4Zn_3 which was statistically identical with T_1Zn_1, T_1Zn_2, T_1Zn_3, T_2Zn_2, T_3Zn_0, T_4Zn_1 and T_4Zn_2. Results also revealed that the lowest plant height (71.90 cm) was obtained from the treatment combination of T_2Zn_0 which was statistically identical with T_2Zn_1. The results obtained from other treatment in respect of plant height was similar with the treatment combination of T_4Zn_3. Here, it was also observed that maximum treatment combination under the present study showed comparatively higher plant growth and irrigation at CRI stage, flowering and heading stage with Zn_2 =0.04% and Zn_3=0.06% showed the best results.

4.3.2 Spike length

The combined effect of irrigation and foliar application of zinc on spike length of wheat has been shown in (Table 5). Significant variation was found in case of spike length. Results revealed that the highest spike length (15.10 cm) was achieved from the treatment combination of T_4Zn_2 followed by T_4Zn_3 and T_1Zn_1. Results also revealed that the lowest spike length (13.23 cm) was obtained from the treatment combination of T_2Zn_1 which was closely followed by T_2Zn_0. The results also obtained from the treatment combination of T_2Zn_1, T_2Zn_3 and T_3Zn_0 were similar with that of T_2Zn_1. Here, it was also observed that maximum treatment combination under the present study showed comparatively higher spike length and skipping irrigation at flowering and heading stage with Zn_2=0.04% and Zn_3=0.06% showed better results.

4.3.3 Number of grain spike^{-1}

The combined effect of irrigation and foliar application of zinc on the yield components of wheat (number of grain spike^{-1}) has been shown in (Table 5). Number of grain spike^{-1} was significantly influenced irrigation and foliar application of zinc. Results showed that the highest number of grain spike^{-1} (48.60) was achieved from the treatment combination of T_4Zn_2 which was closely followed by T_4Zn_3. Results also revealed that the lowest number of grain spike^{-1} (37.30) was obtained from the treatment combination of T_2Zn_0 which was closely followed by T_2Zn_1, T_2Zn_2 and T_2Zn_3. The results also obtained from the treatment combination of T_1Zn_0, T_3Zn_0, T_3Zn_3, T_4Zn_0 and T_4Zn_1 were similar with that of T_2Zn_0. Here, it was also observed that a few treatment combinations under the present study showed comparatively higher number of grain spike^{-1} and skipping irrigation at flowering and heading stage with Zn_2 =0.04% and Zn_3 =0.06% showed better results.

4.3.4 Weight of 1000 grains

Significant variation was found from the interaction effect of irrigation and foliar application of zinc on 1000 grain weight of wheat (Table 5). Results indicated that the highest 1000 grain weight (54.10 g) was achieved from the treatment combination of T_4Zn_3 which was statistically identical with T_1Zn_2 and T_4Zn_2 and closely followed by T_1Zn_0, T_1Zn_0, T_1Zn_3, T_2Zn_1, T_2Zn_2, T_2Zn_3, T_3Zn_0, T_3Zn_1, T_3Zn_2, T_3Zn_3, T_4Zn_0, and T_4Zn_1. Results also revealed that the lowest 1000 grain weight (37.30 g) was obtained from the treatment combination of T_2Zn_0 which was statistically different from all other treatments.

4.2.5 Yield ha^{-1}

The interaction effect between irrigation and foliar application of zinc on the growth and yield components of wheat was statistically significant (Table 5). The highest grain yield (2.90 t ha^{1}) was recorded in skipping irrigation at heading and flowering stage (T_4) with 0.06% foliar application of zinc (Zn_3)

where the lowest grain yield (1.37 t ha^1) was recorded in skipping irrigation at CRI stage (T_2) with no foliar application of zinc (Zn_0). Skipping irrigation at crown root initiation of growth caused the reduction in all yield components and grain yield. This might be due to disturbance of crown root development which decreased the grain yield significantly. This result are in agreement with Thalooth (2006), who reported that missing one irrigation at any stages of growth significantly reduced yield and yield components as well as photosynthetic pigments content as compared with unstressed plant (control). Water deficit imposed after planting significantly reduces the plant growth and yield (Harold, 1986). Skipping irrigation at booting stage and flowering and heading stage with 0.04% foliar application of zinc gave the identical yield in regular irrigation (crown root initiation, booting stage, flowering and heading stage) with 0.02% and 0.06% foliar application of zinc. Asad *et al*., (2002) reported that foliar application of zinc at reproductive growth stage increase grain and straw yield significantly in wheat. Soylu *et al*., (2005) and Guenis *et al*., (2003) reported that significant increase in thousand grains weight with foliar application of zinc. Kenbaev and Sade (2002) and Hosseini (2006) have reported increase in yield components for foliar application of zinc. Foliar application of zinc at reproductive growth stages increase grain and straw yield significantly in wheat (Korzeniowska, 2008; Habib, 2009; Wroble, 2009). Moreover, Zinc fertilizers can improve the crop tolerance to environmental stresses particularly during drought and resulting in grain yield increase (Baybordi, 2005; Cakmak, 2008; Dehghanian and Madandust, 2008).

Table 5: Interaction effect of irrigation and foliar application of zinc on the growth and yield of wheat

Treatment combination		Plant height (cm)	Spike length (cm)	No. of grain spike^{-1}	1000 grain weight plot^{-1} (g)	Yield (t ha^{-1})
Irrigation	Foliar application					
T_1=Control (regular irrigation)	Zn_0=control	76.80^{ab}	13.63^{b-f}	40.60^{b-e}	50.60^{ab}	1.94^{d-g}
	Zn_1 =0.02%	83.00^{a}	14.70^{ab}	44.00^{a-e}	52.30^{ab}	2.58^{a-c}
	Zn_2 =0.04%	83.40^{a}	14.50^{a-c}	46.00^{a-c}	53.00^{a}	2.76^{ab}
	Zn_3 =0.06%	78.10^{ab}	14.00^{b-f}	41.60^{a-e}	49.80^{ab}	2.37^{a-e}
T_2 = skipping irrigation at CRI stage	Zn_0=control	71.90^{b}	13.26^{ef}	37.30^{e}	47.20^{b}	1.37^{g}
	Zn_1 =0.02%	75.60^{b}	13.23^{f}	38.60^{c-e}	52.10^{ab}	1.72^{fg}
	Zn_2 =0.04%	80.50^{a}	13.40^{d-f}	38.30^{de}	52.60^{ab}	1.81^{e-g}
	Zn_3 =0.06%	77.60^{ab}	13.50^{d-f}	38.00^{de}	49.70^{ab}	1.71^{fg}
T_3 = skipping irrigation at booting stage	Zn_0=control	77.10^{ab}	13.70^{c-f}	39.00^{b-e}	51.60^{ab}	1.93^{d-g}
	Zn_1= 0.02%	79.70^{ab}	14.20^{a-e}	45.30^{a-d}	51.70^{ab}	2.05^{c-f}
	Zn_2= 0.04%	79.20^{ab}	14.30^{a-d}	46.00^{a-c}	49.80^{ab}	2.36^{a-e}
	Zn_3 =0.06%	79.90^{a}	14.20^{a-d}	39.60^{b-e}	51.70^{ab}	2.20^{b-f}
T_4 = skipping irrigation at flowering and heading stage	Zn_0=control	78.10^{ab}	14.10^{b-f}	40.00^{b-e}	50.70^{ab}	2.03^{c-f}
	Zn_1 =0.02%	79.90^{a}	14.10^{b-f}	40.30^{b-e}	52.40^{ab}	2.50^{a-d}
	Zn_2 =0.04%	79.90^{a}	15.10^{a}	48.60^{a}	52.80^{a}	2.77^{ab}
	Zn_3 =0.06%	81.00^{a}	14.80^{ab}	46.30^{ab}	54.10^{a}	2.90^{a}
CV %		4.98	9.09	9.65	6.18	9.41

Values in a column followed by a common letter are not significantly different at $p<0.05$

CHAPTER V

SUMMARY

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of foliar application of zinc on yield of wheat grown under water stress condition during the period from October 2013 to February 2014.

The experiment comprised of two different factors such as (1) four levels of irrigation viz. T_1 (Control; regular irrigation), T_2 (Skipping irrigation at CRI stage), T_3 (skipping irrigation at booting stage) and T_4 (Skipping irrigation at flowering and heading stage) and (2) foliar application Zn levels viz. Zn_0 (Control; No Zn application), Zn_1 (0.02% foliar application Zn), Zn_2 (0.04% foliar application Zn) and Zn_3 (0.06% foliar application Zn).

The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 16 treatment combinations. Wheat seed of cv. BARI gom 25 was sown as test crop. Data on different growth and yield parameters were recorded and analyzed statistically.

Results showed that the effect of irrigation was significant in respect of various plant characters including yield and yield attributes. Plant heights, spike length, number of grains spike^{-1} and yield ha^{-1} of wheat were influenced significantly by irrigation levels. It was observed that the highest plant heights (80.30 cm) was recorded in T_1=Control (regular irrigation) but the highest spike length, number of grains spike^{-1} and yield ha^{-1} (13.54 cm, 44.9 and 2.55 t ha^{-1} respectively) were found in T_4 = Skipping irrigation at flowering and heading stage. On the other hand, the lowest plant heights, spike length, number of grains spike^{-1} and yield ha^{-1} (76.40 cm, 10.35 cm, 39.10 and 1.65 t ha^{-1} respectively) were noted in T_2 = skipping irrigation at CRI stage. Results also showed that in terms of 1000 seed weight by irrigation levels at different stages was not significant.

Results also showed significant variation in plant heights, spike length, number of grains spike^{-1} and yield ha^{-1} of wheat by foliar spray of zinc. The highest Plant heights, spike length, number of grains spike^{-1} and yield ha^{-1} (82.70 cm, 13.30 cm, 46.70 and 2.42 t ha^{-1} respectively) was found from Zn_2=0.04% foliar spray where the lowest (78.00 cm, 12.67 cm, 35.20 and 1.82 t ha^{-1} respectively) was obtained from Zn_0=control treatment. In terms of 1000 seed weight by Zn application levels was not significant.

Interaction effect of irrigation water and foliar spray of Zn had significant effect on all the yield and yield contributing parameters that was studied under the present experiment. Plant heights, spike length, number of grains spike^{-1}, 1000 seed weight and yield ha^{-1} of wheat were significantly influenced by irrigation water and foliar spray of Zn. Results indicated that the highest plant height, 1000 grain weight and grain yield (81.00 cm, 54.10 and 2.90 t ha^{1} respectively) were achieved from the treatment combination of T_4Zn_3. Again, the highest spike length and number of grain spike^{-1} (15.10 cm and 48.60 respectively) was achieved from the treatment combination of T_4Zn_2. On the other hand the lowest Results also revealed that the lowest plant height, number of grain spike^{-1}, 1000 grain weight and grain yield (71.90 cm, 37.30, 37.30 g and 1.37 t ha^{1} respectively) was obtained from the treatment combination of T_2Zn_0 where the lowest spike length (13.23 cm) was obtained from the treatment combination of T_2Zn_1.

CONCLUSION

Yield and yield contributing characters of wheat are significantly affected by foliar application of Zn along with water. Foliar application of zinc is more suitable than the soil application, due to the overcoming on deficient, easy to use, reduce the toxicity caused by accumulation and prevent the elements stabilization in the soil. During flowering, adequate water and micronutrient availability is very important for winter wheat production. It can be concluded that wheat plants grown under water stress condition with foliar application of zinc solutions counteracted the deleterious effects of stress on the yield, especially the stress at later stages of growth (booting and flowering and heading of wheat) and helped stressed plants to grow successfully under these adverse unfavorable conditions. Foliar application of 0.04% zinc was found to be the optimum dose. The foliar application of zinc can fairly compensate the decrease of yield caused by drought stress through increasing the seed weight of wheat. The present study was conducted to evaluate the effect of foliar application of zinc on yield of wheat grown under water stress condition. Yield and yield contributing characters of wheat are significantly affected by foliar application of Zn along with water. Foliar application of zinc is more suitable than the soil application, due to the overcoming on deficient, easy to use, reduce the toxicity caused by accumulation and prevent the elements stabilization in the soil. During flowering, adequate water and micronutrient availability is very important for winter wheat production. Under the present study, the highest results in terms of best yield contributing characters with irrigation effect; T_1 gave the best plant height where T_4 gave the best spike length, number of grain/spike, 1000 grain weight and above all the best grain yield. Again, in terms of foliar application of Zn, the treatment of Zn_2 =0.04% gave the best results at all cropping stages except 1000 grain weight. To consider overall results with treat combinations and also individual effect, it can be concluded that wheat plants grown under water stress condition with foliar application of zinc solutions counteracted the deleterious effects of stress on the yield, especially the stress at later stages of growth (booting and flowering and heading of wheat) and helped stressed plants to grow successfully under these adverse unfavorable conditions. Foliar application of 0.04% zinc was found to be the optimum dose. The foliar application of zinc can fairly compensate the decrease of yield caused by drought stress through increasing the seed weight of wheat.

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APPENDICES

Appendix 1. Physical and chemical properties of post harvest soil .

Treat combination		K(meq/100g)	Total N%	P	S	Zn	pH	OM
Irrigation	Foliar application			(µg/g)				%
T_1= regular irrigation	Zn_0=control	0.25	0.076	24.2	21.0	3.89	5.2	1.22
	Zn_1 =0.02%	0.17	0.046	22,6	23.5	3.25	5.5	1.33
	Zn_2 =0.04%	0.32	0.067	20.7	24.0	4.01	5.6	1.43
	Zn_3 =0.06%	0.22	0.065	23.2	22.6	4.00	5.5	1.25
T_2= skipping irrigation at CRI stage	Zn_0=control	0.20	0.069	23.6	23.0	3.39	5.4	1.44
	Zn_1 =0.02%	0.28	0.067	22.8	22.6	3.56	5.3	1.18
	Zn_2 =0.04%	0.24	0.060	26.0	23.8	3.71	5.1	1.27
	Zn_3 =0.06%	0.24	0.073	23.0	24.1	4.02	5.5	1.19
T_3= skipping irrigation at booting stage	Zn_0=control	0.22	0.073	20.7	23.3	3.77	5.7	1.34
	Zn_1= 0.02%	0.25	0.081	22.3	24.5	3.81	5.5	1.38
	Zn_2= 0.04%	0.25	0.073	25.3	25.0	4.01	5.3	1.43
	Zn_3 =0.06%	0.27	0.076	27.0	22.9	3.49	5.4	1.29
T_4= skipping irrigation at flowering and heading stage	Zn_0=control	0.29	0.063	22.9	21.4	3.78	5.4	1.28
	Zn_1 =0.02%	0.23	0.051	20.2	22.8	3.88	5.6	1.37
	Zn_2 =0.04%	0.30	0.050	23.6	20.1	3.57	5.3	1.40
	Zn_3 =0.06%	0.22	0.060	21.7	24.8	3.65	5.5	1.30
Critical Level		0.12	0.12	7.0	10	0.6		

Appendix 2. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from October 2013 to February 2014

Month	Year	Monthly average air temperature (^0C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct	2013	29.36	18.54	23.95	74.80	Trace	218.50
Nov	2013	28.52	16.30	22.41	68.92	Trace	216.50
Dec.	2013	27.19	14.91	21.05	70.05	Trace	212.50
Jan.	2014	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2014	31.35	19.40	25.33	68.78	3.0	225.50

Source: Bangladesh Meteorological Department (Climate division), Dhaka-1212.