COMPARABLE EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON THE GROWTH AND YIELD OF WHEAT

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CERTIFICATE

This is to certify that the thesis entitled "COMPARABLE EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON THE GROWTH AND YIELD OF WHEAT" submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in embodies the result of a piece of bona-fide research work carried out by MD. ABDULLAH AL MASHUD TUSHER, Registration No. 09-03447 under my supervision and guidance. No part of the thesis has been submitted 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, 2016
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ABSTRACT

The experiment was carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the comparable effect of soil and foliar application of zinc on the growth and yield of wheat. BARI Gom-26 was used as test crop. Eight treatments *viz*. T_1 (Control), T_2 (0.02% Zinc solution spray once), T_3 (0.02% Zinc solution spray twice 15days interval), T_4 (0.04% Zinc solution spray once), T_5 (0.04% Zinc solution spray twice 15 days interval), T_6 (0.06% Zinc solution spray once), T_7 (Soil application of recommended dose) and T_8 (0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) were considered for the experiment. The experiment was laid out in a Randomized Complete Block Design with three replications. It was found that the highest number of tillers plant^{-1} (4.00 a), spike length (11.50 cm), number of grain spike^{-1} (36.43), 1000 grain weight (59.10 g), grain yield (4.35 t ha^{-1}), stover yield (5.68 t ha^{-1}) and the highest harvest index (43.37%) were achieved from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval). All the parameters studied under the present experiment, control treatment gave lowest results.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (for example)
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (that is)
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Wheat (*Triticumaestivum* L.) is the major staple crop around the world. Wheat productivity components are affected by physical, chemical and biological soil properties and climatic conditions (Galantine *et al*., 2009).

It is preferable to rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008). About one third of the world population lives on wheat grains for their subsistence (FAO, 2007). Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006).

Bangladesh is an over populated country. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population. From nutritional point of view, wheat is superior to rice for its higher protein content.

Bangladesh produces 1302998 metric tons of wheat per annum from 1061602 acres of land with an average yield of 3.03 t ha^{-1} (BBS, 2014) and it can be increased up to 6.8 t ha^{-1} (RARS, 2002). So, there is an ample opportunity to increase production of wheat per unit area through adoption of modern and improved agronomic practices such as optimum seed rate, timely sowing and judicial application of irrigation, fertilizer and other inputs.

Fertilizers are indispensable for the crop production system of modern agriculture. It plays a very important role in utilizing the soils for an efficient crop production. The elements essential for plants are C, H, O, N, P, K, Ca, Mg, S, Fe, Cu, B, Mn, Mo, Zn, Cl. Out of these 16 elements, 9 essential elements have been classified as “macronutrients” as these are required in relatively large amount by the plants. These elements include C, H, O, N, P, K, Ca, Mg, S. The remaining of the elements (B, Cu, Fe, Cl, Mn, Mo and Zn) is called “trace elements” (Brady and Weil, 2002). Essential trace elements are often called “micronutrients” because they are required in small, but essential by living organisms.

Among different micro nutrients, Zinc play an important role in completion the life cycle of plants and also a key role in nitrogen metabolism, photosynthesis and toxin synthesis Vaillant*et al*. (2005) harvested that Zn is involved in diverse metabolic activities, influences the activity of hydrogenise and carbohydrates, synthesis of cytocrome and the stabilization of ribosomal function (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).

Hence, Application of Zn fertilizer is a promising short-term approach to improve Zn concentrations in seeds and can also contribute to alleviation of Zn deficiency related health problems in the developing world (Aslam*et al*., 2014). Zinc, in addition, is reported to be having possible role in reducing the toxic effects of excessive boron (Singh *et al*., 1990).

Zinc study on wheat production is very important because Zn deficiency and response to zinc in wheat have been reported from various parts of the world. Bangladesh soils are not exception to this.

The prevailing situation underscores the need for investigation Zn deficiency is a causative factor for poor grain formation, grain yield and nutrient content of wheat. Thus the present study was conducted to assess the effect of Zn on the growth and yield of wheat. With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfill the following objectives:

Objectives:

1. To observe the effect of foliar application of Zn on the growth and yield of wheat
2. To find out the optimum foliar dose of Zn for higher yield of wheat
3. To compare the effect of soil application and foliar spray of Zn for wheat cultivation

CHAPTER II

REVIEW OF LITERATURE

An exertion has been taken in this chapter to present a brief review of research in relation to outcome of Zn on the growth and yield of wheat (BARI Gom-26). Zinc is important plant nutrient for growth and yield of wheat which is a micronutrient required for plant growth relatively in a smaller amount. It plays a key role in pollination and seed set processes; so that its deficiency can cause to decrease in seed formation and subsequent yield reduction (Ziaeyan and Rajaiea 2009). Yet, the research work so far done at home and abroad regarding the performance of wheat under different levels of Zn fertilizers along with other relevant information are reviewed below.

2.1 Role of Zinc in wheat

Zinc is a micronutrient which is required for plant growth and development relatively to a smaller amount. The total Zn content of soils lies between 10 to 300ppm. The important Zn containing minerals are sphalerite (ZnS), smithsonite ($ZnCO_3$) hemimorphite [$Zn_4(OH)_2.Si_2O_7.H_2O$] and franklinite ($ZnO.Fe_2O_3$). The normal concentration range for Zn in dry matter of plant is 25 to 150ppm. Deficiencies are usually associated with leaf concentration of less than 20ppm. Plant roots absorb Zn as Zn^{2+}. Zinc is involved in a diverse range of enzymatic activities. Zinc is an important essential element present in plant enzymatic systems.

Ranjbar and Bahmaniar (2007) conducted an experiment in order to investigate the role of Zn application (soil + foliar application) on growth traits, yield, its concentration and accumulation in wheat leaves and grains, two common cultivars of wheat namely Tajan and Nye 60 have been selected. It was found that Zn had increasing effects on grain yield, total dry matter, yield, 1000-grain weight, number of tiller, grain Zn content, flag leaf Zn content, plant height, number of node, protein content and grain Fe content.

Genc*et al*. (2006) reported that Zn has vast functions in plant metabolism and consequently Zinc deficiency has a multitude of effects on plant growth. Zinc sulphate increased the Leaf Area Index, the total number of fertile tillers m^{-2}, number of spikelets $spike^{-1}$, spike length, grain $spike^{-1}$, thousand grain weight, grain yield, straw yield and biological yield and decreased harvest index. All applications of Zinc sulphate gave economic increases in margins over costs but the application of 5 kg ha^{-1} gave the highest marginal rate of return.

Seilsepour (2006) conducted an experiment to optimize consumption of Zinc and evaluate of Zinc effects on quantitative and qualitative traits of winter wheat under saline soil condition. It was done by three replications in randomized complete block design. The experiment had four treatments as Control without Zn, 40 kg ha^{1} Zn as $ZnSO_4$, 80 kg ha^{-1} Zn as $ZnSO_4$ in soil and 120 kg ha^{-1} Zn as $ZnSO_4$ in soil. The highest grain yield (4355 kg ha^{-1}) and the maximum Zn concentration in seeds (39.1 mg kg^{-1}) obtained by using of 120 kg ha^{-1} Zn as $ZnSO_4$ as soil application. Use of Zinc Sulfate had not any effects on straw, ear per square meter, number of seed per ear and concentration of Fe, Mn and Cu in seeds. Totally, use of 80 kghaZn as $ZnSO_4$ in soil was recommended to obtain highest grain yield with high quality in saline condition.

Zinc has been found useful in improving yield and yield components of wheat (Cakmak*et al*., 1996; Modaihsh, 1997; Kaya *et al*., 2002 and Singh, 2004) and adequately applied zinc has been shown to improve the water use efficiency of wheat plants (Bagci*et al*., 2007).

The variations in number of tillers per hill, panicle length, weight of 1000 grains, yields of grain and straw, Zinc concentrations and Zinc uptake by grain and straw and Zinc concentrations both pre-sowing and post-harvest soils clearly indicated that the native Zinc concentration influenced them greatly and the variations were different in different locations. The nature of vegetations was also influenced by application. In order to obtain an optimum production and quality crops application of Zinc with other nutrients should be advised particularly for wheat cultivation (Riffat*et al*., 2007).

In general, Zinc application appears to improve the overall field performance of wheat plants. The most of the seed-Zinc located in embryo and aleurone layer, whereas the endosperm is very low in Zn concentration .The embryo and aleurone parts are also rich in protein and phytate indicating that protein and phytate in seeds could be sinks for Zn. According to a Zn-staining study in wheat seed, Zn concentrations were found to be 150mg kg ha^{-1} in the embryo and the aleurone layer and only 15 mg kg ha^{-1} in the endosperm. The Zn-rich parts of wheat seed are removed during milling, thus resulting in a marked reduction in flour Zn concentrations (Ozturk*et al*., 2006).

The effects of Zinc on the yield and yield components of wheat cv. Kiziltan-91 were determined in a field experiment conducted in Ankara, Turkey during 1998-2000. Zinc application increased the grain yield, number of seeds $spike^{-1}$ and seed weight $spike^{-1}$ of the crop (Atak*et al*., 2004).

As a plant nutrient the role of Zinc in crop production, including wheat cultivation, has been well established (Kanwar and Randhawa, 1974 and Takkar*et al*., 1971). Deficiency and response to zinc in wheat have been reported from various parts of the world. Bangladesh soils are not exception to this.

Zn supply is considered as an important factor in reproduction process. According to Brown *et al*. (1993) formation of male and female reproductive organs and pollination process are disturbed in Zn deficiency which may be attributed to the reduction of Indole acetic acid (IAA) synthesis.

Yilmaz*et al*. (1997) reported that following Zn fertilization, thousand grain weights showed an increase of 26% in wheat plants.

2.2 Effect of zinc on growth, yield and yield Attributing Characters

Zinc is a micronutrient which is required for plants growth relatively in a smaller amount. The normal concentration range for Zn in dry matter of plants is 25 to 150 mg g^{-1}. Roots absorb Zn in the form of Zn^{2+}. Zinc is involved in a diverse range of enzymatic activities.

A field experiment was conducted by Ahmadi*et al.* (2016) to study the Effect of Nitrogen and Zinc on Yield of Wheat (*Triticumaestivitm* L.). Laid out in factorial with 3x3 randomized block design with three levels of Nitrogen (0, 60 and 120) kg ha^{-1}, three levels of Zinc (0, 15 and 30 kg ha^{-1}), respectively. The treatment combination (Nitrogen @ 120 kg ha^{-1} + Zinc @ 30 kg ha^{-1}) gave the best results with respect to plant height 101.2 cm. It also gave highest yield 5.60 t ha^{-1}, straw yield 7.57 t ha^{-1} and test weight 44 g 1000 seed g^{-1}. The economical point of view, the same treatment combination gave the maximum profit of Rs = 63395 ha^{-1} with C:B ratio of 1:2.77.

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

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 Zn content and Zn uptake by plant, from both of locations. However, the results showed that the relative yield was decreased with increasing of Zn application rate from both of locations.

Mekkei and El-HagganEman (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 spikelets $spike^{-1}$ (16.26 and16.37), 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 (12.58and 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.

Ali *et al*. (2013) conducted a field study to evaluate the effect of boron (B) and zinc (Zn) fertilizer alone and in combination on yield, yield components and nutrient concentration in various plant parts. Results showed that combined addition of 2.0 kg B and 5 kg Zn ha^{-1} produced significant impact on the grain yield and its components i.e., number of tillers m^{-2}, spike length, number of grains $spike^{-1}$and 1000-grain weight. The improvement in dry matter production and grain yield was 14.5% and 9.4%, over control, respectively, by the combined application of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1}. There was substantial increase in B concentration in grains i.e., 129.6% and 47.6% by individual addition of 2.0 kg B and 5.0 kg Zn ha^{-1} over control, respectively. The level of Zn content was raised from 15.2 to 37.4 mg kg^{-1} by application of

10.0 kg Zn ha^{-1}. Thus, substantial improvement in wheat productivity could be harvested with simultaneous increased concentration of Zn nutrient in grain for alleviation of syndrome caused due to Zn deficiency across rural and peri-urban communities.

An experiment was carried by Monjezi*et al*.(2013) to study the effect of drought stress, iron and zinc spray on the yield and yield components of wheat. Influencing the seed filling process, in interaction with iron, which is an important leaf's chlorophyll cation, zinc increased the seed yield. The drought stress reduced the thousand kernels weight (TKW) and the number of seeds per spike increased about 24% and 8.5% more than the one of control treatment, respectively. Zinc spray increased seed yield and thousand kernels weight. The results obtained from the present research showed that zinc spray has fairly improved the effects caused by drought stress.

An experiment was conducted by Mohammadi Sultana *et al.* (2013)to study the effect of potassium sulfate and zinc fertilizers on wheat drought resistance under water stress conditions. At the end of the experiment; seed yield, number of grains per spike, number of spikelets per spike, 1000 seed weight and the amount of protein, potassium, zinc and nitrogen on grain measured. Geight, number of grains per spike, grain weight, grain yield and zinc concentration were affected seedling fresh weight. Finally, the amount of 120 kg potassium per ha and 25 kg zinc sulfate per ha for the cultivation of this wheat is recommended.

Bameri*et al*. (2012)conducted an experiment with different microelements (Zn, Fe and Mn) and found that plant height, biological yield ,grain yield and yield components were significantly affected by the application of Zn, Fe, Mn alone and combination. There was a positive effect on yield and yield components of wheat.

Ai-Qing *et al*. (2011) conducted an experiment with combination of two Fe levels (0 and 5 mgl^{-1}) and three Zn levels (0, 0.1 and 10 mgl^{-1}). Results showed that supply of Fe (5 mgl^{-1}) and Zn (0.1 mgl^{-1}) increased plant dry weight and leaf chlorophyll content compared to the Fe or Zn deficient (0 mgl^{-1})

treatments. Results from stepwise regression analysis of Fe, Zn, Cu, and Mn concentrations in wheat tissues, Root- and leaf-Fe concentrations were negatively correlated with Zn, Cu, and Mn, whereas stem-Fe concentrations were positively correlated with leaf-Mn concentrations. Root-, stem- and leaf-Zn concentrations were positively correlated with root- and stem-Cu.

Gul*et al*. (2011) designed an experimental trial 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.

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.

Abbas *et al.* (2010) investigated the effect of Zn as Zinc sulphate on wheat crop cultivar ‘AS-2002’. Levels of $ZnSO_4$ (33%) applied were 0, 7.5, 15, 22.5 and 30 kg ha^{-1}. As evidenced by the grain yield successive increase in grain yield was witnessed with each incremental dose of Zn reaching the threshold level of $ZnSO_4$ at 22.5 kg ha^{-1}. But, for the economic gains in terms of each Rupee invested in Zinc, 7.5 kg $ZnSO_4$ coupled with recommended dose of NPK generated the maximum return (1:4.08). The Zn application at 22.5 kg ha^{-1} having the mean CBR of 2.93 emerged as the next remunerative treatment in the studies. Thus, in the light of our findings it is recommended that along with the recommended dose of NPK at 114-84-62 kg NPK ha^{-1}, $ZnSO_4$ 33% may be applied with the first irrigation either at 7.5 or 22.5 kg ha^{-1} for the highest economic returns in wheat production.

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 system, enzyme activation, oxygen carrier in nitrogen fixation.

Habib (2009) conducted a field experiment on clay-loam soil to investigate the effect of foliar application of zinc and iron on wheat yield and quality at tillering and heading stage. The treatments were control (no Zn and Fe Application), 150 g $Zn.ha^{-1}$ as $ZnSO_4$, 150 g Fe ha^{-1} as Fe_2O_3, 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.

Khan *et al*. (2008) have reported that Zinc applications actually decreased harvest index but this marginal reduction was compensated for by a greater biomass increase. It seems probable that the supplied Zinc had a mitigation effect of high temperature stress during reproductive growth. It is recommended that under such calcareous soil conditions growers can expect good returns from the application of 5 kg ha^{-1} zinc sulphate at the time of sowing. Results showed that maximum increasing of grain yield by Zn application, grain yield increase received to 1200 mg kg^{-1} in soils which contain 0.5 mg kg^{-1} available Zn .

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.

Rajendra*et al*. (2007) also observed that the effects of the application of micronutrients on the performance of a rice-wheat cropping system. Nitrogen, phosphorus and potassium at recommended rates were applied for all treatments. The gross returns and grain and straw yields increased with the application of sulfur, Zinc chloride or Zinc chloride + Zinc sulfate. The total gross returns for both crops increased by 26% over the control following the basal application of 10 kg Zinc ha^{-1} through Zinc sulfate.

Ananda and Patil (2007) reported that with a field experiment the highest total dry matter (DM) production (247.6 g m^{-1} row length), plant height (95.7 cm), number of effective tillers m^{-2} (259) due to combined application of Zn at 25 kg ha^{-1} and Fe at 25 kg ha^{-1}, which also accounted for maximum number of grains per ear head (43.9), weight of grains per ear head (2.00 g) and 1000-grain weight (44.7 g). Grain and straw yields were highest (42.23 and 68.79 q ha^{-1}, respectively) with the combined application of Zn at 25 kg ha^{-1} and Fe at 25 kg ha^{-1} and it was least (37.83 and 62.51 q ha^{-1}, respectively) in control (RDF+FYM).

Jain and Dahama (2007) conducted field trials during the winter (rabi) seasons of 2001-02 and 2002-03, in Rajasthan, India, to evaluate the effects of zinc (0, 3, 6, 9 and 12 kg ha^{-1}) on the yield, nutrient uptake and quality of wheat. Zinc was applied along with the recommended doses of nitrogen and potassium. Results showed that zinc interaction had significant effect on grain, straw and biological yields, protein content, N, P, K and Zn uptake, and available zinc status after harvest. The maximum grain yield of 4907 kg ha^{-1} was recorded with the application of 6 kg zinc ha^{-1}.

Shaheen*et al.* (2007) conducted a field experiment in order to study the yield and yield contributing characters, zinc concentrations and its uptake by wheat at six locations in Bangladesh. 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.

Schmidt and Szakal (2007) found that the effect of Zn tetra mine complex on winter wheat protein and carbohydrate contents was evaluated during 2002 in Komarom, Croatia. Zn rates were 0.1, 0.3, 0.5, 1.0 and 2.0 kg ha^{-1}. Zn treatment at booting increased yield up to 1.0 kg ha^{-1}. Zn at 2 kg ha^{-1} was slightly toxic and reduced yield slightly. At 1 kg ha^{-1}, the yield was 0.6 t ha^{-1} higher than the control. Zn treatment increased protein content, reduced starch content (at rates higher than 0.3 kg ha^{-1}) and increased baking quality. The highest baking quality was obtained at 2 kg ha^{-1}.

Jain and Dahama (2006) have reported that application of 6 kg Zn ha^{-1} significantly increased all the growth and yield attributes (except test weight), protein content and Zn uptake by wheat over no use of Zn (control). Application of graded levels of Zn up to 9 kg Zn ha^{-1} remained at par with 12 kg Zn ha^{-1}, significantly increased Zn uptake by wheat crop over other levels.

Application of 6 kg Zn ha^{-1} increased the grain and straw yields by 19.4 and 16.8% over the no use of Zn (control). Agronomic efficiency (115.3 kg ha^{-1}) and apparent Zn recovery (1.87%) were also higher at 6 kg Zn ha^{-1}.

Mahendra and Yadav (2006) conducted a field experiment, consisting of zinc levels viz., 0, 10, 20, 30 and 40 kg $ZnSO_4$ ha^{-1} conducted during rabi seasons of 2001-02 and 2002-03 on loamy sand soil of Rajasthan, India revealed that application of increasing dose of $ZnSO_4$ improved growth and yield parameters of wheat. Maximum values were recorded with the application of 40 kg $ZnSO_4$ ha^{-1}. However, it was statistically at par with 30 kg $ZnSO_4$ ha^{-1}.

Parihar*et al*. (2005) showed that the application of Zn up to 10 kg ha^{-1} increased the grain yield by 7.2 % over control. In the field experiments on Typical Ustipsamment, the effect of sulphur (0, 25 and 50 kg S ha^{-1}), zinc (0, 5 and 10 kg Zn ha^{-1}) and organic manures (10 t FYM ha^{-1} and 5 t vermicompost ha^{-1}) were studied on wheat for yield and nutrient uptake by wheat.

Swarup and Yaduvanshi (2004) carried out an experiment on wet season rice (Oryza sativa L.) and winter season wheat (Triticumaestivum L.) cropping system at BhainiMajra Experiment Farm, Kaithal, Inda. N, P, K and Zn doses as per treatments (120 kg N, 26 kg P, 42 kg K and 4.5 kg Zn ha^{-1}) were applied as urea, single superphosphate, muriate of potash and zinc sulphate, respectively. They found that zinc application improved the yield of rice and wheat.

Dewal and Pareek (2004) conducted a field experiment was conducted during the winter (rabi) season of 1999-2000 and 2000-01 at Jobner, Rajasthan, India, to study the effect of phosphorus, sulfur and Zinc on wheat (Triticumaestivum) cv. Raj. 3077. Main plots were supplied with 3 levels of Zinc (0, 5 and 10 kg Zn ha^{-1}). Data were recorded for plant height, dry matter accumulation, number of tillers, number of effective tillers, grains per spike, spike length, grain yield, straw yield and biological yield. The growth parameters, yield attributes, yield, net return and benefit: cost ratio increased significantly with application of 5 kg Zn ha^{-1}.

Singh (2004) was carried out a field experiment on wheat during the rabi season of 1998-2000 on an alkali water-irrigated loamy sand soil in Rajasthan, India, to evaluate the effect of nitrogen (0, 90.0, 112.5 and 135.0 kg N ha^{-1}) and zinc. The application of 5.0 kg Zn ha^{-1}significantly increased the growth and yield of wheat over the control, while it was at par with 6.25 and 7.5 kg Zn ha^{-1}. The highest ICBR 1:5.72 was estimated with 5.0 kg Zn ha^{-1}. The application of N significantly increased the N, P and Zn content, while Na content in grain and straw decreased. The application of Zn significantly increased the N and Zn content and decreasing trend of P and Na content was observed in grain and straw.

Chandrakuma*et al*. (2004) was conducted a field experiment in Raichur, Karnataka, India during the rabi season of 2001-02 to investigate the effects of organic, macro and micronutrient fertilizers, and methods of application on the yield of wheat. All micronutrient treatments improved the yield attributing characters. The soil application of $ZnSO_4$ at 10 kg ha^{-1} resulted in higher yield (30.19 q ha^{-1}) than the other micronutrient treatments. Combined treatments of RDF + FYM at 10 t ha^{-1}+ $ZnSO_4$ soil application at 10 kg ha^{-1} showed higher yield (38.65 q ha^{-1}) compared to the other treatment combinations.

Sundar*et al*. (2003) reported that Potted wheat plants grown on sandy clay loam (S1) and clay loam soils (S2) were treated with 0, 10 and 20 kg P ha^{-1}, 0, 5, 10 and 15 kg Zn ha^{-1} sandy clay loam (S1) and clay loam (S2). Grains per ear, test weight, grain and straw yields increased significantly only up to 10 kg Zn ha^{-1}; beyond this level, adverse effects on the yield were observed. Grains per ear, test weight, grain and straw yields were influenced by the soils and were highest with the application of 10 kg Zn ha^{-1}.

Zinc has been reported elsewhere as being effective in increasing dry matter production in wheat plants and it appears that its application acts like nitrogen addition to nutrient rich soil, stimulating greater biomass productivity at a greater proportion to the decrease in harvest index. Zinc deficiency has been reported to cause stunted plant growth and as shown here, the impact of Zinc stress on wheat growth in Zn deficient calcareous soil can be mitigated by Zn fertilization. (Imtiaz*et al*., 2003).

Zeidan and Nofal (2002) showed that application of micronutrients only caused significant increases in straw yield, seed yield and grain protein content compared to the control. In addition, Zn foliar fertilization induced the highest increase in the majority of the studied characters. The addition of Zn is necessary for improving its foliar efficiency, growth, yield and quality of wheat.

Prasad *et al*. (2002) did a field experiment in Bihar, India for five years to study the optimal frequency of zinc application on zinc deficient soil in the rice-wheat cropping system. 'The treatments were soil and foliar application of Zn sulfate at different doses. The results indicated that the pooled yield of rice (32.5 q ha^{-1}) was higher than that of wheat grain (15.8 g ha^{-1}). The frequency of Zn application, based on 10 cropping systems, indicated that the use of 25 kg Zn sulfate ha^{-1} as soil application after a two crop interval was found to be optimal. The rates of increase in yields of rice and wheat were 52.4 and 21.0 kg Zn sulfate ha^{-1}, respectively and the per cent increase in yield of rice was 46.6 and wheat 38.1. The rice and wheat yields in the cropping system were significantly correlated with Zn removal.

Kenbaev and Sade (2002) and Hosseini (2006) have reported increase in yield components for application of Zn in wheat.

Zinc application has been reported to increase thermo-tolerance of the photosynthetic apparatus of wheat (Graham and Mc Donald, 2001).

Sharma *et al*. (2000) conducted a study in 1993-94 and 1994-95, in Rajasthan, India, to determine the effect of N at 0, 40, 80, 120 and 160 kg ha^{-1} and Zn at 0, 5 and 10 kg ha^{-1} on wheat. Wheat responded only to 5 kg Zn ha^{-1}, and Zn at this rate resulted in 13.62% and 6.14% higher grain yield compared to the control and 10 kg Zn ha^{-1}, respectively.

Micronutrients have prominent affects on dry matter, grain yield and straw yield in wheat (Asad and Rafique, 2000).

Zinc application improved spike length and effective tillers plant^{-1} and number of grains plant^{-1} (Islam *et al*., 1999).

Rajput (1997) carried out a field trial at Bahraich, Uttar Pradesh in 1991-93 rainy seasons with wheat cv. HD 2285 grown on sandy loam soil using different combinations with or without soil applied or foliar zinc and found that zinc application increased wheat yield, with no significant difference between application methods.

Modaihsh (1997) also reported that zinc application improved biological yield as well as grain yield of wheat grown on calcareous soils.

Grewal*et al*. (1997) and Torun *et al*. (2001) who have reported that increased dry matter production for application of Zn and B over control.

Brennan (1996) conducted 30 field experiments on a range of soils in different rainfall zones of south-west Australia to examine the effectiveness, relative to freshly applied Zn fertilizer of previously applied Zn fertilizer for grain yield of wheat. The soil had been fertilized with Zn at 0.2-1.2 kg Zn ha^{-1}, 9-24 years previously. The effect of applied N on grain yield and Zn concentration in the youngest emerged leaf blade was also examined. At all sites, the current application of Zn fertilizer to soil previously treated with Zn did not increase grain yield. The lowest Zn rate (0.2 kg Zn ha^{-1}) applied 15 years earlier was still fully effective for maximum grain production. The application of currently applied Zn increased the Zn concentration in the youngest emerged leaf blade for 23 experiments. Zinc concentration in the grain was increased by the current application of Zn in 25 experiments and it had no effect in 5 experiments.

Alam (1995) carried out a field experiment in Mymensingh on wheat (Variety Kanchan, Akbar and Aghrani) with 100 kg N, 80 kg P, 30 kg K, 24 kg S, 4 kg Zn, 2 kg B and 2 kg Mo ha^{-1} respectively. He obtained that Zinc gave 2.10 t ha^{-1} grain yields among the treatments

Ismail *et al*. (1995) conducted a field experiment during rabi season of 1992-93 at Dholi, Bihar, in a Zn deficient highly calcareous sandy loam soil. Ten cultivars of Triticumaestivum L. were grown under 3 levels of Zn application

(0, 5 and 10 kg/ha). Application of Zn markedly increased grain and straw yields but the magnitude of increase varied from one cultivar to another. Cultivars UP 262 K 8804 and HP 1102 appeared to be highly and Sonalika and HP 1633 least responsive to Zn application.

Marschner (1995) declared that Zn is essentially necessary for protein synthesis and following Zn deficiency, reduction in RNA-polymerase activity and increase in RNA destruction can severely reduce grain protein content.

Ahmed and Alam (1994) conducted a greenhouse study on four soils of Bangladesh to determine the effect of Zn and B application singly and in combination on yield and nutrient content of wheat (cv. Kanchan). The significant increase in dry matter yield was recorded from combined application of 20 kg Zn and 5 kg B ha^{-1}

Dasalkar*et al*.(1994) reported on a field experiment at Parbhani, Maharashtra with Sorghum cv. CSH-9 receiving 4 kg Zn ha^{-1} as zincated urea, zinc sulphate or zincated superphosphate or 10 FYM ha^{-1} in addition to the recommended N, P and K rates. Zincated fertilizers gave significantly higher grain yields than FYM,zincated superphosphate gave the highest grain yield of 3.71 t ha^{-1}. Wheat was grown on the same plots after sorghum to examine the residual effects. Wheat grain yield was the highest on the plot supplied with zincated superphosphate (2.35 t ha^{-1}).

Sur *et al*. (1993) showed that in alluvial soils of North Bengal and red lateritic soils of South Bengal (India) Zn application significantly increased yields of wheat. A rate of 25 to 37.5 kg ha^{-1} $ZnSO_4$ was recommended for economic returns. In a field experiment at the North Eastern Hill University, Shillong, Meghalaya, India to elucidate the distribution adsorption and utilization of Zn in wetland soils and its uptake by plant from nutrient solutions. It was concluded that the use of Zn fertilizers increased the yield of wheat in wetland soils of Meghalaya.

Barisal *et al*. (1990) carried out field experiment at 26 Zn deficient sites on typicUstochrepts at Ludhiana, India that the critical deficiency levels of Zn for wheat were 0.60 mg Zn kg ha^{-1} soil and 19 mg kg DM in 45 day plants.

Variations in grain and straw yields of wheat at the different sites were due largely to differences in Zn availability to the crop. Further, field trials at 9 locations with different levels of soil Zn (0.35 to 1.50 mg Zn kg ha^{-1} soil) and with 0, 11 or 22 kg Zn ha^{-1} applied as $ZnSO_4$ were conducted to examine the applicability of this critical level. Yields were significantly increased by Zn application.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2015 to March 2016. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Experimental site

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, under the Agro-Ecological Zone of Modhupur Tract, AEZ-28 during the Rabi season of 2015-16. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.4 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depth were collected from experimental field. The physicochemical properties of the soil are presented in Appendix III.

3.4 Planting material

Wheat (*Triticumaestivum* L.) variety BARI Gom-26 was used as plant material. It is a most popular variety now due to its high yielding potentials and suitable for early and late planting (up to second week of December). This variety attains a height of 92-96 cm and it resistant to leaf rust disease. The number of tillers plant^{-1} is 3-4 and the leaves are wide and deep green in color. Grains are amber in color and bright. Its yield is 4-5 t ha^{-1} and 1000 grain weight is 48-52 g. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

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 5 November and 12 November 2015, 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

The unit plots were fertilized with N-120 kg, P-25 kg, K-65 kg, S -10 kg and Zn-2kg ha^{-1} respectively. Urea, triple super phosphate (TSP) ,muriate of potash (MoP) and Gypsum were used as source of nitrogen, phosphorus, potassium and S. Zinc sulphate (36% Zn) was applied foliar spray and boric acid (17% B) in soil application. The whole amount of TSP, MoP, gypsum and boric acid was applied in the soil of this experiment. Zinc and one third of the urea were applied at the time of final land preparation prior to sowing. The remaining two-thirds of urea were top-dressed in two equal splits on 20 and 55 days after sowing (DAS) the seed. Foliar application of Zinc solution were applied as per treatment after 30 days after sowing and 45 days after sowing.

3.7 Treatments of the experiment

One factor experiment with Zn at nine levels as follows:

1) T_1 : Control
2) T_2 : 0.02% Zinc solution spray once
3) T_3 : 0.02% Zinc solution spray twice 15days interval
4) T_4 : 0.04% Zinc solution spray once
5) T_5 : 0.04% Zinc solution spray twice 15 days interval
6) T_6 : 0.06% Zinc solution spray once
7) T_7: Soil application of recommended dose
8) T_8: 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

3.8 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design. Each treatment was replicated three times. Thus the total number of unit plots was 8×3=24. The size of the unit plot was 3.5 × 2 . The distance maintained between two unit plots was 0.5 and that between blocks was 1m. The treatments were randomly assigned to the plots within each replication. The layout of the experiment field is shown in Appendix IV.

3.9 Sowing of seeds

Seeds were sown on 16th November, 2015 by hand. Seeds were sown in line and then covered properly with soil. The line to line distance for wheat was 20 cm and plant to plant distance was 4 - 5 cm.

3.10 Intercultural operations

3.10.1 Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after seed sowing followed by second weeding at 15 days after first weeding. The weeds identified were kakpayaghash (*Dactylocteniumaegyptium* L.), Shama (*Echinocloacrussgalli*), Durba (*Cynodondactylon*), Arail (*Leersiabexandra*), Mutha (*Cyperusrotundus* L.) Bathua (*Chenopodium album*) Shaknatey (*Amaranthusviridis*), Foska begun (*Physalisbeterophylls*), Titabegun (*Solanumtorvum*), and Shetlomi (*Gnaphaliumluteolabum* L.) etc.

3.10.2 Irrigation

Two times of irrigations were done at 20 and 55 DAS (Days after sowing).

3.10.3 Plant protection measures

The wheat crop was infested by aphid and rodent. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied in some times because wheat field was highly infested by rodent.

3.10.4 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.10.5 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. Ten plants per plot were preselected randomly from which different growth and yield attributes data were collected and 1 m^2 areas from middle portion of each plot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording data of grain and straw. Threshing was done by using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly.

3.11 Recording of data

Experimental data were recorded from 45 days of sowing and continued up to harvest. The following data were recorded during the experimentation.

3.11.1 Crop growth characters

a. Plant height (cm)
b. Number of tillers plant^{-1}
c. Total dry matter

3.11.2 Yield and yield components

a. Length of spike (cm)
b. Number of grains spike^{-1}
c. Weight of 1000 grains (g)
d. Grain yield (t ha^{-1})
e. Straw yield (t ha^{-1})
f. Harvest index (%)

3.12 Detailed procedures of recording data

3.12.1 Crop growth characters

3.12.1.1 Plant height

Plant height was measured at 15 days interval starting from 45 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

3.12.1.2 Number of tillers plant^{-1}

Number of tillers plant^{-1} were counted at harvest from 45 DAS

3.12.2 Yield and yield contributing characters

3.12.2.1 Spike length

Spike length was counted from five plants from basal node of the rachis to apex of each spike and then averaged.

3.12.2.2 Number of grains spike^{-1}

The number of grains spike^{-1} was counted from 10 spike and number of grains spike^{-1} was measured by the following formula

$$\text{Number of grains spike}^{-1} = \frac{\text{Total number of grains}}{\text{Number of spike}}$$

3.12.2.3 Weight of 1000 grains

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

3.12.2.4 Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.12.2.5 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were dried at oven to a constant weight and finally converted to t ha^{-1}.

3.12.2.6 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Where, Biological yield = Grain yield + Stover yield

3.13 Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT computer package program developed. Least Significant Difference (LSD) technique was used by DMRT to compare the mean differences among the treatments at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIN

The research work was accomplished to investigate the wheat yield response to foliar application of zinc on the growth and yield of wheat with comparable effect in soil. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Under the present study, plant height was significantly influenced by the application of different levels of Zn (Appendix V). At different days after sowing (DAS), plant height differed and it was found that the tallest plant (36.18, 54.42, 86.66, 92.37 cm at 25, 50, 75 DAS and at harvest respectively) was achieved from the treatment T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) followed by T_7 (Soil application of recommended dose). Similarly, the shortest plant (29.21, 42.48, 69.90 and 74.71 cm at 25, 50, 75 DAS and at harvest respectively) was obtained from the control treatment T_1 followed by T_2 (0.02% Zinc solution spray once) and T_3 (0.02% Zinc solution spray twice 15days interval).Mekkei and El-HagganEman

(2014) obtained similar results and they observed that combination of micronutrients (Zn) produced the highest values of plant height.

Table 1.Effect of foliar application of Zinc on plant height of wheat (BARI Gom-26)

Treatment	Plant height (cm)			
	25 DAS	50 DAS	75 DAS	At harvest
T_1	29.21 f	42.48 g	69.90 f	74.71 g
T_2	30.67 e	44.88 ef	74.80 e	78.52 f
T_3	30.33 ef	44.20 f	73.84 e	77.82 fg
T_4	32.40 d	46.67 d	77.30 d	81.08 ef
T_5	34.44 b	49.77 b	81.80 bc	86.32 bc
T_6	34.00 bc	48.39 c	80.10 c	85.12 cd
T_8	36.18 a	54.42 a	86.66 a	92.37 a
$LSD_{0.05}$	1.225	1.578	2.448	3.147
CV(%)	6.871	8.319	5.377	8.524

T_1 = Control
T_2 = 0.02% Zinc solution spray once
T_3 = 0.02% Zinc solution spray twice 15days interval
T_4 = 0.04% Zinc solution spray once
T_5 = 0.04% Zinc solution spray twice 15 days interval
T_6 = 0.06% Zinc solution spray once
T_7 = Soil application of recommended dose
T_8 = 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

4.1.2 Number of tillers plant^{-1}

Under the present study, number of tillers plant^{-1} was significantly influenced by the application of different level of Zn (Appendix V). Results revealed that the highest number of tillers plant^{-1} (1.33, 3.12, 4.03 and (4.00) at harvest was achieved from the treatment T_5 (0.04% Zinc solution spray twice 15 days interval)which was closely followed by T_4 (0.04% Zinc solution spray once). Again, the lowest number of tillers plant^{-1} (0.33, 2.83, 2.90 and 2.83 at 25, 50, 75 DAS and at harvest) was obtained from the control treatment T_1 followed by T_8 .Similar results was also observed by Ranjbar and Bahmaniar (2007), Genc*et al*. (2006) and Riffat*et al*., 2007.They also stated that number of tillers plant^{-1} was significantly influenced by foliar application and/or soil application of Zn.

Table 2. Number of tillers $plant^{-1}$ of wheat (BARI Gom-26) affected by foliar application of zinc

Treatment	**Number of tillers $plant^{-1}$**			
	25 DAS	**50 DAS**	**75 DAS**	**At harvest**
T_1	**0.33 e**	**2.30 d**	**2.90 e**	**2.83 e**
T_2	**0.67 c**	**2.60 c**	**3.33 d**	**3.30 cd**
T_3	**0.67 c**	**2.67 bc**	**3.53 cd**	**3.50 bc**
T_4	**1.00 b**	**2.93 ab**	**3.90 ab**	**3.73 b**
T_5	**1.33 a**	**3.12 a**	**4.03 a**	**4.00 a**
T_6	**1.00 b**	**2.70 bc**	**3.72 bc**	**3.67 b**
T_7	**0.50 d**	**2.50 cd**	**3.00 e**	**3.20 d**
T_8	**0.67 c**	**2.70 bc**	**3.67 bc**	**3.60 b**
$LSD_{0.05}$	**0.134**	**0.251**	**0.268**	**0.232**
CV(%)	**6.449**	**7.386**	**6.311**	**6.314**

T_1 = Control
T_2 = 0.02% Zinc solution spray once
T_3 = 0.02% Zinc solution spray twice 15days interval
T_4 = 0.04% Zinc solution spray once
T_5 = 0.04% Zinc solution spray twice 15 days interval
T_6 = 0.06% Zinc solution spray once
T_7 = Soil application of recommended dose
T_8 = 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

4.2 Yield contributing parameters

4.2.1 Spike length

Spike length of wheat significantly influenced by different Zn level applied to the field(Appendix VIII). Results exposed that the highest spike length (11.50 cm) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) which was significantly different from all other treatments followed by T_4 (0.04% Zinc solution spray once) (Table 4). Again, the lowest spike length (7.18 cm) was obtained from the control treatment T_1.Other workers have also reported that Zinc application improved spike length and shortest from control (Dewal and Pareek, 2004 and Islam et al., 1999).

4.2.2 Number of grains spike^{-1}

Significant influence was found for number of grain spike^{-1} of wheat affected by different Zn levels applied to the field (Appendix VIII). Results showed that the highest number of grain spike^{-1} (36.43) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) which was significantly different from all other treatments followed by T_4 (0.04% Zinc solution spray once) and T_6 (0.06% Zinc solution spray once) (Table 3). The lowest number of grain spike^{-1} (23.95) was obtained from the control treatment T_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}.

4.2.3 Weight of 1000 grains

Significant variation was remarked for 1000 grain weight of wheat affected by different Zn levels applied (Appendix VIII). Results exposed that the highest 1000 grain weight (59.10 g) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) followed by T_4 (0.04% Zinc solution spray once), T_6 (0.06% Zinc solution spray once) and T_3 (0.02% Zinc solution spray twice 15days interval) (Table 4). The lowest 1000 grain weight (43.82) was obtained from the control treatment T_1 followed by T_7(Soil application of recommended dose).Mekkei and El-HagganEman (2014) also got similar results. Positive effects of Zn application on 1000 grain weight were also reported by Ananda and Patil (2007). Kenbaev and Sade (2002) and Hosseini (2006) reported that yield components increased with the increasing of Zinc application.

Table 3. Yield contributing characters of (BARI Gom-26) affected by foliar application of zinc

Treatment	**Yield contributing characters**		
	Spike length (cm)	**Number of grain spike^{-1}**	**1000 grain weight (g)**
T_1	**7.18 g**	**23.95 h**	**43.82 d**
T_2	**8.48 e**	**28.64 ef**	**51.18 c**
T_3	**9.28 d**	**29.88 de**	**52.43 bc**
T_4	**10.9 b**	**33.84 b**	**55.16 b**
T_5	**11.5 a**	**36.43 a**	**59.10 a**
T_6	**10.2 c**	**32.67 bc**	**54.32 b**
T_7	**10.1 c**	**27.66 fg**	**50.55 c**
T_8	**8.92 de**	**31.43 cd**	**53.27 bc**
$LSD_{0.05}$	**0.5017**	**1.816**	**2.624**
CV(%)	**4.119**	**8.638**	**9.573**

T_1 = Control

T_2 = 0.02% Zinc solution spray once

T_3 = 0.02% Zinc solution spray twice 15days interval

T_4 = 0.04% Zinc solution spray once

T_5 = 0.04% Zinc solution spray twice 15 days interval

T_6 = 0.06% Zinc solution spray once

T_7 = Soil application of recommended dose

T_8 = 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

4.3 Yield parameters

4.3.1 Grain yield

Significant variation was observed in terms of grain yield due to application of different levels of Zn (Appendix IX). Results signified that that the highest grain yield (4.35 t ha^{-1}) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) which was significantly different from all other treatments followed by T_4 (0.04% Zinc solution spray once) and T_6 (0.06% Zinc solution spray once) (Table 4). The lowest grain yield (3.10 t ha^{-1}) was obtained from the control treatment, T_1 followed by T_7(Soil application of recommended dose).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).These results agreed with Torun et al., (2001) and Grewal et al., (1997) who reported that increased wheat production with application of zinc over control. There were no significant difference regarding wheat yield among the treatment Zn1 (0.02% Zn) and Zn3 (0.06% Zn). Many authors also showed that grain yield increased significantly with increasing Zn levels (El-Majid et al., 2000 and Seilsepour, 2007).

4.3.2 Stover yield

Application of different levels of Zn to wheat had significant effect on stover yield (Appendix IX). Results remarked that that the highest stover yield (5.68 t ha^{-1}) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) which was significantly similar withT_4 (0.04% Zinc solution spray once) and T_6 (0.06% Zinc solution spray once) followed by T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) (Table 5). The lowest stoveryield (4.68 t ha^{-1}) was obtained from the control treatment, T_1 which was significantly similar with T_2 (0.02% Zinc solution spray once) followed by T_7(Soil application of recommended dose).

4.3.3 Harvest index

Significant variation was observed in terms of harvest index due to application of different levels of Zn (Appendix IX). Results signified that that the highest harvest index (43.37%) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval) which was significantly different from all other treatments followed by T_2 (0.02% Zinc solution spray once), T_4 (0.04% Zinc solution spray once) and T_6 (0.06% Zinc solution spray once) and T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) (Table 4). The lowest harvest index (39.85%) was obtained from the control treatment, T_1.

Table 4. Yield parameters of wheat (BARI Gom-26) affected by foliar application of zinc

Treatment	Yield parameters		
	Grain yield	**Stover yield**	**Harvest index (%)**
T_1	3.10 f	4.68 d	39.85 e
T_2	3.58 d	4.86 cd	42.42 b
T_3	3.66 d	5.07 c	41.97 c
T_4	4.18 b	5.60 ab	42.74 b
T_5	4.35 a	5.68 a	43.37 a
T_6	4.09 bc	5.51 ab	42.60 b
T_7	3.28 e	4.68 d	41.21 d
T_8	3.98 c	5.38 b	42.52 b
$LSD_{0.05}$	0.164	0.212	0.402
CV(%)	5.248	6.419	7.176

T_1 = Control
T_2 = 0.02% Zinc solution spray once
T_3 = 0.02% Zinc solution spray twice 15days interval
T_4 = 0.04% Zinc solution spray once
T_5 = 0.04% Zinc solution spray twice 15 days interval
T_6 = 0.06% Zinc solution spray once
T_7 = Soil application of recommended dose
T_8 = 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

4.4 Comparable effect of soil

4.4.1 Nutrient status in post harvest soils

Collected soil samples from the experiment field after harvest were analyzed and Soil pH, % organic matter, % N, available P (µg g^{-1}), exchangeable K (µg g^{-1}) and available Zn (µg g^{-1}) were determined. Among the studied parameters on soil nutrients, all nutrients along with pH showed non-significant variation except available P and available Zn.

Soil pH, % organic matter, % N, available P (µg g^{-1}) and exchangeable K (µg g^{-1}) were statistically non-significant among treatment. But available P (µg g^{-1}) and available Zn (µg g^{-1}) was statistically significant among the treatments (Table 5 and Appendix X).

Results revealed that in terms of available P (µg g^{-1}), T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) gave the highest P content in soil which was statistically identical with T_6 (0.06% Zinc solution spray once). On the other hand, the lowest P (µg g^{-1}) status in soil was with control treatment T_1.

Results also revealed that in terms of available Zn (µg g^{-1}), T_5 (0.04% Zinc solution spray twice 15 days interval) gave the highest Zn content in post harvest soil which was statistically identical with T_6 (0.06% Zinc solution spray once) and statistically similar with T_4 (0.04% Zinc solution spray once) and T_7(Soil application of recommended dose). On the other hand, the lowestZn (µg g^{-1}) status in post harvestsoil was in control treatment T_1.

Table 5.Comparable effect of soil according to soil nutrient status after Zn application to wheat

Treatment	Nutrient status in soil after Zn					
	Soil pH	**% Organic matter**	**% N**	**Available P (μg g^{-1})**	**Exchangeable K (μg g^{-1})**	**Available Zn (μg g^{-1})**
T_1	5.46	0.48	0.05	10.44 f	0.04	2.87 d
T_2	5.47	0.55	0.05	14.18 d	0.05	3.14 bc
T_3	5.48	0.58	0.04	12.37 e	0.05	2.98 cd
T_4	5.52	0.61	0.04	15.20 c	0.07	3.33 ab
T_5	5.51	0.72	0.07	15.52 bc	0.08	3.38 a
T_6	5.57	0.65	0.07	16.92 a	0.06	3.37 a
T_7	5.53	0.54	0.06	15.67 bc	0.06	3.30 ab
T_8	5.57	0.58	0.06	17.32 a	0.08	3.41 a
$LSD_{0.05}$	NS	NS	NS	1.003	NS	0.1896
CV(%)	4.387	5.136	4.229	7.364	4.076	7.559

T_1 = Control

T_2 = 0.02% Zinc solution spray once

T_3 = 0.02% Zinc solution spray twice 15days interval

T_4 = 0.04% Zinc solution spray once

T_5 = 0.04% Zinc solution spray twice 15 days interval

T_6 = 0.06% Zinc solution spray once

T_7 = Soil application of recommended dose

T_8 = 0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the comparable effect of soil and foliar application of zinc on the growth and yield of wheat. Wheat (*Triticumaestivum* L.) variety BARI Gom-26 was used as plant material. Nine treatments were considered for the experiment *viz*. T_1 (Control), T_2 (0.02% Zinc solution spray once), T_3 (0.02% Zinc solution spray twice 15days interval), T_4 (0.04% Zinc solution spray once), T_5 (0.04% Zinc solution spray twice 15 days interval), T_6 (0.06% Zinc solution spray once), T_7(Soil application of recommended dose) and T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application). The experiment was laid out in a Randomized Complete Block Design with three replications.

Different growth and yield parameters were considered for data collection. Data were recorded on plant height (cm), number of tillers plant^{-1}, total dry matter (g), length of spike (cm), number of grains spike^{-1}, weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) and also post harvest soil analysis data were collected.

Significant variation was found for all the treatments. Results revealed that in case of growth parameters, tallest plant (36.18, 54.42, 86.66, 92.37 cm at 25, 50, 75 DAS and at harvest respectively) was achieved from the treatment T_8(0.04% Zinc solution spray once + $\frac{1}{2}$ recommended dose in soil application) but the highest number of tillers plant^{-1} (1.33, 3.12, 4.03 and 4.00 at 25, 50, 75 DAS and at harvest respectively) and highest dry weight plant^{-1} (6.04, 18.32, 27.88 and 33.96 g at 25, 50, 75 DAS and at harvest respectively) were achieved from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval). In case of yield contributing parameters, the highest spike length (11.50 cm), highest number of grain spike^{-1} (36.43) and highest 1000 grain weight (59.10 g) was found from the treatment, T_5 (0.04% Zinc solution spray twice 15 days interval). Considering yield parameters, T_5 (0.04% Zinc solution spray twice 15 days interval) also gave the highest grain yield (4.35 t ha^{-1}), highest stover yield (5.68 t ha^{-1}) and highest harvest index (43.37%) .

All the parameters studied under the present experiment gave lowest results from control treatment. Results showed that the shortest plant (29.21, 42.48, 69.90 and 74.71 cm at 25, 50, 75 DAS and at harvest respectively), lowest number of tillers plant^{-1} (0.33, 2.30, 2.90 and 2.83 at 25, 50, 75 DAS and at harvest respectively) were found from control treatment T_1. The lowest spike length (7.18 cm), lowest number of grain spike^{-1} (23.95), lowest 1000 grain weight (43.82), lowest grain yield (3.10 t ha^{-1}), lowest stover yield (4.68 t ha^{-1}) and lowest harvest index (39.85%) were also obtained from the control treatment, T_1.

In terms of post harvest analysis of soil, Soil pH, % organic matter, % N, available P (µg g^{-1}) and exchangeable K (µg g^{-1}) were statistically non-significant among treatment. But available P (µg g^{-1}) and available Zn (µg g^{-1}) was statistically significant among the treatments.

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APPENDICES

Appendix l: Experimental site showing in the map under the present study

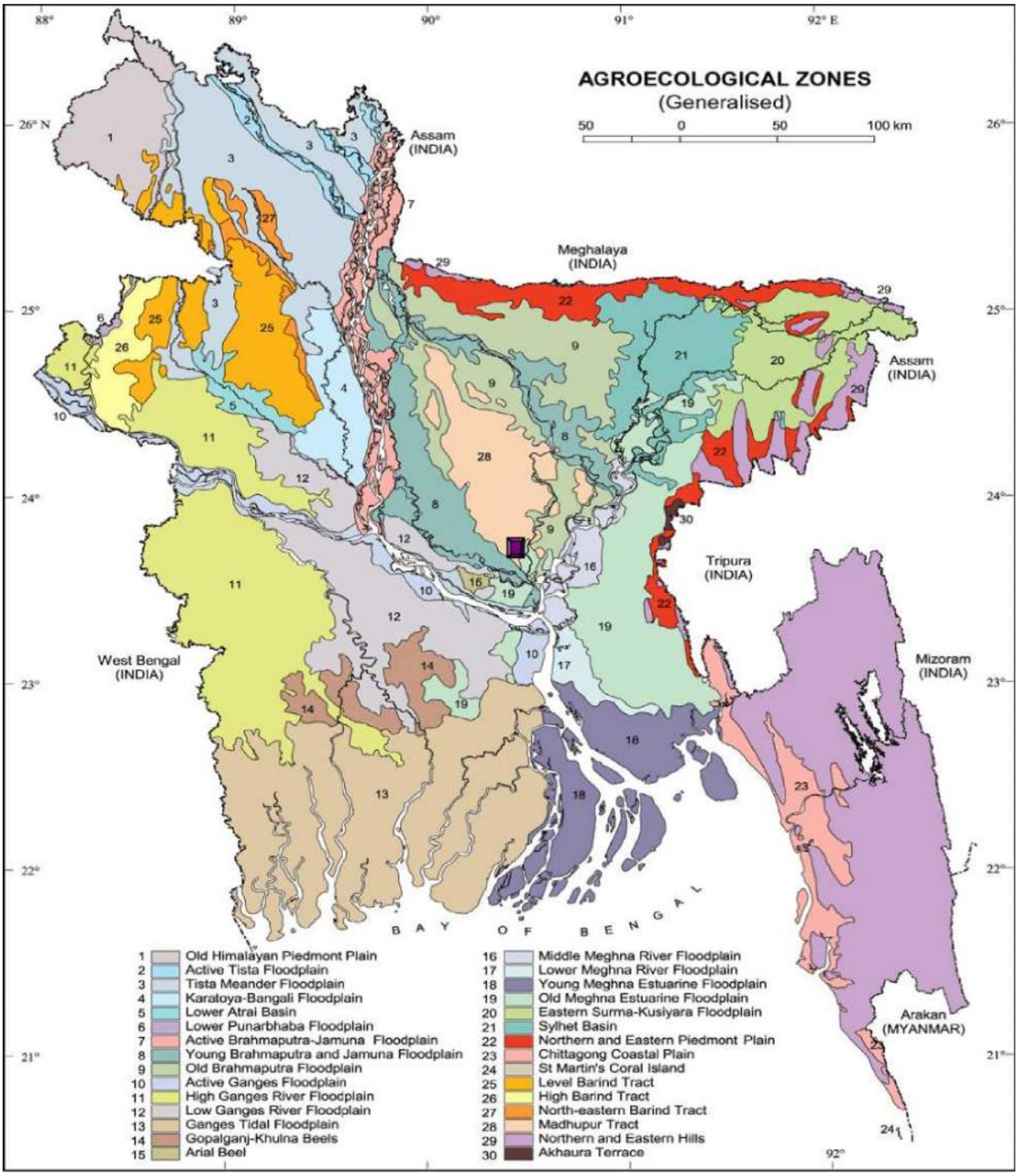

Fig. 5. Map of Bangladesh remarked with study area

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from December 2015 to March 2016

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
		Max.	Min.	Avg.			
2015	December	24.32	15.4	19.86	70.76	0	192.6
2016	January	22.67	13.17	17.92	70.05	8.52	161.6
2016	February	26.56	17.49	22.03	72.25	20.60	219.9
2016	March	30.60	22.76	26.68	80.64	24.40	224.6

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

Appendix III. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Clay loam

Chemical composition:

Soil pH	:	6.2
Total N (%)	:	0.07
Available P (μ gm/gm)	:	18.00
Exchangeable K (μ gm/gm)	:	0.12
Available S (μ gm/gm)	:	24.0
Available Zn (μ gm/gm)	:	0.52
Organic matter (%)	:	0.83

Appendix IV. Layout of the experiment field

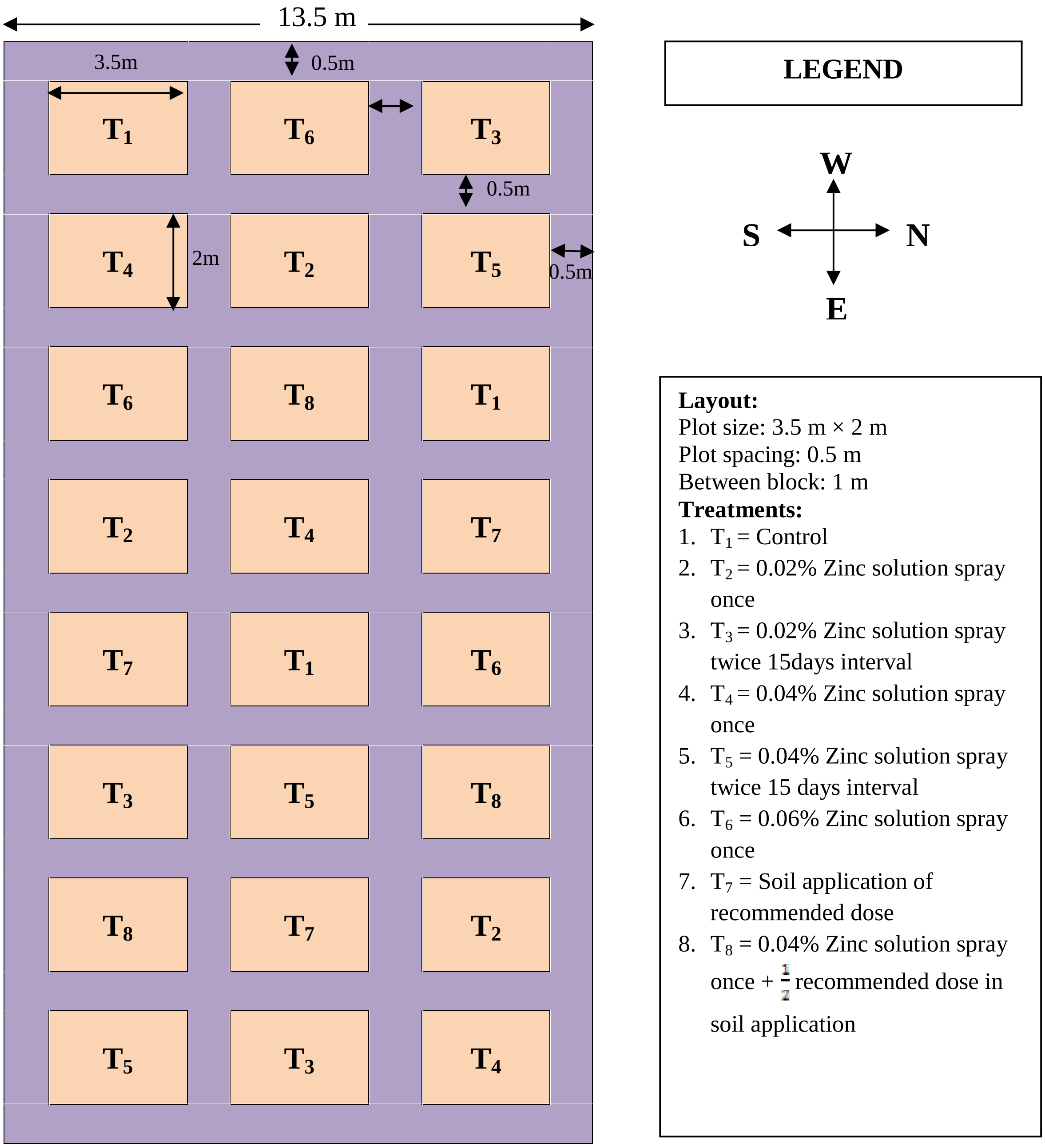

Fig. 9. Layout of the experimental plot

Appendix V. Significant effect on plant height of wheat (BARI Gom-26) affected by foliar application of zinc

Source of variation	Degrees of freedom	Mean square of plant height			
		20 DAS	50 DAS	80 DAS	At harvest
Replication	2	0.710	1.001	1.012	1.047
Factor A	7	17.203*	24.116*	15.509*	17.306*
Error	14	0.508	1.121	2.352	2.544

Appendix VI. Significant effect on number of tillers plant^{-1} of wheat (BARI Gom-26) affected by foliar application of zinc

Source of variation	Degrees of freedom	Mean square of number of tillers plant^{-1}			
		20 DAS	50 DAS	80 DAS	At harvest
Replication	2	0.014	0.115	0.206	0.217
Factor A	7	10.3438**	14.307*	15.008*	18.387*
Error	14	0.108	0.566	1.292	1.428

Appendix VII. Significant effect on dry weight plant^{-1} (BARI Gom-26) affected by foliar application of zinc

Source of variation	Degrees of freedom	Mean square of dry weight plant^{-1}			
		20 DAS	50 DAS	80 DAS	At harvest
Replication	2	0.064	0.117	0.284	0.324
Factor A	7	12.507*	15.511*	13.007*	16.332*
Error	14	0.224	0.368	0.512	1.034

Appendix VIII. Significant effect on yield contributing characters of (BARI Gom-26) affected by foliar application of zinc

Source of variation	Degrees of freedom	Mean square of yield contributing parameters		
		Spike length (cm)	Number of grain spike^{-1}	1000 see weight (g)
Replication	2	0.164	0.277	0.328
Factor A	7	14.509**	18.067*	25.067*
Error	14	0.714	1.243	1.332

Appendix IX. Significant effect on yield parameters of wheat (BARI Gom-26) affected by foliar application of zinc

Source of variation	Degrees of freedom	Mean square of yield parameters		
		Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Replication	2	0.175	0.279	0.166
Factor A	7	8.579*	10.618*	12.002*
Error	14	0.352	0.539	1.049

Appendix X. Significant effect on soil nutrient status after Zn application to wheat

Source of variation	Degrees of freedom	Mean square of post harvestsoil nutrients					
		Soil pH	% Organic matter	% N	Available P (μg g^{-1})	Exchangeable K (μg g^{-1})	Available Zn (μg g^{-1})
Replication	2	0.000	0.001	0.001	0.134	0.001	0.014
Factor A	7	NS	NS	NS	11.14**	NS	6.002**
Error	14	0.004	0.009	0.016	0.368	0.011	0.043

Appendix XI. Significant effect on comparable effect of soil according to soil nutrient status after Zn application to wheat

Source of variation	Degrees of freedom	Nutrient status in soil after Zn					
		Soil pH	% Organic matter	% N	Available P (μg g^{-1})	Exchangeable K (μg g^{-1})	Available Zn (μg g^{-1})
Replication	2	0.00	0.00	0.00	0.042	0.04	0.018
Factor A	7	NS	NS	NS	6.619**	NS	2.104**
Error	14	0.001	0.003	0.001	0.376	0.002	0.149