International Journal of Biological and Environmental Engineering
2018; 1(1): 10-16
http://www.aascit.org/journal/ijbee

American Association for Science and Technology

Effect of Foliar Zinc Spray on Growth and Yield of Heat Tolerant Wheat Under Water Stress

Md Hasibur Rahaman Hera[1], Mohammod Hossain[1, *], Alok Kumar Paul[2]

[1]Plant Pathology Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh
[2]Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

Email address

hossainmbd@yahoo.com (M. Hossain)
[*]Corresponding author

Citation

Md Hasibur Rahaman Hera, Mohammod Hossain, Alok Kumar Paul. Effect of Foliar Zinc Spray on Growth and Yield of Heat Tolerant Wheat Under Water Stress. *International Journal of Biological and Environmental Engineering.* Vol. 1, No. 1, 2018, pp. 10-16.

Received: January 16, 2018; **Accepted**: February 11, 2018; **Published**: March 23, 2018

Abstract: Crop production under field conditions decrease by several abiotic stresses including water stress. An experiment was conducted to investigate the effect of foliar application of Zinc (Zn) on growth and yield of heat tolerant wheat (*Triticum aestivum* L. cv. BARI ghom25) under water stress conditions. Treatments comprised of four water stress (control, skipping one irrigation at crown root initiation (CRI) stage, skipping one irrigation at booting, and heading and flowering stage) and foliar application Zn (0.04%). The results showed that irrigation skipping at CRI stage affected the growth and yield whereas irrigation skipping at both booting, and heading and flowering stage did not effect. Foliar application of Zn could mitigate the adverse effects of water stress at CRI stage and irrigation skipping at both booting, and heading and flowering stage also affected growth and yield of wheat. It is suggest that BARI ghom25 appeared to be sensitive to water shortage during CRI stage and foliar application of Zn could mitigate the adverse effects on growth and yield caused by water stress at CRI stage.

Keywords: Wheat, Water Stress, Zinc, Growth, Yield

1. Introduction

Wheat (*Triticum aestivum L.*) belongs to family Poaceae and is very important crop as it contributes major portion of staple food for the world's population and provides more calories and protein in the world's diet than any other cereal [1]. Water stress reduces plant growth and manifests several morphological, physiological and biochemical alterations leading to massive loss in yield [2]. The response of plants to water stress depends on several factors such as developmental stage; timing, severity and duration of stress and cultivar genetics [3, 4]. The crop water need is related to moisture sensitive periods. Water shortage at critical growth stages such as crown root initiation, tillering, booting, anthesis and grain filling has deleterious effects on plant growth, development and economic yield of wheat [5, 6].

During water shortage, plants that used the methods to obtain tolerance to water stress [7]. One of these methods is using nutritional element supplies such as zinc (Zn) [8]. 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 [9, 10]. According to Brown et al. [11] formation of male and female reproductive organs and pollination process are disturbed in Zn deficiency, which in result causes a sever reduction in plant yield. Several studies have shown that foliar application of Zn can increase growth and yield of crops [12, 13]. Zn is required for plant growth as an activator of several enzymes and is directly involved in the biosynthesis of growth regulators such as auxin, which promotes production of more plant cells and biomass that will be stored in the plant organs especially in seeds [14]. Productivity is often limited by periods of water deficit and in a number of regions Zn deficiency occurs, but the interaction between zinc nutrition and water stress has not been studied extensively [15].

Cell membrane is one of the first targets of many plant stresses [16] and it is generally accepted that maintenance of their integrity and stability under water deficit conditions is major component of drought tolerance in plants [17]. Zinc sulfate fertilizer plays a more important role in adjusting stomata and ionic balance in plant system to decrease stresses caused by water shortage [18, 19] and adequately applied zinc has been shown to improve the water use efficiency of wheat plants [20]. Zinc can provide thermo-tolerance to the photosynthetic apparatus of wheat [21]. In this study we investigated the effect of foliar application of Zn on growth and yield of heat tolerant wheat at different growth stages under water stress.

2. Materials and Methods

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Bangladesh during the period from October 2013 to February 2014 on a Deep Red Brown Terrace Soil of Madhupur Tract. A physico-chemical property of soil of the experimental plot is shown in Table 1. Very little rainfall, low humidity, and bright sunny days were the characteristic features of the growing season (Table 2). Wheat (*Triticum aestivum* L., cv. BARI ghom25) was chosen as the plant material. The seeds of wheat were obtained from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement and replicated thrice. The plot size was 2 m × 2 m. Row to row distance was 20 cm. Nitrogen, Phosphorus and Potassium were applied at 150, 125, 67 kg ha^{-1} using urea, triple super phosphate and muriate of potash, respectively. The irrigation levels were imposed in the experiment to stimulate the type of stress. i.e., control (regular irrigation), skipping irrigation at CRI stage (stressed by skipping one irrigation at CRI stage), skipping irrigation at booting stage (stressed by skipping one irrigation at booting stage), skipping irrigation at heading and flowering stage (stressed by skipping one irrigation at heading and flowering stage). Zinc sulphate Monohydrated ($ZnSO_4.H_2O$) at 0.04% was used as a source of Zn. Foliar application of Zn was done during the skipping irrigation at respective days. All agronomic practices were carried out uniformly for all treatments. At maturity, when 90% of the crops became brown in color data on five plants per treatment were selected at random, tagged and leveled properly to record plant height, spike length, number of grain $spike^{-1}$, 1000-grain weight. 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}.

Table 1. *Physical and chemical properties of the initial soil sample.*

Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
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 Boron	0.48 µg/g soil
Available Iron	262.6 µg/g soil
Available Zinc	3.32 µg/g soil

Table 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 (°C)			Av. relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
October	2013	29.36	18.54	23.95	74.80	Trace	218.50
November	2013	28.52	16.30	22.41	68.92	Trace	216.50
December	2013	27.19	14.91	21.05	70.05	Trace	212.50
January	2014	25.23	18.20	21.80	74.90	4.0	195.00
February	2014	31.35	19.40	25.33	68.78	3.0	225.50

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

3. Results and Discussion

Wheat grain yield is a result of shared factors of some yield-related traits, i.e. Plant height, spike length, number of grain per spike, and weight. Water stress diminished the yield under CRI stage due to marked reduction in traits relevant to yield in BARI ghom25.

3.1. Plant Height

Skipping one irrigation at booting, and heading and flowering stage had no effect on plant height (cm) (Figure 1), suggesting that BARI ghom25 copes with stress and showed tolerance at booting, and heading and flowering stage except CRI stage. Substantial decline in plant height has been reported when irrigation was withheld at anthesis, however tolerant genotypes attained more plant height [22]. The decrease in plant height in response to water stress at CRI stage could be due to decrease in relative turgidity and dehydration of protoplasm, which is associated with a loss of turgor and reduced expansion of cell and cell division [23, 24]. Foliar application of Zn increased plant height by 11.96% at CRI stage whereas at booting, and heading and flowering stage, the percent of increased in the plant height was 2.72 and 2.30 under water stress (Figure 1). These suggest that Zn alleviated the inhibitory effect of water stress at CRI stage. Zn is involved in biosynthesis of tryptophane, a precursor of auxin, which is essential for cell elongation. High osmotic pressure resulting from Zn deficiency is due to reduced water uptake which is restricted by failure of cell walls to grow because of lack of auxin [25].

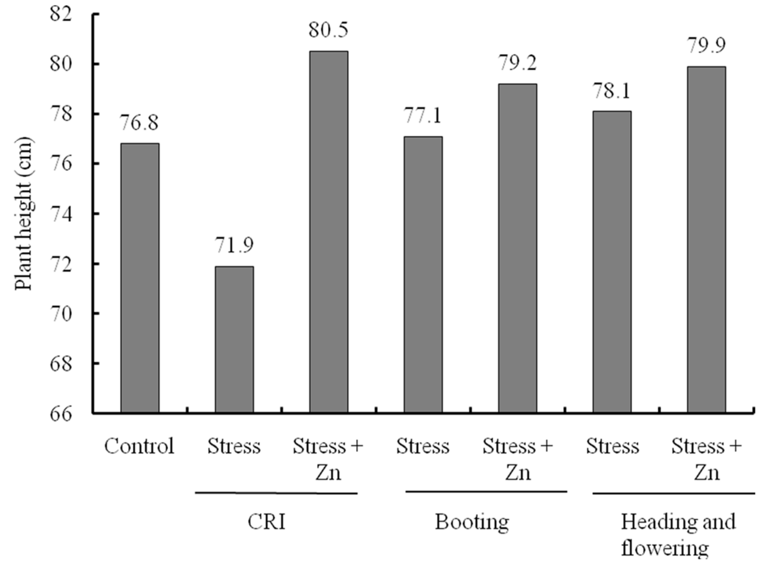

Figure 1. *Effect of foliar application of Zn on plant height of wheat grown under water stress conditions at different growth stages.*

3.2. Spike Length

The data pertaining to spike length (cm) of wheat variety BARI ghom25 as affected by foliar applied zinc under water stress were shown in Figure 2. At CRI stage, skipping one irrigation decreased the spike length by 2.71% as compared to regular irrigation. Spike length was not reduced when plants subjected to skipping one irrigation during booting, and heading and flowering stages. Foliar application of Zn improved the spike length at CRI stage by 1.05% under water stress; whereas more spike length was recorded on the plants applied with Zn at booting, and heading and flowering stages by 4.37% and 7.09%, respectively (Figure 2). The shorter spikes observed at stress at CRI stage could be as a result of skipping one irrigation at that stage which resulted to shorter plants (Figure 1). The decrease in stem height and ear length due to water stress has been reported earlier in wheat [26]. The results of experiments by Mirbahar et al. [27] also indicate that water stress decreased spike length of wheat. Khan and Naqvi [22] reported that water deficit tolerant wheat genotype showed minimum reduction on spike length at vegetative stage whereas promotion has been noticed under anthesis stress. It was reported that Zn through improved catalytic activity in anther wheat and increased spike length [28]. Also, Shaheen et al. [29] stated that application of zinc increase spike length of wheat.

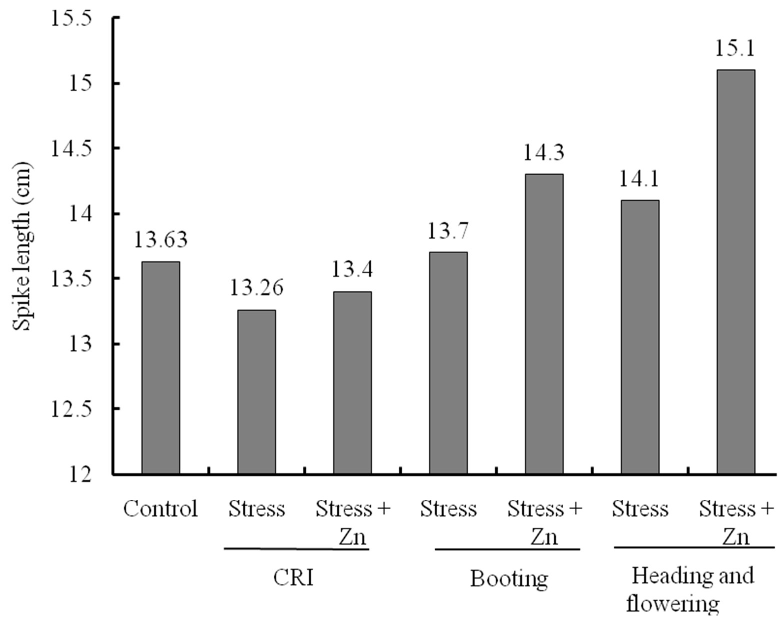

Figure 2. *Effect of foliar application of Zn on spike length of wheat grown under water stress conditions at different growth stages.*

3.3. Number of Grain Spike^{-1}

A marked decrease (8.12%) in number of grains per spike has been noticed at CRI stage. However, Skipping one irrigation at booting, and heading and flowering stage had no effect on number of grains per spike (Figure 3). It may be suggested that this genotype had the ability to cope the stress or is tolerable to water stress at booting, and heading and flowering stage. Dzisah [30] observed that heat tolerant tomato variety recorded the highest fruit number or seed number per fruit at deficit water treatment. Drought at crown-root initiation in wheat caused significant reduction in number of spikelets per spike [31, 32]. Zinc effect was considerable on the grains per spike. Its spray under water stress improved the number of grains per spike (Figure 3). Among water stressed treatments, the maximum grain number was obtained in plants treated with Zn at booting (17.94%), and heading and flowering stages (21.5%) and minimum (2.68%) was observed in plants which were given water stress at CRI stage. Increase in number of grains per spike due to foliar application of Zn might be due to the involvement of Zn in pollen tube formation, resulting in more seed set [33]. Our results are in line with that of Soleimani [34] who also reported increase in number of grains spike^{-1} for foliar application of zinc.

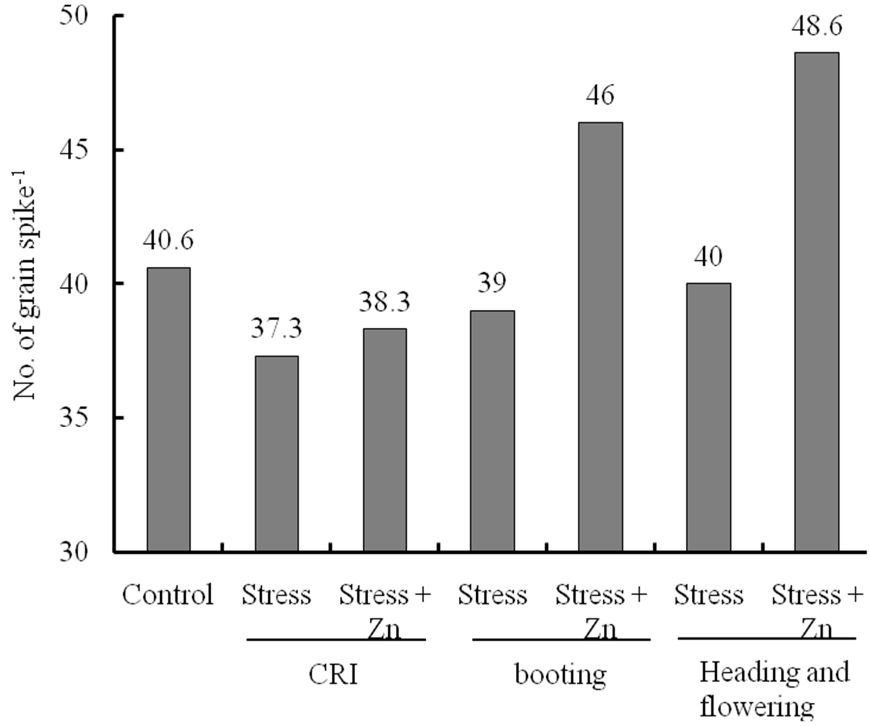

***Figure 3.** Effect of foliar application of Zn on number of grain per spike plant of wheat grown under water stress conditions at different growth stages.*

3.4. One Thousand Grain Weight (1000-Grain Weight)

Results indicate that skipping one irrigation at CRI stage decreased 1000-grain weight (gm) by 6.71% (Figure 4). However, water stress imposed by skipping one irrigation at booting, and heading and flowering stage did not decrease 1000-grain weight. Under drought conditions the availability of current assimilates for extending seed filling will often be severely reduced. In such circumstances, the variety that can mobilize reserves of carbohydrates in the stem will be able to maintain better seed filling. Dzisah [30] also observed that heat tolerant tomato recorded the highest fruit weight at deficit water treated plants. Zinc spray in stress treatments at CRI stage, and heading and flowering stage increased the 1000-grain weight as 11.44% and 4.14%, respectively (Figure 4). Zn increased thousand grains weight due to the involvement of the Zn in enzyme activation [14], membrane integrity [35, 36], chlorophyll formation [37], nitrogen metabolism [38], stomatal regulation [39] and starch utilization at early stages, while enhanced accumulation of assimilate in the grains, which resulted in heavier grains. These results are supported by Harris et al. [40] and Karim et al. [41] who observed increase in 1000-grain weight with each increment of Zn. Zinc by increasing the soluble sugars and maintain osmotic potential able to store carbohydrates to basic cell metabolism and increases the grain weight [42]. However, at booting stage Zn spray did not change 1000-grain weight.

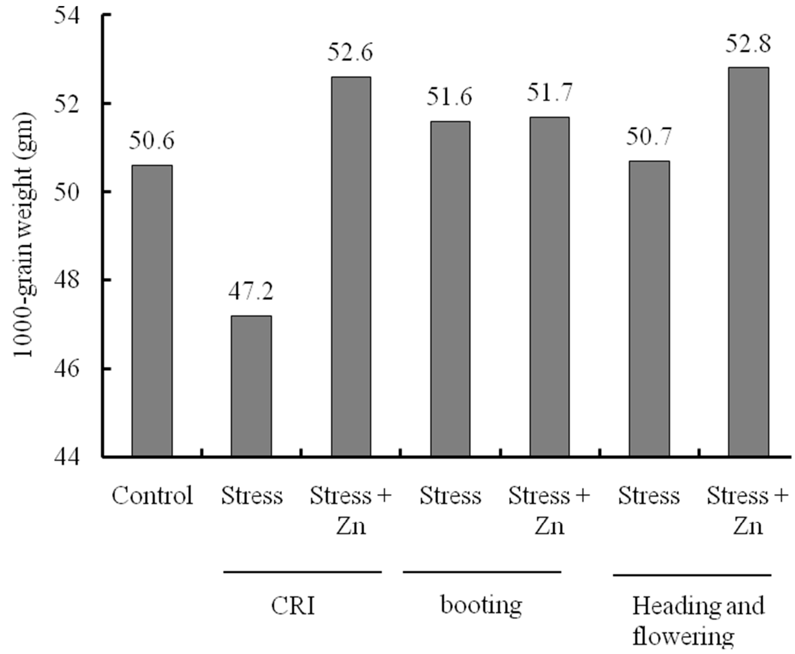

Figure 4. *Effect of foliar application of Zn on 1000-grain weight of wheat grown under water stress conditions at different growth stages.*

3.5. Grain Yield

Result show that skipping one irrigation at CRI stage 29.38% decreased grain yield (t ha^{-1}) of wheat. Foliar application of Zn 32.11% increased grain yield of wheat at CRI stage under water stress condition (Figure 5), due to higher plant height (Figure 1) and highest 1000-grain weight (Figure 4). Results showed that water stress imposed by skipping one irrigation at booting, and heading and flowering stages did not decrease grain yield, which might be due to the stress tolerant. Ali et al. [43] reported that drought tolerant genotypes produced higher grain yield in drought stress conditions. Foliar application of Zn increased 22.27% and 36.45% grain yield at booting, and heading and flowering stages, respectively under skipping one irrigation (Figure 5), due to higher number of grain $spike^{-1}$ (Figure 3). The foliar spray of Zn at tillering and/or booting and milking growth stage (s) increased the grain yield of wheat [44, 45]. 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 [33]. Jiang and Huang [46] reported that the yield and its components in wheat are increased due to the effects of zinc on the amount of chlorophyll. The increase of chlorophyll increases yield through the increase of photosynthesis. Cakmak [47] reported that Zn plays a fundamental role in structural and functional integrity of biomembranes and photosynthetic carbon metabolism.

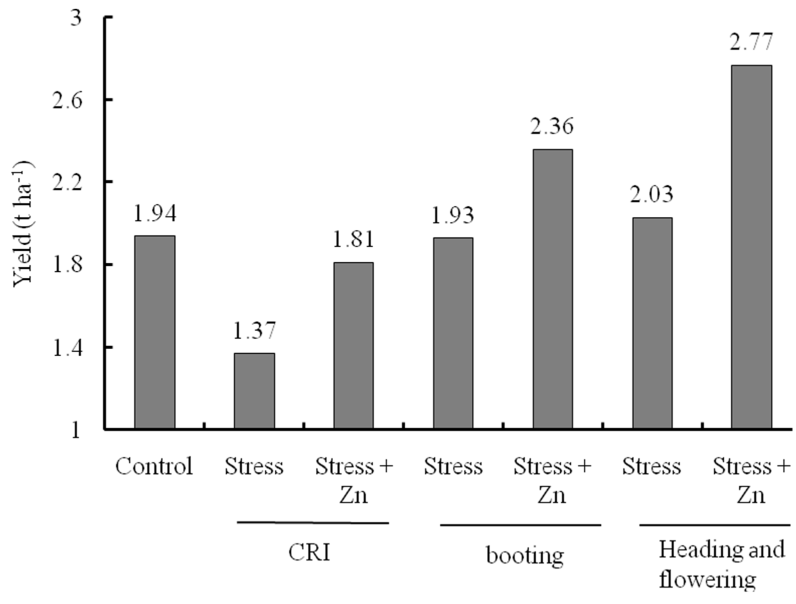

Figure 5. *Effect of foliar application of Zn on yield of wheat grown under water stress conditions at different growth stages.*

4. Conclusion

It could be concluded that growth and yield attributes of the heat tolerant wheat cultivar BARI ghom25 studied respond differently to different growth stages under water stress. Skipping irrigation at CRI stage decreased plant height, spike length, number of grain spike^{-1}, 1000-grain weight and grain yield compared with regular irrigation. BARI ghom25 gave higher growth and yield under skipping one irrigation at booting, and heading and flowering stage. It is advised that wheat producers should use lower water volumes or irrigation levels at booting, and heading and flowering stage when cultivating heat tolerant wheat cultivars. Foliar application of Zn mitigates adverse effects of water stress at CRI stage by increasing growth and yield. Interestingly, this micronutrient, at booting, and heading and flowering stages, also increased yield under water stress. Therefore, it seems essential to particular consider this important nutritional element in the programs of fertilizer recommendations at CRI stage under water stress condition in BARI ghom25.

References

[1] CIMMYT 2002. Wheat the vital grain of civilization and food security. Wheat annual report. Mexico, DF.

[2] Farooq MA, Wahid L, Kobaayashi D, Fujita, Basra SMA. 2009. 'Drought review' Agron. Sustainable Develop. 29: 185-212.

[3] Beltrano J, Ronco MG. 2008. Improved tolerance of wheat plants (*Triticum aestivum* L.) to drought stress and rewatering by the arbuscular mycorrhizal fungus *Glomus claroideum*: effect on growth and cell membrane stability. Brazilian J. Plant Physiol. 20: 29-37.

[4] Pandey RK, Maranville JW, Admou A. 2001. Tropical wheat response to irrigation and nitrogen in a Sa-helian environment. European J. Agron. 15: 93-105.

[5] Khan MA. 2003. 'Introduction: wheat crop management for yields maximization' Agri. Department, Lahore (Pak). 1-5.

[6] Manikavelu A, Nadarajan N, Ganesh SK, Gnanamalar RP, Babu RC. 2006. Drought tolerance in rice: morphological and molecular genetics consideration. Plant Growth Regula. 50: 121-138.

[7] Bartles, RA, Villalobos, AD. 2009. Mulch and Fertilizer effect on soil Nutrient content, water conservation. ASD plain papers, Number 16, 2009.

[8] Tisdalo SL. 2005. Soil fertilizers. 9th ed. N.Y. Macmillan publication.

[9] Baydar H, Erbas S. 2005. Influence of seed development and seed position on oil, faty acids and total tocophorol contents in sunflower (*Helianthus annuus* L.). Turkish J. Agric. 29: 179-186.

[10] Ehdaie B, Alloush GA, Waines JG. 2008. Genotypic variation in linear rate of grain growth and contribution of stem reserves to grain yield in wheat. Field Crop Res. 106: 34-43.

[11] Brown PH, Cakmak I, Zhang Q. 1993. Form and function of zinc in plants. In: Robson AD. (ed). Zinc in Soil and Plants. Kluwar Academic Publishers. Dordecht, The Netherlands. PP. 93-106.

[12] Aslam W, Arfan M, Shahid SA, Anwar F, Mahmood Z, Rashid U. 2014. Effects of exogenously applied Zn on the growth, yield, chlorophyll contents and nutrient accumulation in wheat line L-5066. Int. J. Chemic. Biochemic. Sci. 5: 11-15.

[13] Han JL, Li YM, Ma CY. 2004. The impact of zinc on crop growth and yield (review). J. Hebei Normal University of Sci. Technol. 18: 72-75.

[14] Marschner H. 1995. Mineral Nutrition of Higher Plants. 2nd Edition, Academic Press, London, 645.

[15] Khan HR, McDonald GK, Rengel Z. 2004. Zinc fertilization and water stress affects plant water relations, stomata conductance and osmotic adjustment in chickpea (*Cicer arientinum* L.). Plant and Soil. 267 (1-2): 271-284.

[16] Levitt J. 1972. Responses of plants to environmental stresses. Academic press, New York.

[17] Bajjii M, Kinet JM, Lutts S. 2001. The use of the electrolyte leakage method for assessing cell membrane stability as a water stress tolerance test in durum wheat. Plant Growth Regul. 00: 1-10.

[18] Karam F, Lahoud R, Masaad R, Kabalan R, Breidi J, Chalita C, Rouphael Y. 2007. Evaporation, seed yield and water use efficiency of drip irrigated sunflower under full and deficit irrigation conditions. Agri. water management. 90: 213-223.

[19] Babaeian M, Heidari M, Ghanbari A. 2010. Effect of water stress and foliar micronutrient application on physiological characterstics and nutrient uptake in sunflower (*Helianthus annuus L.*). Iranian J. crop sci. 12: 311-391.

[20] Bagci SA, Ekiz H, Yilmaz A, Cakmak I. 2007. Effect of zinc deficiency and drought on grain yield of field-grown wheat cultivars in Central Anatolia. J. Agron. Crop Sci. 193: 198-206.

[21] Graham AW, McDonald GK. 2001. Effect of zinc on photosynthesis and yield of wheat under heat stress. Proceedings of the 10th Australian Agronomy Conference 2001, Australian Society of Agronomy. Hobart, Tasmania, Australia. Available on line at http:/www.regional.org.au/au/asa/2001/2/c/graham.htm.

[22] Khan N. and Naqvi FN. 2011. Effects of water stress in bread wheat hexaploids. Current Res. J. Biol. Sci. 3 (5): 487-498.

[23] Arnon I. 1972. Crop Production in Dry Regions, Background and Principles. (Ed.): Polunin N. Leonard Hill Book, London. 1: 203-211.

[24] El-Kholy MA, Gaballah MS. 2005. Productivity of Wheat Cultivars as Affected by Seeding Methods and Reflectant Application under Water Stress Condition. J. Agron. 4: 23-30.

[25] Singh SS. Mitra SK. 1975. Diagonose zinc deficiency and protect your crops. Indian Farmers Digest. 12: 32-34.

[26] Iqbal M, Ahmed K, Ahmed I, Sadiq M, Ashraf M. 1999. Yield and yield components of durum wheat as influenced by water stress at various growth stages. Pakistan J. Biol. Sci. 2: 11-14.

[27] Mirbahar AA, Markhand GS, Mahar AR, Abro SA, Kanhar NA, 2009. Effect of Water Stress on Yield and Yield Components of Wheat (*Triticum aestivum* L.) Varieties, Pakistan J. Bot. 41 (3): 1303-1310.

[28] Abbas G, Khan MQ, Jamil M, Tahir M, Hossain F. 2009. Nutrient uptake, growth and yield of wheat (*Tritcum aestivum L.)* as affected by Zinc application rates. Int. J. Agri. Biol., 11: 389-396.

[29] Shaheen R, Samim MK, Mahmud R. 2007. Effect of zinc on yield and zinc uptake by wheat on some soils of Bangladesh. J. Soil Nature. 1 (1): 07-14.

[30] Dzisah SK. 2013. Growth, yield and quality of heat tolerant tomato as influenced by different watering regimes. Thesis of Mphil Crop Science Degree, University of Ghana, Legon.

[31] Shalaby EM, Rahim HMA, Massad MG. Masoud MM. 1988. Effect of watering regime on morphological traits and harvest index and its components. Sustainable J. Agri. Sci. 19: 195-207.

[32] Shpiler L, Blum A. 1991. Heat tolerance to yield and its components in different wheat cultivars. Euph. 51: 257-263.

[33] Ziaeyan AH, Rajaiea M. 2009. Combined effect of Zinc and Boron on yield and nutrients accumulation in corn. Journal of Plant Production. 3: 1735-8043.

[34] Soleimani R. 2006. The effects of integrated application of micronutrient on wheat in low organic carbon conditions of alkaline soils of western Iran. 18th World Congress of Soil Science.

[35] Shkolnik MY. 1984. Trace Elements in Plants. Elsevier, Amsterdam.

[36] Aown M, Raza S, Saleem MF, Anjum SA, Khaliq T, Wahid MA. 2012. Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*triticum aestivum* l.). J. Animal & Plant Sci., 22 (2): 431-437.

[37] Graham RD, Welch RM, Bouis HE. 2000. Addressing micronutrient nutrition through enhancing the nutritional quality of staple foods. Advances Agron. 70: 77-161.

[38] Potarzycki J, Grzebisz W. 2009. Effect of zinc foliar application on grain yield of maize and its yielding components. Plant Soil Environ. 55 (12): 519-527.

[39] Sharma PN, Tripathi A, Bisht SS. 1995. Zinc requirement for stomatal opening in cauliflower. Plant Physiol. 107: 751-756.

[40] Harris A, Rashid G, Miraj G, Asif M, Shah H. 2007. On-farm seed priming with zinc sulphate solution. A cost-effective way to increase the maize yield of resources of poor farmers. Field crop Res. 110: 119-127.

[41] Karim MR, Zhang YQ, Zhao RR, Chen XP, Zhang FS, Zou CQ. 2012. Alleviation of drought stress in winter wheat by late foliar application of zinc, boron and manganese. J. Plant Nutri. 175: 142-151.

[42] Singh KS, Chosals S. Singh J. 1992. Effect of sulphur, zinc and iron on chlorophyll content, yield, protein, harvest and nutrients uptake of French bean (*Phaseolus vulgaris* L.). J. Plant Nutri. 15: 2025-2033.

[43] Ali A, Ali N, Ullah N, Ullah F, Adnan M, Ahmed Swati Z. 2013. Effect of drought stress on the physiology and yield of the pakistani wheat germplasms. Int. J. Advancements Res. Technol., 2: 419-430.

[44] Mohammad RPR, Mohammad P. 2009. Response of Wheat Plants to Zinc, Iron, and Manganese Applications and Uptake and Concentration of Zinc, Iron, and Manganese in Wheat Grains. Commun. Soil Sci. Plant Analysis. 40 (7/8): 1322-1332.

[45] Cheema SS, Dhingra KK, Gill GS. 1973. Effect of missing irrigation on the growth of dwarf wheat. J. Res. Punjab Agri. University. 10 (1): 41-44.

[46] Jiang Y, Huang B. 2002. Protein alterations in tall fescue in response to drought stress and abscisic acid. Crop Sci. 42: 202-207.

[47] Cakmak I. 2000. Possible role of zinc in protecting plant cells from damage by reactive oxygen species. New Phytologist. 146: 185-205.