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EFFECT OF FOLIAR APPLICATION OF ZINC ON YIELD OF WHEAT GROWN BY AVOIDING IRRIGATION AT DIFFERENT GROWTH STAGES

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Abstract

A field experiment was carried out at micronutrient experimental field of Soil Science Division, BARI, Joydebpur, Gazipur to study the effect of foliar application of zinc on yield of wheat (BARI gom-25) grown by skipping irrigation at different growth stages of the crop. The experiment was designed in a split plot design on sixteen treatments comprising four irrigation treatments (regular irrigation, skipped irrigation at crown root initiation, skipped irrigation at booting stage and skipped irrigation at grain filling stages of wheat growth) and four foliar application of zinc (0.0%, 0.02%, 0.04% and 0.06% of zinc). Zinc Sulphate Monohydrate ($ZnSO_4$. H_2O) was used as a source of Zn. The 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).

Keywords: Foliar, Zinc, Irrigation, Wheat and Yield.

Introduction

Wheat is an important cereal crop and serves as a staple food in many countries of the world. Most of the wheat-growing areas in the world suffer from low water supply and irregular distribution of rainfall during the growing season (Bagci *et al.*, 2007). Drought stress is also a serious abiotic stress factor limiting crop production in Bangladesh. However, the stress response depends upon the intensity, rate and duration of exposure and the stage of crop growth (Wajid *et al.*, 2004). Depending on the time, amount and distribution of the precipitation,

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drought stress results in substantial yield losses and in combination with Zn deficiency the decreases in yield becomes more severe (Ekiz *et al.,* 1998). When considering a water regime for a crop, it is wise to understand the sensitive growth stages for water and the water requirement of the crop. In order to achieve maximum yield and, maintaining adequate soil moisture condition during moisture-sensitive stages of growth so irrigation water may be saved if soil water could be depleted to a greater extent during certain growth stages without affecting yield (Thalooth *et al.,* 2006).

As well documented by plant physiologists, 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; (iii) resistance to abiotic and biotic stresses – protection against oxidative damage (Cakmak, 2008). Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Zinc also plays an important role in the production of biomass (Kaya and Higgs, 2002; Cakmak, 2008). Furthermore, zinc may be required for chlorophyll synthesis, pollen function and fertilization (Kaya and Higgs, 2002; Pandey *et al.,* 2006). Low solubility of Zn in soils rather than low total amount of Zn is the major reason for the widespread occurrence of Zn deficiency problem crop plants (Cakmak, 2008).

Zinc nutritional status of plants may affect the drought sensitivity of plants in different ways. Zinc is involved in detoxification of Reactive Oxygen Species (ROS) and it is also important for reducing the production of free radicals by superoxide radical producing enzymes (Cakmak *et al.,* 1989; Cakmak, 2000). An adequate Zn nutrition has also protective effects on photoxidative damage catalyzed by ROS in chloroplasts (Cakmak, 2000, Wang and Jin, 2005). Drought stress represents an oxidative stress and kills plants by inducing production of ROS, especially during photosynthesis (Selote *et al.,* 2004, Goodman and Newton, 2005). It is, therefore, likely that drought stress-related production of ROS and sensitivity of plants to photoxidative damage in chloroplasts are additionally accentuated when plants would simultaneously suffer from Zn-deficiency stress.

Foliar-applied nutrients have limited direct use for enhancement of stress resistance mechanisms in field crops. Among the micronutrients, Zn and Fe nutrition can affect the susceptibility of plants to drought stress (Sultana *et al.,* 2001; Khan *et al.,* 2003; Cakmak, 2008). Foliar application of zinc greatly affects plant growth and crop production. It is, therefore, important to study the efficiency of foliar application of zinc on yield of wheat under water stressed condition at different growth stages of the crop. The present study was, therefore, undertaken a) to know the effect of foliar application of zinc on yield of wheat grown by skipping irrigation and b) to find out the optimum foliar dose of Zn application for sustainable yield of wheat.

Materials and Method

A field experiment was carried out in the micronutrient experimental field of Soil Science Division, Bangladesh Agricultural Research Institute located at 23º59′26″ N and 90º24′52″ E., Grey Terrace Soil of Joydebpur, Gazipur (AEZ-28) on 27 November, 2013 with a view to studying the effect of foliar application of zinc on yield of wheat grown by skipping irrigation. The experiment was laid out in a split plot design with three replications. Irrigation was assigned in a main plot and foliar application in the subplot. Wheat (*Triticum aestivum* var. BARI Gom 25) was used in the experiment.

There were sixteen treatment combinations comprising of four irrigation treatments *i.e.,* T_1: regular irrigation: irrigation at crown root initiation stage, booting stage and grain filling stage, T_2: skipping one irrigation at crown root initiation stage, T_3: skipping one irrigation at booting stage, T_4: skipping one irrigation at grain filling stage and four levels of foliar spray of zinc i.e., Zn_0: control, Zn_1: 0.02%, Zn_2: 0.04% and Zn_3: 0.06% foliar application of Zn. Irrigation water was applied to the field condition in each plot as per treatment. Foliar application of zinc was done during the skipping irrigation at respective days. Zinc Sulphate Monohydrate ($ZnSO_4$. H_2O) was used as sources of Zn. Urea, triple supper phosphate, muriate of potash, gypsum and boric acid were used as sources of N, P, K, S and B, respectively. Fertilizers were applied based on BARC Fertilizer Recommendation Guide-2012. All PKSB and half of N were applied at the final land preparation and the remaining half of N was applied before booting stage. Initial properties of the soil samples of experimental field are presented in Table 1. Weather data during the crop growth period was presented in Fig.1. Wheat seeds were sown directly on 27 November, 2013 and the crops were harvested on 21 March, 2014 at full maturity. Ten plants from each plot were sampled randomly for collection of different plant characters and yield attributes. Data on yield and yield contributing characters such as plant height (cm), spike length (cm), grain spike^{-1}, 100 grain wt, yield (t ha^{-1}) were recorded. Plants of 1 m^2 area from each plot were selected for data collection. Data on yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package MSTAT-C and mean separation was tested by Duncan’s Multiple Range Test (DMRT) at 5% level of probability.

Determination of Zn content in wheat grain

One gram of each sample was weighed into 50 ml beaker, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HClO_4$ in the ratio 5:1, and left overnight for complete contact of material. Next day, the digestion was performed at a temperature of about 190 ºC for 1.5 h. After cooling, the samples were transferred into 100 ml volumetric flask and solution was made up to a final volume raised up to the mark with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a Zeenit model 700 Atomic Absorption Spectrophotometer (AAS). Analysis of each sample was carried out three times to obtain representative results and the data reported in µg g^{-1} (on a dry matter basis).

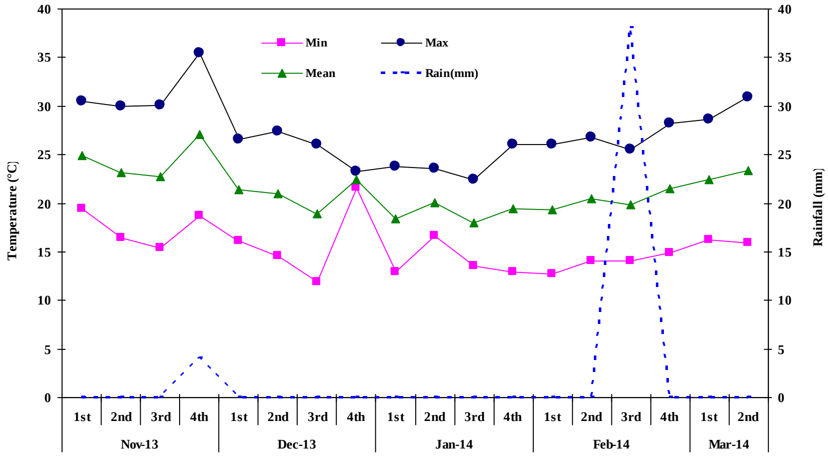

Fig. 1. Rainfall, minimum, maximum and mean temperature during growing period.

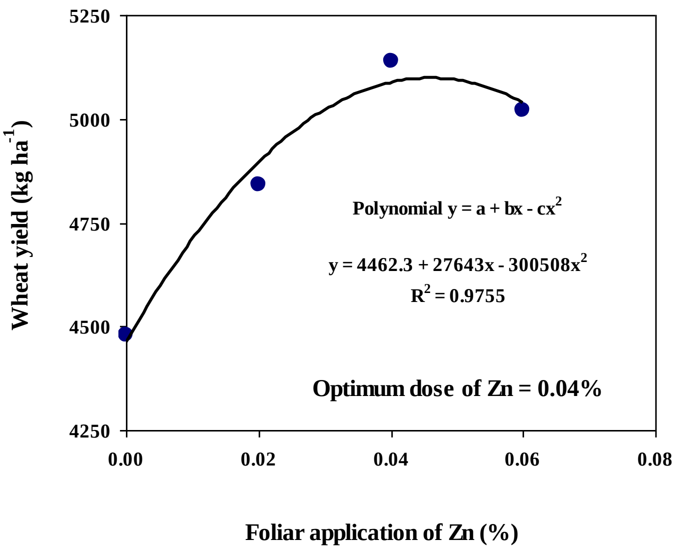

Fig. 2. Response of wheat to foliar application of Zn.

Results and Discussion

Effect of irrigation

The effect of irrigation on the grain yield and yield components of wheat has been shown in Table 3. The highest grain yield (5.29 t ha^{-1}) was obtained with regular irrigation (T_1), which was identical with skipping irrigation at heading and flowering stage (T_4). The lowest yield (4.33 t ha^{-1}) was obtained from skipping irrigation at crown root initiation stage (T_2), which was significantly lower than other treatments. This finding revealed that crown root initiation was the most critical stage for irrigation and its omission at this stage reduced the grain yield of 33 to 42% which was supported by Cheema *et al.* (1973). Crown root initiation (CRI) stage is the most critical stage for irrigation in wheat because any shortage of moisture at this stage results in less tillering and great reduction in yield. Bajwa *et al.* (1993) reported that number of tillers improved with irrigation at crown root stage and better grain yield was recorded with irrigation at crown root and booting stage.

Effect of foliar application of zinc

Foliar application of zinc played a significant role in the yield and yield components of wheat (Table 2). Yield components were influenced significantly due to foliar application of Zn. The grain yield of wheat increased significantly due to added zinc up to 0.04%. Kaya and Higgs (2002) and Cakmak (2008) reported that zinc plays an important role in the production of biomass. Firstly, Zn is involved in detoxification of Reactive Oxygen Species (ROS) and in this respect may play a protective role in preventing photoxidative damage catalyzed by ROS in chloroplasts (Cakmak, 2000; Cakmak and Römheld, 1997; Ducic and Polle, 2005). Secondly, this micronutrient might greatly contribute to drought-stress tolerance by protection against oxidative damage of membranes (Cakmak, 2000; Cakmak and Römheld, 1997; Ducic and Polle, 2005).The highest yield (5.14 t ha^{-1}) was found with 0.04% foliar application of Zn which was higher than the rest of the doses. There was no significant difference between 0.02% and 0.06% foliar application of Zn.

Interaction effects of irrigation and foliar application of zinc

The interaction effect between irrigation and foliar application of zinc on the yield and yield components of wheat was significant (Table 3). The highest grain yield (5.59 t ha^{-1}) was recorded in regular irrigation (T_1) with 0.04% foliar application of zinc which was statistically with T_4 treatment (skipping irrigation at grain filling stage). Skipping irrigation at crown root initiation (CRI) stage of growth caused the reduction in all yield components and grain yield of wheat. This might be due to reduced crown root development which decreased the grain

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM (%)	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
				meq $100g^{-1}$				$\mu g\ g^{-1}$					
Result	Sandy clay loam	6.50	1.06	10.2	1.49	0.67	0.03	22	11	0.50	1.6	120	0.96
Critical level	-	-	-	2.0	0.80	0.20	-	14	14	0.20	1.0	10	2.0

ASI method.

Table 2. Main effect of irrigation and foliar application of Zn on yield and yield components of wheat in 2014

Treatment	Plant height (cm)	spike length (cm)	No of grain $spike^{-1}$	100 grains wt. (g)	Grain wt. m^{-2} (g)	Grain yield (t ha^{-1})
Irrigation mean						
T_1 = Regular irrigation	80.8ab	10.8a	50.4a	5.78a	529a	5.29a
T_2 = Skipping irrigation at CRI stage	78.3bc	10.3a	45.4b	4.98b	433c	4.33c
T_3 = Skipping irrigation at booting stage	77.79c	10.6a	47.4ab	5.16b	464b	4.64b
T_4 = Skipping irrigation at grain filling stage	82.0a	10.5a	50.1a	5.56a	520a	5.20a
Foliar application						
Zn_0 =Control	79.0a	10.1c	45.9b	5.21b	447c	4.47c
Zn_1 = 0.02% Zn	79.9a	10.4bc	47.6bc	5.24ab	484b	4.84b
Zn_2 = 0.04% Zn	80.4a	11.0a	50.2a	5.63a	514a	5.14a
Zn_3 = 0.06% Zn	79.5a	10.7ab	49.5ab	5.48ab	502ab	5.02ab

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

Table 3. Interaction effect of irrigation and foliar application of Zn on yield and yield components of wheat

Treatment combination		Plant height (cm)	Spike length (cm)	No of grain $spike^{-1}$	100 grains wt. (g)	Grain wt. m^{-2} (g)	Grain yield ($t\ ha^{-1}$)
Irrigation	Foliar application						
T_1 = Regular irrigation	Zn_0 = Control	78.1abcd	10.6abc	48.3ab	5.68abc	491bcde	4.91bcde
	Zn_1 = 0.02% Zn	79.1abcd	10.5abc	52.6ab	5.42abc	539abc	5.39abc
	Zn_2 = 0.04% Zn	84.3a	11.2ab	53.6ab	6.13a	559a	5.59a
	Zn_3 = 0.06% Zn	81.8abcd	10.8abc	47.0ab	5.92ab	527abc	5.27abc
T_2 = Skipping irrigation at CRI stage	Zn_0 = Control	77.9abcd	10.0abc	42.0b	4.50d	396h	3.96h
	Zn_1 = 0.02% Zn	82.7abc	10.1abcd	45.0ab	4.93cd	430fgh	4.30fgh
	Zn_2 = 0.04% Zn	75.6d	10.4abc	48.0ab	5.49 abc	463defg	4.63defg
	Zn_3 = 0.06% Zn	77.0cd	10.6abc	46.6ab	5.00cd	445efgh	4.45efgh
T_3 = Skipping irrigation at booting stage	Zn_0 = Control	78.8abcd	9.8c	46.3ab	4.93cd	418gh	4.18gh
	Zn_1 = 0.02% Zn	76.8cd	10.7abc	44.0ab	5.17bcd	454efg	4.54efg
	Zn_2 = 0.04% Zn	83.3abcd	11.3a	49.47ab	5.18bcd	498bcde	4.98bcde
	Zn_3 = 0.06% Zn	77.2bcd	10.7abc	50.0ab	5.35abcd	488cde	4.88cde
T_4 = Skipping irrigation at grain filling stage	Zn_0 = Control	81.3abcd	9.86bc	47.0ab	5.41abc	484cdef	4.84cdef
	Zn_1 = 0.02% Zn	80.9abcd	10.2abc	49.0ab	5.45abc	513abcd	5.13abcd
	Zn_2 = 0.04% Zn	83.6ab	11.1abc	50ab	5.73abc	535abc	5.35abc
	Zn_3 = 0.06% Zn	82.2abc	10.7abc	54.4a	5.64abc	548ab	5.48ab
CV (%)		4.74	5.63	9.77	3.36	8.28	8.28

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

CRI = Crown Root Initiation.

yield significantly. This result is in agreement with Thalooth *et al.* (2006) who reported that missing one irrigation at any stages of growth significantly reduced yield and yield components as well as photosynthetic pigments content as compared with regular irrigation. Skipping irrigation at flowering and heading stage with 0.04% foliar application of zinc gave the identical yield in regular irrigation (crown root initiation, booting stage, flowering and heading stage) with 0.04% and 0.06% foliar application of zinc. Timing of foliar Zn application is an important factor determining the effectiveness of the foliar applied Zn fertilizers in increasing grain Zn concentration. It is expected that large increases in loading of Zn into grain can be achieved when foliar Zn fertilizers are applied to plants at a late growth stage. Ozturk *et al.* (2006) studied changes in grain concentration of Zn in wheat during the reproductive stage and found that the highest concentration of Zn in grain occurs during the milk stage of the grain development. Results showed a high potential of Zn fertilizer strategy for rapid improvement of grain Zn concentrations, especially in the case of late foliar Zn application. Khan *et al.* (2010) reported that foliar application of zinc at reproductive growth stage increased grain and straw yield significantly in wheat. Foliar application of crop nutrients at latter stages will ensure better crop nutrition at anthesis and grain filling stage which in turn may result in increased grain weight. These results are in agreement with those of Soylu *et al*. (2005) who reported significant variations for 1000 grains weight for foliar application of boron. Similarly Kenbaev and Sade (2002) and Hosseini (2006) reported improvement in yield components for application of zinc. Moreover, zinc by its participation in the action of superoxide dismutase (SOD) enzyme, may contribute to drought stress tolerance (Bagci *et al.*, 2007).

Zn content and uptake by wheat grain

The concentration of Zn in wheat grain ranged from 46.5 to 63.0 ppm (Table 4). Skipping irrigation at grain filling stage treatment (T_4) under foliar applied different zinc concentrations showed significantly higher content of Zn in grain compared to other irrigation treatment with different size concentrations that were foliar sprayed. Consequently the uptake of Zn was higher in T_4 treatment compared to other treatments under different size concentrations which were foliar sprayed.

Economic performance:

The economic performance of different treatments is presented in Table 5. The highest gross return, gross margin and BCR (TK. 87713 ha^{-1}, Tk. 69257 ha^{-1} and 4.75, respectively) was recorded in T_4 Zn_3 concentration. The lowest gross return, gross margin and BCR (TK. 63360 ha^{-1}, Tk. 45044 ha^{-1} and 3.46, respectively) was found in T_2 Zn_0 combination.

Table 4. Zn concentration and uptake of wheat grain in different treatment

Treatment combination		Grain yield	Zn concentration	Zn concentration	Zn uptake by grain
Irrigation	Foliar application	(kg ha^{-1})	(ppm)	(%)	(kg ha^{-1})
T_1 = Regular irrigation	Zn_0 = Control	4921	46.5	0.0047	0.229
	Zn_1 = 0.02% Zn	5397	46.5	0.0047	0.251
	Zn_2 = 0.04% Zn	5588	48.8	0.0049	0.273
	Zn_3 = 0.06% Zn	5275	50.3	0.0050	0.265
T_2 = Skipping irrigation at CRI stage	Zn_0 = Control	3960	51.8	0.0052	0.205
	Zn_1 = 0.02% Zn	4300	54.8	0.0055	0.236
	Zn_2 = 0.04% Zn	4633	55.2	0.0055	0.256
	Zn_3 = 0.06% Zn	4449	60.8	0.0061	0.271
T_3 = Skipping irrigation at booting stage	Zn_0 = Control	4189	56.8	0.0057	0.238
	Zn_1 = 0.02% Zn	4544	57.3	0.0057	0.261
	Zn_2 = 0.04% Zn	4987	61.2	0.0061	0.305
	Zn_3 = 0.06% Zn	4881	61.0	0.0061	0.298
T_4 = Skipping irrigation at grain filling stage	Zn_0 = Control	4849	56.3	0.0056	0.273
	Zn_1 = 0.02% Zn	5129	56.7	0.0057	0.291
	Zn_2 = 0.04% Zn	5350	59.3	0.0059	0.317
	Zn_3 = 0.06% Zn	5482	63.0	0.0063	0.345

CRI = Critical Root Initiation

Table 5. Economic performance of wheat production was influenced by irrigation and application of Zinc.

Treatment combination		Grain yield ($kg\ ha^{-1}$)	Variable cost ($Tk\ ha^{-1}$)	Gross return ($Tk\ ha^{-1}$)	Gross margin ($Tk\ ha^{-1}$)	BCR on variable cost ($Tk\ ha^{-1}$)
Irrigation	Foliar application					
T_1 = Regular irrigation	Zn_0 = Control	4921	19190	78737	59547	4.10
	Zn_1 = 0.02% Zn	5397	19237	86356	67119	4.49
	Zn_2 = 0.04% Zn	5588	19283	89409	70125	4.64
	Zn_3 = 0.06% Zn	5275	19330	84394	65064	4.37
T_2 = Skipping irrigation at CRI stage	Zn_0 = Control	3960	18316	63360	45044	3.46
	Zn_1 = 0.02% Zn	4300	18363	68800	50437	3.75
	Zn_2 = 0.04% Zn	4633	18409	74133	55724	4.03
	Zn_3 = 0.06% Zn	4449	18456	71185	52729	3.86
T_3 = Skipping irrigation at booting stage	Zn_0 = Control	4189	18316	67022	48706	3.66
	Zn_1 = 0.02% Zn	4544	18363	72710	54347	3.96
	Zn_2 = 0.04% Zn	4987	18409	79788	61379	4.33
	Zn_3 = 0.06% Zn	4881	18456	78091	59635	4.23
T_4 = Skipping irrigation at grain filling stage	Zn_0 = Control	4849	18316	77584	59268	4.24
	Zn_1 = 0.02% Zn	5129	18363	82061	63698	4.47
	Zn_2 = 0.04% Zn	5350	18409	85600	67190	4.65
	Zn_3 = 0.06% Zn	5482	18456	87713	69257	4.75

§ Variable cost considered only fertilizer and irrigation cost.
Input prices ($Tk\ kg^{-1}$): Urea: 16; TSP: 25; MOP: 15; Gypsum: 15; Zinc sulphate: 140; Boric acid: 240. Single irrigation cost 874 Tk.
Out put price ($Tk\ kg^{-1}$): Wheat grain: 16.

Response function

A quadratic relationship was observed between grain yield of wheat and foliar application of zinc (Fig. 2). From the regression equation, the optimum dose of foliar application of zinc appeared as 0.046%. So foliar application of 0.04% Zn may be considered as the best suitable dose for grain yield of wheat.

Conclusion

It can be concluded that wheat plants grown by skipping irrigation with foliar application of zinc counteracted the adverse effect of water deficit on the yield, especially at later stages of growth and helped the plants grow successfully under these unfavorable conditions. According to the results of the experiment, using 0.04% zinc as foliar application increased grain yield compared to all other treatments.

References

Bagci, S. A., H. Ekiz, A. Yilmaz and I. Cakmak. 2007. Effects of zinc deficiency and drought on grain yield of field-grown wheat cultivars in Central Anatolia *J. Agron. & Crop Sci.* **193:** 198–206.

Bazwa, M. A. M. H. Choudhury and A. Sattar. 1993. Influence of different irrigations regimes on yield and yield components of wheat. *Pakistan J. Agric. Res.* **14**(4):361–365.

Cakmak, I. 2008. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant Soil.* **302:** 1–17.

Cakmak, I. 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. New Phytol. **146:** 185–205.

Cakmak, I. and V. R. omheld, 1997. Boron deficiency induced impairments of cellular functions in plants. *Plant Soil.* **193:**71–83.

Cakmak, I., H. Marschner and Bangert, F. (1989). Effect of zinc nutritional status on growth, protein metabolism and levels of indole-3-acetic acid and other phytohormones in bean (*Phaseolus vulgaris* L.). *J. Exp. Bot.* **40:**404–412.

Cheema, S. S., K. K. Dhingra and G. S. Gill. 1973. Effect of missing irrigations on the growth of dwarf wheat. *J. Res. Punjab Agric. Univ.* **10**(1):41–44.

Ducic, T., A. Polle. 2005: Transport and detoxification of manganese and copper in plants. *Braz. J. Plant Physiol.* **17:** 103–112.

Ekiz, H., S. A. Bagcı, A. S. Kıral, S. Eker, I. Gu¨ ltekin, A. Alkan and I. Cakmak. 1998. Effects of zinc fertilization and irrigation on grain yield and zinc concentration of various cereals grown in zinc-deficient calcareous soils. *J. Plant Nutr.* **21:** 2245–2256.

Goodman, B. A., and A. C. Newton. 2005. Effects of drought stress and its sudden relief on free radical processes in barley. *J. Sci. Food Agric.* **85:** 47–53.

Grotz, N. and M. L. Guerinot. 2006. Molecular aspects of Cu, Fe and Zn homeostasis in plants. Biochim. *Biophys. Acta.* **1763:** 595–608.

Hosseini, S.M. 2006. Zinc- Boron interaction effects on yield, yield components and chemical composition of wheat. The 18th World Congress of Soil Sci.

Kaya, C. and D. Higgs. 2002. Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. *Sci. Hortic.* **93:** 53–64.

Kenbaev B. and B. Sade. 2002. Response of field-grown barley cultivars grown on zinc-deficient soil to zinc application. *Comm. Soil Sci. Plant Anal.* **33**(3-4): 533–5544.

Khan S, K.J. Mirza, F. Anwar, M. Z. Abdin. 2010. Development of RAPD markers for authentication of Piper nigrum . Environment & International Journal of Science and Technology. **5:** 53–62.

Khan, H. R., G. K. McDonald and Z. Rengel. 2003: Zn fertilization improves water use efficiency, grain yield and seed Zn content in chickpea. *Plant Soil.* **249:** 389–400.

Ozturk L, MA Yazici, C Yucel, A Torun, C Cekic, A Bagci, H Ozkan, HJ Braun, Z Sayers, I. Cakmak. 2006. Concentration and localization of zinc during seed development and germination in wheat. *Physiol. Plant.* **128:** 144–152.

Pandey, N., G. C. Pathak and C. P. Sharma. 2006. Zinc is critically required for pollen function and fertilisation in lentil. *J. Trace Elem. Med. Biol.* **20:** 89–96.

Selote, D. S., S. Bharti and R. Khanna-Chopra. 2004. Drought acclimation reduces O_2-accumulation and lipid peroxidation in wheat seedlings. Biochem. Biophys. Res. Commun. **314:** 724–729.

Soylu S, B.Sade, A.Topalv, N. Akgun and S. Gezgin. 2005. Responses of irrigated durum and bread wheat cultivars to boron application in low boron calcareous Soil. *Turk. J. Agric.* **29:** 275–286.

Sultana, N., T. Ikeda and M. A. Kashem. 2001. Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in seawater-stressed rice. *Environ. Exp. Bot.* **46:** 129–140.

Thalooth, A.T., M.M. Tawfik and H. M. Mohamed. 2006. A Comparative Study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. *World J. Agril. Sci.* **2**(1): 37-46.

Wajid, A., A. Hussain, A. Ahmed, M. Rafiq, A.R. Goheer and M. Ibrahim. 2004. Effect of sowing date and plant density on growth, light interception and yield of wheat under semi arid condition. Intl. *J.Agric. Biol.* **6:** 1119–1123.

Wang, H., and J. Y. Jin. 2005: Photosynthetic rate, chlorophyll fluorescence parameters, and lipid peroxidation of maize leaves as affected by zinc deficiency. *Photosynthetica*. **43:** 591–596.