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Full Research Article

Effect of Foliar Application of Zinc on Yield of Wheat Grown under Water Stress Condition

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Abstract

A field experiment was carried out to study the effect of foliar application of zinc on growth and yield of wheat (BARI gom-25) grown under water stress condition in the farm of the Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 under the AEZ 28 (Madhupur Tract) on November, 2013 to March, 2014. The experiment was designed in randomized complete block for factor A (represented as irrigation), with factor B (represented as Zn application) a split plot on factor A with 16 treatments combination comprising 4 irrigation treatments regular irrigation, skipped irrigation at crown root initiation, skipped irrigation at booting stage and skipped irrigation at heading and flowering stage of growth) and four application of zinc i.e. one as soil application (Zn_{Soil}: 2 kg ha^{-1}) and three as foliar application (Zn_1: 0.02%, Zn_2:0.04% and Zn_3: 0.06% of zinc). Zinc Sulphate Monohydrate ($ZnSO_4.H_2O$) was used as a source of Zn. Water at crown root initiation stage had the most negative effect on growth and yield of wheat. The interaction effect of irrigation and foliar application of zinc significantly influenced the yield and yield components of wheat. The highest yield (3.57 t ha^{-1}) was recorded in the combined treatment Zn_2 that received skipping irrigation at flowering and heading stage along with 0.04% foliar application of zinc. Thus, foliar application of zinc played a major role on yield and yield components of wheat under water stress condition.

1. Introduction

Wheat is an important cereal crop and also serves as a staple food for many countries of the World. It is the major source of plant based human nutrition and a part of daily dietary need in one form or the other. Besides its tremendous significance, average yield in Bangladesh is far below than developed countries (FAO, 2013). Major yield limiting factors includes delayed sowing, high weeds infestations, and water shortage at critical growth stages and non-judicious fertilizers use. Several studies revealed that drought stress along with Zn deficiency is the major causes of yield declining of wheat in our country.

Water deficit is the primary limiting factor for crop production under arid and semi-arid conditions (Hussain et al., 2004). It affects nearly all the plant growth processes. When considering irrigation scheduling for a crop, it is wise to understand the critical growth stages for water stress and the water requirements of the crop in order to achieve maximum yield and maintaining adequate soil moisture conditions during moisture-sensitive stages of growth. So, irrigation water may be saved if soil water could be depleted to a greater extent during certain growth stages without affecting yield.

Grain yield in wheat and other cereals is the end result of a number of contributing and inter-related components such as number of grains ear^{-1}, number of ears unit area^{-1} and mean grain mass. The magnitude of each component is determined by processes such as tillering, ear development and grain filling at different stages of crop development. Karim et al. (2000) investigated the effect of water stress at reproductive stage on grain development and yield responses of wheat and found that 94% of tillers of irrigated plants produced ears, compared to 79% of the stressed plants. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated plants (Karim et al., 2000).

Wajid et al. (2002) reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. The impact of soil moisture deficit on crop yield depends on the particular physiological stage of the crop, and the most sensitive stage can show region-by-region variations (Singh et al., 1991). These differences relate to regional variability in environment and information specific to a region is needed for developing and refining limited irrigation schemes applying water to crops at critical growth stages where the crop may utilize the water efficiently.

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

Foliar application of Zn leads to increase the grain yield and protein percentage in seed of wheat (Jiang and Huang, 2002). Many researchers reported that increasing in agronomic traits is caused by foliar application of Zn. Jiang and Huang (2002) reported that the yield and its components of wheat are increased due to the effects of zinc on the amount of chlorophyll and concentration of abscisic acid. The increase of chlorophyll increases yield through the increase of photosynthesis. Sultana et. al. (2012) found that foliar application of zinc and irrigation significantly influences the growth and yield contributing characters of wheat. Zinc is also involved in key metabolic processes such as respiration, photosynthesis and assimilation of some major nutrients. Zinc plays an important role in enzymes activation as well.

Drought is one of the factors, which threatens the agricultural products in most parts of the World (Abolhasani and Saeidi, 2004). Drought stress is a serious abiotic stress factor limiting crop production in Bangladesh. Zinc plays a more important role in adjusting stomata and ionic balance in plant system to decrease stresses caused by water shortage (Karam et al., 2007; Babaeian et al., 2010). Moreover, zinc by its participation in the action of superoxide dismutase (SOD) enzyme, may contribute to drought stress tolerance ((Bakalova et al., 2004; Csiszar et al., 2005). Under drought stress, plant roots cannot absorb micronutrients (Heidarian et al., 2011), and foliar spraying of micronutrients is useful and more influential as compared to soil application (Narimani et al., 2010). Although plants needa little amount of zinc, if sufficient amount of this element is not available, plants suffer physiological stresses resulted from inefficiency of various enzyme systems and other metabolic functions related to zinc (Baydar and Erbas, 2005; Ehdaie et al., 2008).

With conceiving the above scheme in mind, the present research work has been undertaken in order to evaluate the effect of foliar application of Zn on water stress tolerance in wheat and find out the optimum dose of zinc for higher yield of wheat under water stress condition.

2. Materials and Methods

A field experiment was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2013 to March, 2014 to study the effects of foliar application of zinc and water stress condition on the growth and yield of wheat. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28). The physical and chemical properties of initial soils are presented in Table 1. The experiment was designed in randomized complete block for factor A (irrigation), with factor B (Zn application) a split plot on factor A with 16 treatment combination comprising 4 irrigation treatments i.e. T_1: regular irrigation (depending on shortage of soil moisture), T_2: skipped irrigation at crown root initiation, T_3: skipped irrigation at booting stage and T_4: skipped irrigation at heading and flowering stage of growth and four application of zinc i.e. one as soil application (Zn_{Soil}: 2 kg ha^{-1}) and three as foliar application (Zn_1:0.02%, Zn_2:0.04% and Zn_3: 0.06% of zinc). BARI Gom-25 was used as a test crop. Zinc Sulphate Monohydrate ($ZnSO_4.H_2O$) was used as a source of Zn. On the other hand, urea, TSP, MoP, gypsum and Boric acid was used as a source of N, P, K, S and B, respectively. All TSP, MoP, gypsum, boric acid and half of urea were applied at the final land preparation and the remaining half of urea was applied

Table 1: Physical and chemical properties of the initial soil samples

Characteristics	Value
Textural class	Silty clay
pH	6.0
Bulk density (g cc^{-1})	1.45
Particle density (g cc^{-1})	2.52
Organic matter (%)	1.18
Total N (%)	0.06
Available P (ppm)	21.0
Exchangeable K (meq 100 g^{-1} soil)	0.12
Available S (ppm)	24.0
Available Zn	2.12 µg g^{-1} soil

before booting stage. Fertilizer was applied based on BARC fertilizer recommendation guide-2012. The harvesting of wheat crop was done on 23rd March, 2014 at full maturity stage. At harvest, ten plants were selected randomly from each plot for collecting data of different plant characters and yield attributes of wheat. Data on yield and yield contributing characters i.e. plant height (cm), spike length (cm), number of grain spike^{-1}, 1000 grain weight (g) and grain yield (t ha^{-1}) were recorded as per treatments. Data on yield and yield contributing parameters were recorded as per treatments and statistically analyzed with the help of statistical package MSTAT-C and mean separation was tested by Least Significant Difference (LSD).

3. Results and Discussion

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

Foliar application of zinc had a significant influence on the growth and yield contributing characteristics of wheat (Table 2). The highest plant height (80.29 cm) was obtained from Zn_2 (0.04%) where the lowest plant height (75.70 cm) was obtained from Zn_1 (0.02%) treatment. In case of spike length, the highest spike length (11.52 cm) was achieved from Zn_2 (0.04%) treatment. The lowest spike length (10.19 cm) was obtained from Zn_1 (0.02%) treatment which was significantly different from all other treatments. For number of grain spike^{-1}, the maximum number of grain spike^{-1} (43.22) was observed in Zn_2 (0.04%) treatment which was statistically similar with Zn_{Soil} (2 kg ha^{-1}) treatment. On other hand, the lowest number of grain spike^{-1} (40.09) was obtained from Zn_1 (0.02%) treatment. The highest 1000 grain weight (52.64 g) was obtained from Zn_2 (0.04%) and the lowest (49.69 g) was obtained from Zn_1 (0.02%) treatment. For gain yield of wheat, Zn plays a significant role. The grain yield of wheat increased significantly due to application of zinc up to 0.04%. The highest grain yield (3.56 t ha^{-1}) was obtained from Zn_2 (0.04%) treatment and the lowest grain yield (2.92 t ha^{-1}) was found in Zn_1 (0.02%) treatment.Mekkei and El-HagganEman (2010) obtained the similar results and they observed that foliar application of Zn significantly increase the plant height (cm), spike length (cm), number of grain spike^{-1}, 1000 grain weight (g) and grain yield (t ha^{-1}) of wheat.

Table 2: Effect of foliar application of zinc on the growth and yield of wheat

Zinc	Plant height (cm)	Spike length (cm)	No. of grain spike^{-1}	1000 grain wt (g)	Yield (t ha^{-1})
Zn_{Soil}	78.23^b	11.03^b	41.68^a	51.21^{ab}	3.22^b
Zn_1	75.70^c	10.19^c	40.09^c	49.69^b	2.92^c
Zn_2	80.29^a	11.52^a	43.22^a	52.64^a	3.56^a
Zn_3	78.53^b	11.02^b	41.70^b	50.93^b	3.25^b

Zn_{Soil}: 2 kg ha^{-1}; Zn_1: 0.02%; Zn_2: 0.04%; Zn_3: 0.06% of zinc

3.2. Effect of irrigation on the growth and yield of wheat

Irrigation is a major constrain of lower wheat yield in Bangladesh. Irrigation has a significant effect on the growth and yield contributing characters of wheat (Table 3). The plant height of wheat was significantly influenced by irrigation. It was observed that the highest plant height (79.70 cm) was achieved from the treatment T_1 (regular irrigation) which was statistically similar with T_4 (skipping irrigation at flowering and heading stage) treatment and the lowest plant height (76.22 cm) was obtained from T_2 (skipping irrigation at CRI stage) treatment. For spike length, the highest spike length (11.34 cm) was obtained from T_4 (skipping irrigation at flowering and heading stage) treatment which was statistically similar with T_1 (regular irrigation) and T_3 (skipping irrigation at booting stage) treatment. The lowest spike length (09.05 cm) was obtained from T_2 (skipping irrigation at CRI stage) treatment. In case of number of grain spike^{-1}, the highest number of grain spike^{-1} (42.45) was found in T_4 (skipping irrigation at flowering and heading stage) treatment which was statistically identical with T_1 and T_3 treatments and the lowest number of grain spike^{-1} (39.11) was received from T_2 (skipping irrigation at CRI stage) treatment. The highest 1000 grain weight (51.64 g) was observed with T_4 (skipping irrigation at flowering and heading stage) treatment which was statistically similar with T_1 and T_3 treatments. On the other hand, the lowest 1000 grain weight (50.12 g) was found in T_2 (skipping irrigation at CRI stage) treatment. The yield of wheat significantly influence by irrigation that was applied at different condition according to the experimental design. The highest wheat grain yield (3.39 t ha^{-1}) was obtained with T_4 (skipping irrigation at heading and flowering stage) treatment, which was statistically similar with T_1 (regular irrigation) treatment. The lowest yield (2.43 t ha^{-1}) was obtained from T_2 (skipping irrigation at crown root

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

Irrigation	Plant height (cm)	Spike length (cm)	No. of grain spike^{-1}	1000 grain wt (g)	Yield (t ha^{-1})
T_1	79.70^a	11.04^a	41.91^a	51.47^a	3.25^a
T_2	76.22^c	9.05^b	39.11^b	50.12^b	2.43^c
T_3	78.04^b	11.02^a	42.22^a	51.51^a	3.04^b
T_4	79.58^a	11.34^a	42.45^a	51.64^a	3.39^a

T_1: Regular irrigation; T_2: Skipped irrigation at crown root initiation; T_3: Skipped irrigation at booting stage; T_4: Skipped irrigation at heading and flowering stage of growth initiation stage) treatment. This finding revealed that crown root initiation stage was the most critical stage for irrigation and its omission at this stage reduced the grain yield of 33 to 42%. Chauhan et al., 2008, Hussain, 1996; Akram, 2000; Wisal et al., 2006 found the similar result and they concluded that application of irrigation significantly influence the growth and yield of wheat.

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

Significant variation was found in the interaction effect of irrigation and foliar application of zinc on the growth and yield of wheat (Table 4). The highest plant height (81.20 cm) was achieved from the treatment combination of T_4Zn_2 which was statistically similar with T_1Zn_3 and T_3Zn_2 treatments combination and the lowest plant height (73.12 cm) was obtained from the treatment combination of T_2Zn_1 treatment. For spike length, the highest spike length (12.03 cm) was achieved from T_4Zn_2 treatment and the lowest spike length (10.05 cm) was obtained from T_2Zn_1 treatment that was statistically similar with T_1Zn_1 treatment. In case of number of grain spike^{-1}, significant variations were observed due to the combined effects of foliar application of Zn and irrigation. The highest number of grain spike^{-1} (43.50) was obtained from T_4Zn_2 treatment combination which was statistically similar with T_1Zn_2 treatment combination and the lowest number of grain spike^{-1} (39.11) was found in T_2Zn_1 treatment. In case of 1000 grain weight, the highest 1000 grain weight (53.29 g) was achieved fromT_4Zn_2 treatment combination which was statistically similar with T_1Zn_2 treatment combination. On the other hand, the lowest 1000 grain weight (49.10 g) was observed in T_2Zn_1 treatment combination that was statistically similar with T_2Zn_3 treatment combination. Interaction effects of foliar application of zinc and irrigation has a greater influence on the grain yield of wheat. The highest grain yield (3.57 t ha^1) was recorded in skipping irrigation at heading and flowering stage (T_4) with 0.04% foliar application of zinc (Zn_3) i.e. T_4Zn_2 treatment combination, which was statistically similar with T_1Zn_2 treatment combination. On the other hand, the lowest grain yield (2.14 t ha^{-1}) was recorded in skipping irrigation at CRI stage (T_2) with 0.02% foliar application of zinc (Zn_1) i.e. T_2Zn_1 treatment combination.

Table 4: Interaction effect zinc and irrigation on the growth and yield of wheat

Treat-ments	Plant height (cm)	Spike length (cm)	No. of grain spike^{-1}	Test wt, (g)	Yield (t ha^{-1})
T_1Zn_{Soil}	79.52^{bcd}	11.28^{bc}	42.14^{bcd}	52.13^{b}	3.24^{bc}
T_1Zn_1	77.13^{defg}	10.14^{d}	40.18^{cd}	50.12^{c}	2.40^{bcde}
T_1Zn_2	79.49^{bcd}	11.55^{b}	43.15^{a}	53.11^{a}	3.45^{a}
T_1Zn_3	80.81^{a}	11.21^{bc}	42.19^{bcd}	51.22^{bc}	3.20^{bc}
T_2Zn_{Soil}	75.13^{gh}	10.25^{cd}	40.13^{cd}	50.09^{c}	2.24^{de}
T_2Zn_1	73.12^{h}	10.05^{d}	39.11^{d}	49.10^{d}	2.14^{e}
T_2Zn_2	79.36^{bcd}	10.81^{bcd}	41.13^{bcde}	52.14^{bc}	2.94^{cd}
T_2Zn_3	77.27$^{d\text{-}g}$	10.30^{cd}	40.06^{cd}	49.15^{d}	2.38^{cde}
T_3Zn_{Soil}	79.31^{bcd}	11.06^{bcd}	42.16^{bcd}	51.47^{bc}	3.11^{bcd}
T_3Zn_1	76.51^{efg}	10.29^{cd}	40.53^{cd}	50.51^{c}	3.07^{bcd}
T_3Zn_2	81.11^{a}	11.67^{b}	42.30^{bcd}	52.00^{bc}	3.34^{bc}
T_3Zn_3	78.19$^{c\text{-}f}$	11.05^{bcd}	42.07^{bcd}	52.04^{bc}	3.30^{bc}
T_4Zn_{Soil}	78.96^{cde}	11.53^{b}	42.30^{bcd}	51.16^{bc}	3.30^{bc}
T_4Zn_1	76.03^{fg}	10.30^{cd}	40.53^{cd}	50.12^{c}	3.01^{bcde}
T_4Zn_2	81.20^{a}	12.03^{a}	43.50^{a}	53.29^{a}	3.57^{a}
T_4Zn_3	78.66^{bcde}	11.51^{b}	42.48^{bcd}	51.33^{bc}	3.31^{bc}

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

3.4. Zn content in wheat grain

The concentration of Zn in wheat grain ranged from 46.15 to 63.96 ppm (Table 5). Skipping irrigation at heading and flowering stage (T_4) along with 0.04% foliar application of Zn showed significantly higher contentof Zn in grain compare to other treatment.

3.5. Effect of foliar application of zinc and irrigation on post-harvest soil

Data on Table 6 showed the interaction effect of irrigation and

Table 5: Zinc content of wheat grain

Treatments	Zn concentration (ppm)	Level of significance at p=0.05
T_1Zn_{Soil}	50.00	a
T_1Zn_1	46.15	
T_1Zn_2	50.8	
T_1Zn_3	50.01	
T_2Zn_{Soil}	56.13	b
T_2Zn_1	50.08	
T_2Zn_2	57.31	
T_2Zn_3	56.10	
T_3Zn_{Soil}	54.51	b
T_3Zn_1	51.21	
T_3Zn_2	54.80	
T_3Zn_3	51.23	
T_4Zn_{Soil}	61.31	c
T_4Zn_1	52.07	
T_4Zn_2	63.96	
T_4Zn_3	62.01	

Table 6: Effect of foliar application of zinc and irrigation on post-harvest soil

Treatments	pH	Organic matter	Total N (%)	Available P (ppm)	Exchangeable K (meq 100 g^{-1} soil)	Available S (ppm)	Available Zn (μg g^{-1} soil)
T_1Zn_{Soil}	6.01	1.15	0.05	23.12	0.20	24.12	2.30
T_1Zn_1	6.05	1.13	0.04	22.65	0.19	23.52	2.18
T_1Zn_2	6.00	1.10	0.05	21.58	0.19	22.65	2.12
T_1Zn_3	6.03	1.12	0.04	21.50	0.18	22.13	2.16
T_2Zn_{Soil}	6.05	1.09	0.04	25.65	0.21	24.18	2.13
T_2Zn_1	6.00	1.10	0.05	24.12	0.18	25.15	2.10
T_2Zn_2	6.08	1.12	0.05	23.04	0.18	24.78	2.08
T_2Zn_3	6.10	1.12	0.04	23.61	0.19	23.98	2.07
T_3Zn_{Soil}	6.08	1.10	0.04	24.18	0.22	23.12	2.21
T_3Zn_1	6.02	1.05	0.05	20.09	0.21	22.36	2.18
T_3Zn_2	6.12	1.09	0.04	19.18	0.22	22.78	2.15
T_3Zn_3	5.98	1.08	0.03	19.10	0.21	22.12	2.11
T_4Zn_{Soil}	5.96	1.15	0.03	20.78	0.21	21.96	2.14
T_4Zn_1	6.00	1.10	0.05	19.78	0.20	22.15	2.11
T_4Zn_2	6.01	1.08	0.05	19.80	0.19	21.09	2.08
T_4Zn_3	6.01	1.08	0.04	19.17	0.20	21.06	2.09
Level of significance	NS	NS	NS	**	**	**	NS
CV%	3.79	6.29	10.01	8.61	7.89	7.12	6.78

foliar application of zinc on post harvest soil. Foliar application of zinc and irrigation had a significant effect on phosphorus, potassium and sulphur content of post harvest soil. On the other hand, there is no significant effect on pH, organic matter, Total N and available Zn content in post harvest soil.

4. Conclusion

Yield and yield contributing characters of wheat are significantly affected by foliar application of Zn under different water stress condition. Foliar application of zinc @ 0.04% along with skipping irrigation at heading and flowering stage are the best combination for growth and grain yield of wheat.

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