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EFFECT OF FOLIAR APPLICATION OF IRON AND ZINC ON NUTRIENT UPTAKE AND GRAIN YIELD OF WHEAT UNDER DIFFERENT IRRIGATION REGIMES

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Abstract

A field experiment was carried out to study the zinc-iron relationship in wheat (BARI Gom-26) plant grown under water stress condition in the field near net house of Soil Science Division, BARI, Joydebpur, Gazipur, during November 2015 to March 2016. The experiment was designed in a split plot on sixteen treatments comprising four irrigation treatments (regular irrigation, stopping irrigation at crown root initiation, stopping irrigation at booting stage and stopping irrigation at grain filling stage) and four foliar application of zinc and iron (control, 0.05% of zinc, 0.05% of iron and 0.05% of zinc +0.05% of iron). Zinc sulphate monohydrate ($ZnSO_4$. H_2O) and ferrous sulphate ($FeSO_4$. H_2O) were used as a source of Zn and Fe. The highest yield (4.01 t ha^{-1}) was recorded in stopping irrigation at grain filling stage which was identical with regular irrigation. Water stress at crown root initiation stage had the most negative effect on growth and yield. Foliar application of zinc and iron played a major role on yield and yield components of wheat at later stages of growth. The results obtained from the present research showed that iron and zinc spray increased grain yield and quality of wheat and improved the effects caused by drought stress.

Keywords: Wheat, foliar application, iron, zinc, yield.

Introduction

Increasing the zinc and iron concentration in food crop plants, resulting in better crop production and improved human health is an important global challenge. Micronutrient malnutrition, particularly Zn and Fe deficiency, affects over three billion people worldwide (Bouis, 2007). Producing micronutrient enriched cereals via biofortification, either agronomically or genetically, and improving Fe and Zn bioavailability are considered promising and cost effective approaches for diminishing malnutrition (Distelfeld *et al.*, 2007). Foliar fertilizer sprays have

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proved to be a sustainable, effective and low cost strategy to improve Fe and Zn levels in edible portions of staple food crops (Ling *et al.*, 2013).

Foliar spraying is a new method for crop feeding in which micronutrients in form of liquid are sprayed on leaves (Nasiri *et al.*, 2010). Foliar application of microelements is more beneficial than soil application. Since application rates are lesser as compared to soil application, same application could be obtained easily and crop reacts to nutrient application immediately (Zayed *et al.*, 2011). Foliar spraying of microelements is very helpful when the roots cannot provide necessary nutrients (Babaeian *et al.*, 2011). Moreover, soil pollution would be a major problem by micronutrients through soil application. Narimani *et al.* (2010) reported that microelements foliar applications improve the effectiveness of macronutrients. It has been found that microelements foliar application is in the same level and even more influential as compared to soil application. Resistance to different stresses will be increased by foliar application of micronutrients (Ghasemian *et al.*, 2010).

Plant nutrition has an important role in raising level of plants tolerance against a variety of environmental stresses and in this regard, iron and zinc are the most important essential micronutrients in plant nutrition (Baybordy and Mamedov, 2010). Metal ions such as iron, zinc, copper, manganese and magnesium as a cofactor participate in construction of many antioxidant enzymes and results of Cakmak *et al.* (2010) studies showed that under micronutrients deficiency conditions, antioxidant enzyme activities decrease and thus increases the sensitivity of plants to environmental stresses. Thalooth *et al.* (2006) reported that foliar application of zinc sulfate in water stress conditions had a positive effect on growth, yield and yield component of mungbean plant. Experimental result of Odeley and Animashaun (2007) also showed that foliar application of micronutrients increased the soybean yield, quality, resistance to pests and diseases and drought stress. Therefore, the micronutrients such as iron, copper, boron, zinc and manganese have many contributions in cell wall formation and plant resistance to pests and diseases and environmental stresses.

The micronutrients play an important role in increasing crop yield. Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Asad and Rafique, 2000). Zinc and Fe are involved in detoxification of reactive oxygen specious (ROS) and they are also important for reducing the production of free radicals by superoxide radical producing enzymes (Cakmak, 2000). Iron plays a key role in biological redox system, enzyme activation and oxygen carrier in nitrogen fixation (Weisany *et al.*, 2013). Previously, many reports have evaluated the response of wheat to micronutrients (soil or foliage) application but little information is available regarding combined application of micronutrients. This experiment was conducted to evaluate the role of mixed application of micronutrients in improving wheat performance under water different irrigation regimes.

Materials and Methods

A field experiment was carried out in the field near net house of Soil Science Division of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during November, 2015 to March, 2016 with a view to studying zinc-iron relationship in wheat plant grown under water stress condition. The experiment was arranged as split plot based on randomized complete block design with three replications. Main plots included irrigation period with three levels (irrigation at CRI stage, booting stage and grain filling stage) and sub-plots were treatments of Zn, Fe and Zn+Fe foliar application and control (water foliar application). BARI Gom-26 variety was tested. Each split plot was 2 m^2 in size with 0.5 m border distance.

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 $100g^{-1}$			%	µg g^{-1}					
Result	Sandy clay loam	7.7	1.06	6.5	2.2	0.21	0.056	3.6	29.7	0.20	2.4	24.6	3.46
Critical level	-	Alkaline	-	2.0	0.5	0.12	-	10.0	10	0.2	0.2	4.0	0.6

Table 2. Moisture status of soil at different days during the study

Treatment	Moisture status (%) of 0-15 cm depth of soil						
	Initial	18 DAS	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS
T_1 = Control (regular irrigation)	17	15.3	18.1	15.1	18.3	20.5	10.6
T_2 = Skipping irrigation at CRI stage	17	13.4	15.5	12.5	10.3	15.1	9.50
T_3 = Skipping irrigation at booting stage	17	15.5	13.3	11.7	13.2	14.6	8.40
T_4 = Skipping irrigation at heading & flowering stage	17	14.3	15.6	13.5	13.5	11.0	6.50

There were sixteen treatment combinations comprising four irrigation treatments, i.e T_1: full irrigation (unstressed); irrigation at crown root initiation stage, booting stage and grain filling stage, T_2: stressed by stopping one irrigation at crown root initiation stage, T_3: stressed by stopping one irrigation at booting stage, T_4: stressed by stopping one irrigation at grain filling stage and four levels of foliar sprays are F_1: control (foliar application of distilled water), F_2: foliar application of 0.05% of Zn, F_3: foliar application 0.05% of Fe and F_4: foliar application of 0.05% of Zn and 0.05% of Fe. Foliar application of zinc and iron was done during the stopping irrigation at respective days. Zinc sulphate monohydrate ($ZnSO_4$. H_2O) and ferrous sulphate ($FeSO_4$. H_2O) were used as a source of zinc and iron. Urea, TSP, MP, gypsum and boric acid were used as a source 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. The crops were harvested on 04 March 2016 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 wgt, yield (t ha^{-1}) were recorded. Plants of 1 m^2 area from each plot were selected for data collection. Soil moisture data collected at different growth stages of wheat are shown in Table 2. Weather data during the crop growth period are presented on Fig 1. 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). Moisture content in soil was calculated by using the following formula.

$$\text{Soil Moisture (\%)} = \frac{\text{Wet soil (g) - Dry soil (g)}}{\text{Dry soil (g)}} \times 100$$

Methods of chemical analysis

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). The soil was found to be Alkaline. Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode. Organic carbon was determined by the wet oxidation method. Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were determined by NH_4OAc extractable method, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with $BaCl_2$.

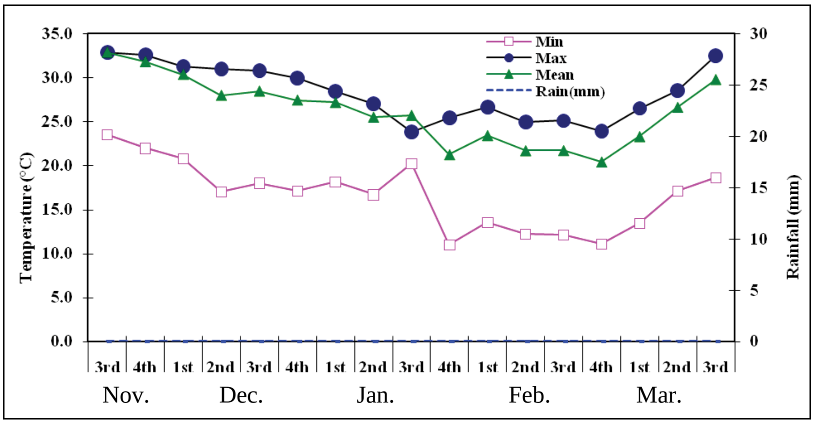

Figure 1. Rainfall, minimum, maximum and mean air temperature during growing period.

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 (4.01 t ha^{-1}) was obtained in T_4 treatment (stopping irrigation at grain filling stage) which was identical with T_1 treatment (regular treatment). The lowest yield (3.02t ha^{-1}) was obtained from stopping 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. 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 and iron

The effect of foliar application of zinc and iron on the grain yield and yield components of wheat has been shown in (Table 3). Foliar application of zinc and iron played a significant role on the yield and yield components of wheat. The highest grain yield (4.02 t ha^{-1}) was obtained by using (Fe+Zn) treatment. Due to the enzymatic activity enhancement, microelements effectively increased photosynthesis and translocation of assimilates to the seed. Foliar application of Fe and Zn increased grain yield and protein content (Seilsepour, 2007). Chaudry *et al.* (2007) reported that micronutrients (Zn, Fe, B) significantly increased the wheat yield over control when applied in single and in combination, along with basal dose of NPK, whilst Mandal *et al.* (2007) noticed significant optimistic

Table 3. Main effect of irrigation and foliar application of Zn and Fe 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						
T_1 = Control (regular irrigation)	72.7	10.4	46.4	51.8	400a	4.00a
T_2 = Stopping irrigation at CRI stage	68.2	9.80	37.2	42.1	302b	3.02b
T_3 = Stopping irrigation at booting stage	69.7	10.3	43.2	45.6	343ab	3.43ab
T_4 = Stopping irrigation at Grain filling stage	73.9a	10.3a	46.0	51.8	401a	4.01a
Foliar application						
F_1 = Control	68.1c	9.5d	38.9	45.6	323c	3.23c
F_2 = 0.05% Zn	71.5b	10.5b	43.7	48.4	373ab	3.73ab
F_3 = 0.05% Fe	70.0bc	10.0c	41.7	45.8	348bc	3.48bc
F_4 = 0.05% Zn + 0.05% Fe	75.0a	10.9a	48.4	51.5	402a	4.02a

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$) by DMRT.

Table 4. Interaction effect of irrigation and foliar application of Zn and Fe on yield and yield components of wheat

Treatment combination		Plant height (cm)	Spike length (cm)	No of grain spike^{-1}	1000 grains wt. (g)	Grain wt. m^{-2} (g)	Grain yield (t ha^{-1})
Irrigation	Foliar application						
T_1 = Control (regular irrigation)	F_1 = Control	69.4	9.81	40.8	50abcd	373abc	3.73abc
	F_2 = 0.05% Zn	73.0	10.71	47.9	52abc	413ab	4.13ab
	F_3 = 0.05% Fe	70.7	10.41	45.4	49abcd	368abc	3.68abc
	F_4=0.05%Zn+0.05%Fe	77.6	10.82	51.4	56a	447a	4.47a
T_2 = Skipping irrigation at CRI stage	F_1 = Control	65.9	8.98	35.2	39d	267c	2.67c
	F_2 = 0.05% Zn	68.6	10.24	36.8	42cd	311bc	3.11bc
	F_3 = 0.05% Fe	65.7	9.83	36.1	43bcd	296bc	2.96bc
	F_4 = 0.05% Zn+0.05%Fe	72.7	10.34	40.5	44bcd	333bc	3.33bc
T_3 = Skipping irrigation at booting stage	F_1 = Control	65.7	9.56	39.8	43bcd	294bc	2.94bc
	F_2 = 0.05% Zn	70.4	10.68	43.0	46abcd	359abc	3.59abc
	F_3 = 0.05% Fe	70.1	9.97	41.8	43bcd	341abc	3.41abc
	F_4=0.05%Zn+0.05% Fe	72.4	11.13	48.1	50abcd	379abc	3.79abc
T_4 = Skipping irrigation at grain filling stage	F_1 = Control	71.3	9.60	39.6	50abcd	359abc	3.59abc
	F_2 = 0.05% Zn	73.8	10.40	47.0	53ab	410ab	4.10ab
	F_3=0.05%Fe	73.4	9.85	43.8	48abcd	387abc	3.87abc
	F_4 = 0.05% Zn+0.05%Fe	77.2	11.17	53.6	56a	449a	4.49a
CV%		2.93	2.88	3.83	5.83	7.42	7.42

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$) by DMRT.

Table 5. Concentration of Zn and Fe in wheat grain and their uptake as influenced by the interaction of irrigation and foliar application of Zn and Fe

Treatment combination		Grain yield	Concentration				Fe uptake by grain	Zn uptake by grain
			Fe	Zn	Fe	Zn		
Irrigation	Foliar application	(kg ha^{-1})	(ppm)		(%)		(kg ha^{-1})	
T_1 = Control (regular irrigation)	F_1= Control	3730	82.19	90.5	0.0082	0.0090	0.307	0.337
	F_2 = 0.05% Zn	4130	83.88	94.7	0.0084	0.0095	0.346	0.391
	F_3 = 0.05% Fe	3680	84.74	97.8	0.0085	0.0098	0.312	0.360
	F_4=0.05%Zn + 0.05%Fe	4470	87.12	112.9	0.0087	0.0113	0.389	0.505
T_2 = Skipping irrigation at CRI stage	F_1= Control	2670	76.21	89.5	0.0076	0.0090	0.203	0.239
	F_2= 0.05% Zn	3110	80.53	91.7	0.0081	0.0092	0.250	0.285
	F_3 = 0.05% Fe	2960	78.32	92.4	0.0078	0.0092	0.232	0.274
	F_4=0.05%Zn + 0.05%Fe	3330	82.13	99.5	0.0082	0.0100	0.273	0.331
T_3 = Skipping irrigation at booting stage	F_1= Control	2940	77.03	88.7	0.0077	0.0089	0.226	0.261
	F_2 = 0.05% Zn	3590	90.98	81.6	0.0091	0.0082	0.327	0.293
	F_3 = 0.05% Fe	3410	79.52	92.4	0.0080	0.0092	0.271	0.315
	F_4=0.05%Zn + 0.05%Fe	3790	89.93	95.5	0.0090	0.0096	0.341	0.362
T_4 = Skipping irrigation at grain filling stage	F_1= Control	3590	90.30	80.7	0.0090	0.0081	0.324	0.290
	F_2 = 0.05% Zn	4100	91.52	85.9	0.0092	0.0086	0.375	0.352
	F_3 = 0.05% Fe	3870	93.46	95.3	0.0093	0.0095	0.362	0.369
	F_4=0.05%Zn + 0.05% Fe	4490	101.80	116.2	0.0102	0.0116	0.457	0.522

interaction among physiological stages of wheat growth and fertilizer treatments. Bameri *et al.* (2012) showed that foliar micronutrient application (Fe, Zn, and Mn) significantly improved the plants height, number of spike per plant, number of grain per spike, 1000-grain weight, grain yield, biological yield and harvest index. Application of Fe and Zn alone or combination had positive effect on grain yield and its components. Zain *et al.* (2015) showed that the application of micronutrients (Fe, Zn and Mn) substantially improved plant height, spike length cm, spikelets per spike, grains per spike, 1000-grain weight, number of tillers square meter, grain yield, biological yield and harvest index of wheat. Zayed *et al.* (2011) announced that due to the synergistic effect, zinc + iron treatment as compared to Zn treatment and Fe treatment was more helpful in rice. Kobraee *et al.* (2011) claimed that zinc and iron application at the same time could be lead to higher dry matter and seed yield as compared to using them separately. Foliar application with micronutrients (Fe, B and Zn) might be due to their critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activates and thus their importance in achieving higher yields (Salih, 2013). Habib (2012) obtained significant increase in 1000-kernels weight when Zn and Zn+Fe supplied on foliage at grain filling period of wheat in comparison with Fe supplement without affecting grain numbers per spike. Zeidan *et al.* (2010) recorded significant increase in all grain yield parameters and straw yield when Zn and Fe were sprayed on foliage at tillering and booting stage.

Interaction effects of irrigation and foliar application of zinc and iron

The interaction effect between irrigation and foliar application of zinc and iron on the grain yield and yield components of wheat was statistically significant (Table 4). The highest weight of 1000 seed (56 g) was recorded in T_4 treatment (stopping irrigation in grain filling stage) with a mixture of zinc and iron which was statistically identical to T_1 treatment (regular irrigation). The highest yield (4.49 t/ha) was recorded on T_4 treatment (stopping irrigation at grain filling stage with foliar spray of zinc and iron), which was followed by T_1 treatment (regular irrigation with foliar spray of zinc and iron), but the variation was non-significant. Stopping irrigation at crown root initiation of growth caused the reduction in all yield components and grain yield. The lowest grain yield (2.67 t ha^{-1}) was recorded from T_2 treatment (stopping irrigation at crown root initiation stage). This might be due to disturbance of crown root development which decreased the grain yield significantly. Foliar application of zinc and iron at grain filling stage was more effective in alleviating the adverse effect of water deficit on grain yield. Many current and past researches pointed soil and/or foliage supplied Zn and Fe can increase the accumulation of Zn and Fe in wheat grain, respectively (Kutman *et al.*, 2010; Habib, 2012; Kutman *et al.*, 2012). Micronutrients fertilizer when applied at milking dough stage of grain increase the mineral contents of grain and improved its nutritional quality (Zhang *et al.*, 2010). Translocation of nutrients from the old to young leaves and leaves or stem to grains occur through phloem transport system and translocation ranges from utilization to storage sinks (Campbell and Reece, 2002). In case of wheat plant, grain resembles the storage sink and rest as utilization sink. Thus the availability of Zn and Fe at later stage of plant development particularly at grain filling period could increase the uptake as well as concentration of these elements in wheat grain (sink). The iron and zinc element in stress condition have an enhancing role on osmotic adjustment process (due to the increase of soluble carbohydrates). Under drought stress conditions the role of these elements can be seen as a contributor to osmotic regulation that with intervention in the synthesis of osmotic compounds for compatibility with stress and maintain turgor pressure performed their roles (Akbari *et al.*, 2013).

Iron and Zn content in wheat grain

The concentration of Zn in wheat grain ranged from 76.2 to 101.80 ppm (Table 5). Drought at grain filling stage treatment (T_4) showed significantly higher content of Zn in grain compared to other treatments. The concentration of Fe in wheat grain ranged from 80.7 to 116.2 ppm (Table 5). Drought at grain filling stage treatment (T_4) showed significantly higher content of Fe in grain compared to other treatment. Ling *et al.* (2013) demonstrated that foliar Fe amino acid and a relatively low concentration of $ZnSO_4$. $7H_2O$ significantly increase the Fe and Zn concentration in brown rice of different cultivars. Indeed, many previous studies have also reported a positive correlation between grain Zn and Fe concentrations in cereals (Cakmak *et al.*, 2004; Morgounov *et al.*, 2007).

Conclusion

It can be concluded that the foliar application of zinc and iron fertilizers have positive effect on growth, yield components and grain yield by wheat when plants are not able to absorb the iron and zinc from soil due to high soil pH. As a result, foliar application of zinc and iron develops plant growth, grain yield and enhances its quality. Under drought stress, foliar application of zinc and iron improved yield of wheat, grain filling stage being more responsive.

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