Bangladesh Agron. J. 2021, 24(1): 119-128

GROWTH AND YIELD OF WHEAT AS INFLUENCED BY MICRONUTRIENTS UNDER WATER DEFICIT CONDITION

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(**Received**: 25 April 2021, **Accepted**: 10 June 2021)

Keywords: Zn, Fe, application strategy, drought tolerance.

Abstract

Crop productivity is greatly affected by drought stress. In order to evaluate the effects of Zn and Fe micronutrients on growth and yield of wheat (*Triticum aestivum* L.) variety BARI Gom 29, a pot experiment was conducted at the Agronomy research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University during November 2018 to March 2019. Two water regimes i.e. control (80% of field capacity) and drought (40% of field capacity) were maintained throughout the growing season. Micronutrients Zn and Fe viz. i) $ZnSO_4.7H_2O$ and $Fe_3SO_4.7H_2O$ @22 kgha^{-1}were applied in soil before sowing; ii) $ZnSO_4.7H_2O$ solution and $Fe_3SO_4.7H_2O$ solution @ 5% of each were applied as foliar spray at flowering stage following completely randomized design (CRD) with three replications. The results indicated that drought stress affected negatively wheat growth such as plant height, fresh weight of leaf, stem, root and total weight of plant as well as yield. Zn and Fe mitigate the drought effects in wheat which ultimately improve the growth and the yield. Among the micronutrients, Fe ($Fe_3SO_4.7H_2O$) was found more effective when it was applied as foliar spray @ 5% solution for increasing the growth and yield of wheat under water deficit stress condition.

Introduction

Wheat (*Triticum aestivum* L.) is economically one of the most important cereal crops in the world. Wheat, next to rice is the staple food of the people in Bangladesh. Less rainfall is the main constraint for wheat production in the arid/semi-arid regions, and it is reducing 50% crop yield (Wang *et al.*, 2003). Climate change is associated with global warming that affects climatic variability. Drought is the environmental stress that negatively affects the growth, development and productivity of a crop (Kamal *et al.*, 2010).

Various techniques are being used to protect plants from the adverse effects of abiotic stresses like drought, which include exogenous supplementations of silicon, nitric oxide, growth-promoting hormones, enzymes, and nutrient management (Saxena and Shekhawat, 2013). Among the remedies for abiotic stress, nutrient regulations or management are considered as the cost effective and ecofriendly techniques (Tripathi *et al.*, 2017). In addition, studies also showed that an exogenous supply of nutrients plays a crucial role in the enhancement of plant tolerance against various abiotic stresses. Some nutrients such as calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), and iron (Fe) have shown significant results when they are examined under salinity, drought, and heavy-metal stresses (Nazar *et al.*, 2012). Currently, the application of Fe as a nutrient supplement and its role in imparting tolerance to plants against abiotic stresses are gaining attention as an area of research. Tabatabai *et al.* (2015) reported that zinc sulfate played a more important role in stomata regulation and ion balance in plant systems to reduce the tension of drought. Considering above facts, the objectives of the present study were to investigate the effectiveness of zinc (Zn) and iron (Fe) micronutrients in reducing the adverse effects of drought stress in wheat in relation to growth and yield, and to identify the effective application method of zinc (Zn) and iron (Fe) for improving the drought tolerance potential of wheat.

Materials and Methods

Site and soil description: A pot experiment was conducted under semi-controlled environment (inside screen house) at Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during November 2018 to March 2019. The experimental site is in the center of Madhupur Tract (24.09° N latitude and 90.26° E longitude) at 8.4 m above the sea level. Plastic pots (30 cm length and 24 cm diameter) were used in the experiment which was filled with soil, holds about 28% moisture at field capacity (FC). The soil of the pot was fertilized uniformly with 0.9, 0.8 and 0.8 g urea, triple super phosphate and muriate of potash corresponding to 160-150-150 kg urea, triple super phosphate and muriate of potash per hectare, respectively (BARC,2012). The experimental soil was sandy loam with pH 6.93, soil organic carbon 0.61%, total N 0.070%, available P 0.06 mg 100 g^{-1}, exchangeable K 0.79 $cmol_c$ kg^{-1} dry soil, available S 10.00 µg g^{-1}, CEC 13.05 $cmol_c$ kg^{-1} dry soil and EC 0.04 dSm^{-1}. Air temperature, relative humidity and rainfall in the period of experimentation are presented in Table 1.

Table 1. Air temperature, relative humidity and rainfall in the period of experimentation

Month	Air temperature (ºC)			Relative humidity (%)	Total rainfall(mm)
	Maximum	Minimum	Average		
November, 2018	29.22	17.22	23.22	86.73	71.10
December, 2018	25.50	13.10	19.30	86.65	21.69
January, 2019	26.61	11.61	19.22	85.42	0.00
February, 2019	27.82	14.34	20.26	85.36	46.10
March, 2019	27.88	14.43	24.5	85.27	51.32

Source; Department of Agricultural Engineering, BSMRAU (http://bsmrau.edu.bd/age/weather-data/)

Treatments and experimental design: The experiment was designed at Completely Randomized Design (CRD) with three replications. Ten seeds of BARI Gom 29 were sown in each pot and light irrigation was given by using the watering can to ensure uniform germination. After germination thinning were done remaining 3 healthy seedlings in each pot. The treatment combinations were: C=Control (80% of field capacity), D_1=Drought (40% of field capacity), D_2=Drought+ $ZnSO_4.7H_2O$@22$kgha^{-1}$ (11 $mgkg^{-1}$ soil), D_3=Drought+ $Fe_3SO_4.7H_2O$ @22$kgha^{-1}$ (11 $mgkg^{-1}$ soil), D_4=Drought+ $ZnSO_4.7H_2O$ + $Fe_3SO_4.7H_2O$ @22$kgha^{-1}$ (11 $mgkg^{-1}$ soil)of both, D_5=Drought+ $ZnSO_4.7H_2O$ @ 5%(5 g 100 mL^{-1} water) as foliar spray, D_6=Drought+ $Fe_3SO_4.7H_2O$ @ 5% (5 g100 mL^{-1} water)as foliar spray, D_7=Drought+ $ZnSO_4.7H_2O$ + $Fe_3SO_4.7H_2O$ @ 5%(5 g100 mL^{-1} water) of both foliar spray. $ZnSO_4.7H_2O$ and $Fe_3SO_4.7H_2O$ were applied in soil before sowing and solutions treatments were applied as foliar spray at flowering stage. Moisture level in pot soil was measured daily using portable digital moisture meter (POGO Soil Sensor II, Stevens, USA) and required amount of water was added daily to reach 80% of field capacity and 40% of field capacity for control and drought treatments, respectively.

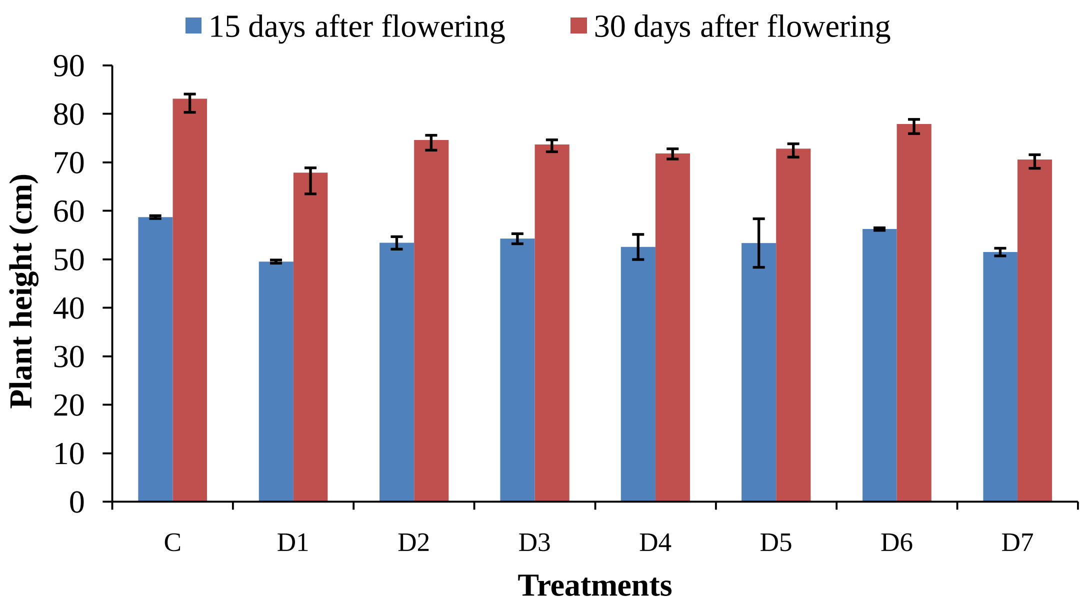
Data recorded: Growth parameters like plant height, fresh weight of leaf, stem, root and total weight of plant were recorded at 15 and 30 days after flowering. Yield and yield contributing parameters were recorded at maturity after harvest.

Data analysis: The recorded data were statistically analyzed by "Crop Stat 7.2" software to examine the significant variation of the results due to different treatments. The treatment means were compared by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984). Microsoft EXCEL 2013 software program was used wherever appropriate to perform statistical analysis.

Results and Discussion

Growth attributes

Plant height of wheat variety BARIGom 29 varied appreciably under drought stress as presented in Figure 1. Though plant height is genetically controlled, drought stress also played a significant role in its regulation. Plant height showed an increasing trend but drought stress significantly reduced the rate of increase in plant height of the wheat variety. At 15 days after flowering, in control condition the plant height was 58.72 cm and in drought condition the plant height was 49.55 cm. Application of Zn and Fe micronutrients increased the plant height under drought stress and the highest plant height (56.26 cm) was recorded when $Fe_3SO_4.7H_2O$ was applied @5% solution as foliar spray followed by $Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$(54.27 cm), $ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$ (53.40 cm), $ZnSO_4.7H_2O$ @ 5%



C= Control, D_1= Drought, D_2=Drought+$ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$, D3= Drought+$Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$, D4=Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22$kgha^{-1}$ of both, D5=Drought+ $ZnSO_4.7H_2O$ @ 5% solution as foliar spray, D6= Drought+ $Fe_3SO_4.7H_2O$ @5% solution as foliar spray, D7= Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5 % solution of both as foliar spray

Fig. 1. Effect of Zn and Fe on plant height of wheat under drought stress at 15 and 30 days after flowering.
Bars indicate (±SE).

solution as foliar spray (53.38 cm), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (52.27 cm) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (51.51 cm). On the other hand, at 30 days after flowering, in control condition the plant height was 83.11 cm and in drought condition it was 67.89 cm. Under drought condition the highest plant height (77.89 cm) was recorded when $Fe_3SO_4.7H_2O$ was applied @5% solution as foliar spray and the lowest was recorded in 70.59 cm when $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ was applied @ 5% solution of both as foliar spray. The decrease in plant height might be due to decrease in relative turgidity and dehydration of protoplasm which in associated with the loss of turgor and reduce expansion of cell and cell division (Arnon, 1972). Soil application and foliar spray of Fe alone or in combination with other micronutrients increase plant height of wheat reported by Abbas *et al.* (2009). Monjezi *et al.* (2013) was found that drought stress on wheat reduced the plant height, but with Zn application significantly increased the plant height. These findings agreed with those of Bayoumi *et al.* (2008) in wheat, Manivannan *et al.* (2007) in sunflower those reported reduction in plant height under drought stress and found positive effects of micronutrients on plant height.

Drought stress exerted significant effect on leaf fresh weight of BARI Gom 29 as shown in Table 2. Leaf fresh weight showed an increasing trend but drought stress appreciably reduced the rate of increase in leaf fresh weight of the wheat variety. It was observed that in control condition the leaf fresh weightplant^{-1} was 3.57g and in drought condition it was 2.15gat 15 days after flowering. Zn and Fe micronutrients tended to reduce the adverse effect of drought stress in relation to leaf fresh weight and the highest leaf fresh weight (3.40g) was recorded when $Fe_3SO_4.7H_2O$ was applied @5% solution as foliar spray followed by $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (2.58g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (2.57g), $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(2.42g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(2.40g) and the lowest was recorded in $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (2.37 g). Consequently, at 30 days after flowering, in control condition the leaf fresh weightplant^{-1} was 3.98g and in drought condition the leaf fresh weightplant^{-1} was 2.22g. The highest leaf fresh weight plant^{-1} (3.40g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(2.72 g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (2.71 g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (2.64 g), $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(2.50 g) and the lowest was recorded in $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (2.57 g) under drought condition. It was found that drought stress reduced the leaf fresh weightplant^{-1} but application of Zn and Fe increases the leaf fresh weight in all of the cases. Reduction in leaf fresh weight might be due to loss of leaf turgidity under drought (Salsinha *et al.*, 2020), which was maintained at a satisfactory level when micronutrients were applied in drought condition in our study.

Stem fresh weight of wheat variety BARIGom 29 showed a great variation due to drought stress as indicated in Table 2. The stem fresh weightplant^{-1} was 5.43 g in control condition and in drought condition it was 3.34g at 15 days after flowering. Both Zn and Fe had positive impact under drought stress on stem fresh weight and the highest value of stem freshweightplant^{-1} (4.44 g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (4.14g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (3.93g), $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(3.79g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(3.69g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (3.45g). Thus, at 30 days after flowering, the stem fresh weight plant^{-1} was 10.38g in control condition and in drought condition it was 6.01g. Application of Zn and Fe improved the ability of wheat plant to tolerate drought stress by maintaining greater stem fresh weight and the highest stem fresh weightplant^{-1} (7.03g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$(6.90g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22$kgha^{-1}$ of both (6.40g), $Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$(6.37g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (6.27g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (6.21g). Though drought stress adversely affected stem fresh weight in wheat, but the application of micronutrients established a positive effect with stem fresh weight in most of the cases.

Root fresh weight of the wheat variety BARI Gom 29 varied appreciably under drought stress as presented in Table 2. Application of Zn and Fe showed a better performance at 15 days after flowering in terms of root fresh $weightplant^{-1}$ and in control condition it was recorded 1.18g, whereas in drought condition it was found $0.56gplant^{-1}$. After Zn and Fe application in drought condition, the highest root fresh $weightplant^{-1}$ (0.81g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22$kgha^{-1}$ of both (0.74g), $Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$(0.68 g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (0.68g), $ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$(0.62g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (0.61g). Likewise, at 30 days after flowering, the positive influence of Zn and Fe on root fresh weight $plant^{-1}$ was found and in control condition it was 1.83 g, whereas in drought condition it was 0.89g. The highest root fresh $weightplant^{-1}$ (1.70g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$ @ 5% solution as foliar spray(1.38g), $Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$ (1.32g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22 kg ha^{-1} of both(1.31g), $ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$ (1.22g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (1.13g) under drought condition. It was reported by Morizet *et al.* (1983) that root weight increased while shoot weight decreased with the application of water deficit stress. This result is in agreement with the findings reported by Shahbaz *et al.* (2012) who showed a marked reduction of root fresh weight when wheat varieties were grown under drought stress for 7 weeks.

Table 2. Effect of Zn and Fe micronutrients on leaf fresh weight, stem fresh weight, root fresh weight, and total fresh weight of wheat under drought stress at 15 and 30 days after flowering (DAF)

Treat ments	Leaf fresh weight ($gplant^{-1}$)		Stem fresh weight ($gplant^{-1}$)		Root fresh weight ($gplant^{-1}$)		Total fresh weight ($gplant^{-1}$)	
	15 DAF	30 DAF	15 DAF	30 DAF	15 DAF	30 DAF	15 DAF	30 DAF
C	3.57	3.98	5.43	10.38	1.18	1.83	10.18	16.19
D_1	2.15	2.22	3.34	6.01	0.56	0.89	6.02	9.12
D_2	2.42	2.57	3.79	6.90	0.62	1.22	6.83	10.69
D_3	2.40	2.72	3.69	6.37	0.68	1.32	6.77	10.41
D_4	2.57	2.64	4.14	6.40	0.74	1.31	7.45	10.25
D_5	2.58	2.71	3.93	6.27	0.68	1.38	7.19	10.29
D_6	3.30	3.40	4.44	7.03	0.81	1.70	8.55	12.13
D_7	2.37	2.56	3.45	6.21	0.61	1.13	6.43	9.90
LSD(5%)	0.9	0.97	1.13	3.45	0.19	0.42	2.07	3.89
CV (%)	36	19.5	17.5	31.5	15.9	23.2	16.2	25.4

C= Control, D_1= Drought, D_2=Drought+$ZnSO_4.7H_2O$ @ 22 $kgha^{-1}$, D_3= Drought+$Fe_3SO_4.7H_2O$ @ 22 $kgha^{-1}$, D_4=Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22$kgha^{-1}$ of both, D_5=Drought+ $ZnSO_4.7H_2O$ @ 5% solution as foliar spray, D_6= Drought+ $Fe_3SO_4.7H_2O$ @5% solution as foliar spray, D_7= Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray.

Total fresh weight of wheat variety BARI Gom 29 varied under drought stress as presented in Table 2. At 15 days after flowering, in control condition the total fresh weightplant^{-1} was 10.18g and in drought condition it was 6.02g. Application of Zn and Fereduced the adverse effect of drought stress and the highest total fresh weightplant^{-1} (8.55g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment, followed by $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (7.45g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray, (7.19g), $ZnSO_4.7H_2O$ @ 22 kgha^{-1} (6.83g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}, (6.77 g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (6.43g). Likewise, at 30 days after flowering, in control condition the total fresh weightplant^{-1} was 16.19g and in drought condition it was 9.12g and the highest total fresh weightplant^{-1} (12.13g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1} (10.69g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(10.41g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (10.29 g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (10.25g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (9.90g). It was noticed that drought stress badly reduced total fresh weight in wheat and the application of micronutrients showed the positive effects to mitigate the drought stress in wheat. Zhang *et al.*(2011) reported that drought stress inhibited the growth of wheat seedlings, under drought stress, the root fresh weight was inhibited; reduction of water to promote root growth, and the root was relatively stout (Ma *et al.*, 2012). Due to the lack of water, the aerial parts of slow growth, aboveground growth was inhibited, studies have shown that (Yuehua, 2013; Li and Ma, 2013), drought stress suppressed the dry matter accumulation in wheat seedling, so for plant height, root length, fresh weight, dry weight, etc. the trend were decreasing, but the effect of the Zn and Fe were found better in this experiment. Adequate Zn nutrition improves vegetative growth and drought tolerance in alfalfa by enhancing root growth and RWC (Grewal and Williams, 2000). The maintenance of good leaf water status is a result of proper control exerted by the guard cells in diverse conditions, which improves the growth and enhances crop survival under stress conditions (Steudle, 2002).

Yield attributes

Number of spikeplant^{-1} of wheat variety BARIGom 29 reduced significantly under drought stress as presented in Table 3. The number of spikeplant^{-1} was 3.42in control condition and in drought condition it was 1.39. Application of Zn and Fe had an influence to decrease the negative effect of drought stress and the highest number of spikeplant^{-1} (2.45) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment, followed by $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both(2.14), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(2.04), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (2.03), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (1.89) and the lowest was recorded in $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(1.76) under micronutrients treated condition.

Spike length of wheat variety BARI Gom 29 varied significantly under drought stress as presented in Table 3. The spike length was 10.80 cm in control condition and in drought condition it was found9.01 cm. Application of Zn and Fe tended to reduce the adverse effect of drought stress in most of the cases and the highest spike length (10.72cm) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (10.18 cm), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(10.12cm), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both (9.87cm), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (9.82cm) and the lowest was recorded in $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(9.75cm) under Zn and Fe applied condition. Spike length has important contribution to the final crop yield, it effects on the number of spikeletspike^{-1}, grain size and number of grainsspike^{-1}. More spike length leads to more number of spikelet spike^{-1} which leads to more number of grains and then ultimately the maximum crop yield. Sharafizad *et al.* (2013) reported that moderate dosage of salicylic acid (1.2 mM) increased spike length.

Table 3. Effect of Zn and Fe micronutrients on yield and yield contributing characters of wheat under drought stress

Treatments	Number of spikeplant^{-1}	Spike length (cm)	100-grain weight (g)	Grain yieldplant^{-1} (g)	Straw yieldplant^{-1} (g)
C	3.42	10.80	5.41	35.89	20.20
D_1	1.39	9.01	4.16	10.85	6.70
D_2	1.76	9.75	4.49	11.13	7.48
D_3	2.04	10.12	4.84	14.97	8.28
D_4	2.14	9.87	4.92	11.30	6.97
D_5	1.89	10.18	4.68	15.06	8.48
D_6	2.45	10.8	5.16	16.10	9.12
D_7	2.03	9.82	4.35	11.29	7.57
LSD (5%)	0.96	0.72	0.59	5.91	3.02
CV (%)	26.9	4.2	7	21.8	18.8

C= Control, D_1= Drought, D_2=Drought+$ZnSO_4.7H_2O$ @ 22 kg ha^{-1}, D_3= Drought+$Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}, D_4=Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1} of both, D_5=Drought+ $ZnSO_4.7H_2O$ @ 5% solution as foliar spray, D_6= Drought+ $Fe_3SO_4.7H_2O$ @5% solution as foliar spray, D_7= Drought+ $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5 % solution of both as foliar spray.

Individual grain weight is an important yield parameter that plays an important role in the actual yield of the crop. 100-grain weight of wheat variety BARI Gom 29 showed a variation due to drought stress as presented in Table 3. In control condition the 100-grain weight was 5.41 g and in drought condition it was 4.16 g. Under drought stress when Zn and Fe were applied, the highest 100- grain weight (5.16g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1}of both (4.92g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1} (4.84g), $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (4.68g), $ZnSO_4.7H_2O$ @ 22 kgha^{-1}(4.49g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (4.35g).Monjezi *et al.* (2013) proposed that zinc spray alleviates drought stress effect on thousand grain weight in wheat. Treated wheat plants with SA or Zn resulted in significant increases in the number of tillers and spikesplant^{-1} as well as of grainsplant^{-1}and weight of grains when irrigated water every 14 and 28 days reported by Mahmoud (2015).

Grain yieldplant^{-1} of wheat variety BARI Gom 29 varied widely under drought stress as presented in Table 3. In control condition the grain yieldplant^{-1}was 35.89 g and in drought conditions it was 10.85g. and under drought condition the highest grain yieldplant^{-1} (16.10g) was recorded when $Fe_3SO_4.7H_2O$ @5% solution was applied as foliar spray followed by $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (15.06 g), $Fe_3SO_4.7H_2O$ @ 22 kg ha^{-1} (14.97g), $ZnSO_4.7H_2O$ + $Fe_3SO_4.7H_2O$ @ 22 kg ha^{-1} of both(11.30g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (11.29g) and the lowest was recorded in $ZnSO_4.7H_2O$ @ 22 kgha^{-1} (11.13g). These findings are in agreement with the results of Monjezi *et al.* (2013) who recorded the highest seed yield from the simultaneous application of iron and zinc, under the stress-free condition and application of iron under the stress-free condition were 660.79 and 651.67 gm^{-2}, respectively. Drought stress at any particular stage or during entire growing season considerably reduced the yield and components of yield in wheat crop (Nasri, 2005). Raza *et al.* (2012) found maximum reduction in grain yield plant^{-1} (48.45%)when drought occurred at grain filling stage, whereas about 10.45% and 25.15%in grain yield plant^{-1} was noticed when drought occurred at tillering and anthesis stage of wheat, respectively. Maleki *et al.* (2014) stated that, zinc sulfate can decrease negative effects of drought stress on maize grain yield and yield components

Straw yieldplant^{-1} of wheat variety BARIGom 29 varied appreciably under drought stress as presented in Table 3. In control condition the straw yieldplant^{-1}was 20.20 g and in drought condition it was 6.70 g. Application of Zn and Fe tended to alleviate the detrimental effect of drought stress in most of the cases and the highest straw yieldplant^{-1}(9.12 g) was recorded in $Fe_3SO_4.7H_2O$ @5% solution as foliar spray treatment followed by $ZnSO_4.7H_2O$ @ 5% solution as foliar spray (8.48g), $Fe_3SO_4.7H_2O$ @ 22 kgha^{-1}(8.28g), $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 5% solution of both as foliar spray (7.57g) D_2(7.48 g) and the lowest was recorded in $ZnSO_4.7H_2O$+ $Fe_3SO_4.7H_2O$ @ 22kgha^{-1}of both (6.97g). Withholding water after anthesis reduced straw yield by 28.5% as claimed by Johari-Pireivatlou (2010). Shirazi *et al.* (2014) found that different irrigation regimes had significant effect on the straw yield. Straw yield exhibited the tendency of increasing with the increase of irrigation levels. This might be due to the luxuriant vegetative growth in terms of plant height and numbers of tillerplant^{-1}. Zn application results in appreciable increase in leaf area, the content of chlorophyll and other photosynthetic pigments, and stomatal conductance, thus resulting in improved growth and yield (Karim *et al.*, 2012). Similarly, Sultana *et al.* (2016) noted that Zn countered the adverse impact of drought and remarkably increased wheat productivity. In another study, Chattha *et al.* (2017) noted that Zn application improved maize yield and harvest index in drought stress. Moreover, Hera *et al.* (2018) noted that foliar applied Zn diminished the negative impacts of water deficit and increased growth and yield of wheat. Seadh *et al.* (2009) reported that the mixture of four micronutrients (Cu, Mn, Fe and Zn) at the rate of 500 ppm produced the highest values of grain and straw yields with the micronutrient foliar application treatments in wheat.

Conclusion

Water deficit stress negatively affects the plant height, fresh weight of leaf, stem and root as well as yield of wheat. Application of Fe and Zn micronutrients reduced the adverse effects of drought stress and improved these parameters of wheat under drought condition. Among the micronutrients, Fe ($Fe_3SO_4.7H_2O$) was found more effective when it was applied as foliar spray @ 5% solution for increasing the growth and yield of wheat in water deficit condition.

Acknowledgement: The authors are grateful to Ministry of Science and Technology, Government of Bangladesh for funding the research.

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