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Proceeding

Evaluating the Synergistic Effects of Foliar Boron and Magnesium Application on Mitigating Drought in Wheat †

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Abstract: Grain yield of wheat is primarily limited by drought. To increase the productivity under these conditions, a pot experiment was carried out to investigate the effect of foliar fertilizer by boron and magnesium under drought at either tillering or anthesis stages on some physiological parameters and yield components of two varieties of durum wheat. Foliar application by combined boron and magnesium had improved significantly the transpiration rate, relative water content and total chlorophyll content. Foliar application by combined boron and magnesium had significantly increased grain weight of wheat varieties at tillering and anthesis drought by 25% and 36%, respectively. Our findings showed the significance of foliar application at anthesis drought rather than at tillering for improvement of grain yield.

Keywords: macronutrient; relative water content; tillering drought; yield component

1. Introduction

Wheat (*Triticum durum*) is among the most crucial field crops grown under rainfed conditions in Jordan and considered essential for food security at the national and global level [1]. Drought is a major abiotic stress and the most unpredictable constraint, with adverse effects on crop production. Drought has a negative impact on plants by disturbing many plant activities, including the carbon assimilation rate, decreased turgor, and changes in leaf gas exchange, thus causing a reduction in yield [2]. Reduced chlorophyll due to water stress causes chlorosis, leads to a reduction in photosynthesis [3]. In addition, drought also reduces leaf relative water content (RWC) and stomatal conductance, which ultimately leads to reducing growth and biomass production [4]. Drought stress most commonly occurs after anthesis in wheat [5].

The foliar application of different nutrients on different crops and at different growth stages can increases the tolerance mechanism in crops and therefore enhances crop yield [6]. Boron (B) is required by plants in micro quantities and had stimulating responses of resistance against drought stress [7]. The nutritional supply of B resulted in improved stomatal conductance and carbon assimilation [8]. Boron application improves growth, grain production and water use efficiency of wheat [9]. In addition, magnesium (Mg) is a macronutrient required for chlorophyll synthesis and thus is essential for photosynthesis process by plants. Also, Mg enhanced the drought tolerance and also played a vital role in all the biochemical and physiological processes of plants by different pathways [10].

Several studies have shown that foliar application of boron and magnesium can increase the yield of crops. However, limited or no information is available regarding the effect of combined foliar application of boron and magnesium on the growth and yield of durum wheat under water stress. Therefore, this study was designed to evaluate the effect of B and Mg application alone and in combination in improving some of physio-

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logical traits and yield components of two varieties of durum wheat grown under tillering or anthesis drought stress.

2. Materials and Methods

2.1. Plant materials

Two durum wheat (*Triticum durum* L.) varieties (Hourani and Maru 1) were used in this experiment. Maru1 is an improved variety released and registered in 2019-2020, while Hourani is an old variety (released in 1976) and known as a drought-tolerant variety.

2.2. Soil preparation and seed sowing

A pot experiment was conducted in a glasshouse at Maru Agricultural Research Station (MARS), Jordan. Seventy two pots (27 cm diameter × 27 cm height) were used for this experiment, and each pot was filled with 4 kg of clay soil mixed with peat (1:1) (v/v). Plants were thinned to two seedlings per pot at the two-leaf stage one week after emergence.

2.3. Growth conditions and treatments

Temperature in the greenhouse was controlled at 25/15°C (day/night). Pots were supplied with NPK fertilizer on a weekly basis from the beginning of tillering. Foliar spraying was applied twice during the experiment; once at tillering drought and another at anthesis drought and compared with those sprayed at well-watered conditions. Fertilizer treatments (Boron, Magnesium, and Boron+ Magnesium) were sprayed one day before beginning of drought either at tillering or anthesis growth stages while controls were sprayed with distilled water. Boron was sprayed in the form of boric acid (H_3BO_3) at concentration of 0.3 g/L (% B in boric acid=17.48%) whereas magnesium in the form of magnesium sulphate ($MgSO_4.7H_2O$) at concentration of 5g/L (% Mg in magnesium sulphate=9.86%). Drought was imposed by withholding watering for 7 days at at tillering (GS 22; D1) or anthesis (GS 65; D2) according to the Zadoks scale [11] on separate sets of plants, and compared with well watered (WW) plants which were regularly watered to field capacity.

2.4. Physiological measurements and RWC

Transpiration rate (µg cm^{-2} s^{-1}) was measured with a portable steady state porometer (LICOR model LI-1600), while total chlorophyll content (TCC) was determined non-destructively using a portable chlorophyll meter; SPAD 502 Chlorophyll Meter (Spectrum Technologies Inc., Plainfield, IL, USA) on the same leaf as RWC prior to excision at beginning and one week after plant stresses at either tillering or anthesis stages. Relative water content (RWC) was determined according to the method of [12].

2.5. Growth and yield components

At full maturity stage, the number of tillers and heads were counted. The above-ground plant parts were harvested and separated into vegetative and head parts. The grains were separated from heads by threshing and grain weight was determined for each pot. Total dry weight of shoots was determined after drying in an oven at 80°C for two days. The one thousand-grain weight was determined from the weight of 200- seeds per sample. Harvest index (HI) was calculated by dividing grain weight by total (grain plus shoot) weight.

2.6. Statistical analysis

The experiment was performed in a factorial completely randomized design. There were three replicates for each treatment. Data were analyzed by factorial ANOVA using

Statistix 8.1. When there were significant interactions, one-way ANOVA was used and means were separated by least significant differences (LSD).

3. Results

Transpiration rate was significantly ($p < 0.05$) higher in var. Maru 1 than those in var. Hourani at tillering. Moreover, controls had significantly lower transpiration rate and RWC than foliar fertilizer treatments (Table 1). At anthesis, measured physiological parameters revealed a significant reduction in controls when compared with other foliar fertilizer treatments. However, B+ Mg treatment had significantly higher RWC than either B or Mg- treatments (Table 1).

Table 1. Mean values of transpiration rate (µg cm^{-2} s^{-1}), total chlorophyll content by SPAD, and relative water content (RWC %) for two durum wheat varieties and four foliar fertilizer treatments under beginning of tillering and anthesis droughts (Day 0) and end of tillering and anthesis droughts (Day 7). According to least significant difference (LSD) test, different letters within the same columns indicate significant differences (p < 0.05). B: Boron; Mg: Magnesium; B+ Mg: combined boron and magnesium.

Variety	**Drought**	**Transpiration rate**		**SPAD**		**RWC**	
		Tillering	Anthesis	Tillering	Anthesis	Tillering	Anthesis
Hourani	Day 0	4.92	10.84	52.06	53.39	91.93	92.28
	Day 7	2.82	2.88	46.47	43.11	71.49	50.65
Variety mean		3.87B	6.8 A	49.26A	48.25A	81.71A	71.47A
Maru 1	Day 0	4.78	10.59	52.16	53.53	92.34	92.09
	Day 7	3.83	2.82	46.11	44.34	72.05	54.21
Variety mean		4.30A	6.70A	49.13A	48.93A	82.19A	73.15A
Foliar treatment							
B	Day 0	4.82	10.78	50.95	54.33	92.18	92.55
	Day 7	3.39	2.92	48.10	43.45	79.39	52.48
Treatment mean		4.11A	6.85A	49.53A	48.89A	85.78A	72.52B
Mg	Day 0	4.86	10.87	52.85	54.03	92.79	90.97
	Day 7	3.73	3.25	45.32	44.42	72.89	55.50
Treatment mean		4.29A	7.06A	49.08A	49.23A	82.84A	73.23B
B + Mg	Day 0	4.79	11.01	53.07	53.28	91.84	92.53
	Day 7	3.99	3.85	47.52	46.83	73.26	62.03
Treatment mean		4.39A	7.43A	50.29A	50.06A	82.55A	77.28A
Control	Day 0	4.94	10.21	51.57	52.18	91.74	92.69
	Day 7	2.18	1.38	44.22	40.20	61.52	39.72
Treatment mean		3.56B	5.79B	47.89A	46.19B	76.63B	66.21C
LSD (0.05)							
variety		0.33	0.53	2.06	1.11	2.85	2.60
Foliar treatment		0.47	0.76	2.92	1.57	4.03	3.68

The main means of foliar fertilizer treatments for growth and yield of the two wheat varieties are presented in Table 2. Number of heads (HN) and tillers (TN) per plant for var. Maru 1 was significantly higher than those for var. Hourani. Variety Maru 1 showed significantly a higher grain number (GN), grain weight (GW) and 1000-grain weight (TGW) per plant ($P < 0.01$) than var. Hourani. Controls had significantly reduced GW, GN and TGW per plant by 18%, 16% and 6%, respectively when compared with those sprayed by B+Mg treatment. Dry matter weight (DMW) per plant was similarly affected by treatments as the GW and GN. The overall mean harvest index (HI) of var. Maru 1 was significantly higher than those of var. Hourani.

Table 2. Main effect of wheat varieties and foliar fertilizer treatments on growth and yield components. B: Boron; Mg: Magnesium; B+ Mg: combined boron and magnesium; TN: number of tillers per plant; HN: number of heads per plant; GN: number of grains per plant; TGW: 1000-grain weight; GW: grain weight per plant; DMW: shoot dry weight per plant excluding grain; HI: harvest index; LSD: least significant difference at $p < 0.05$. Figures labeled with the same letter in each column are not significantly different.

Main effect	TN	HN	GN	TGW (g)	GW (g)	DMW (g)	HI
Variety							
Hourani	9.0b	8.5b	310.1b	37.3b	12.1b	19.1b	0.37b
Maru 1	9.8a	9.3a	452.8a	42.6a	20.1a	22.3a	0.46a
Foliar treatment							
B	9.5a	9.1a	396.4a	40.3b	16.8a	21.3a	0.42a
Mg	9.5a	9.0a	383.1a	42.0a	16.8a	21.4a	0.42a
B+ Mg	9.3a	9.0a	405.2a	40.0b	16.9a	21.9a	0.42a
Control	9.0a	8.5a	340.9b	37.4c	13.8b	18.1b	0.40a
LSD (0.05)							
variety	0.34	0.33	20.84	1.10	0.73	1.29	0.019
Foliar treatment	0.49	0.47	29.48	1.56	1.04	1.82	0.027

There was significant ($p < 0.05$) foliar fertilizer × drought interaction effect for GW per plant (Figure 1). Combined foliar fertilizer (B+ Mg) treatment did not improve GW under well-watered (WW) conditions when compared with controls. However, B+ Mg treatment had significantly increased the GW per plant by 33% and 57% at tillering drought (D1) and anthesis drought (D2), respectively when compared with controls.

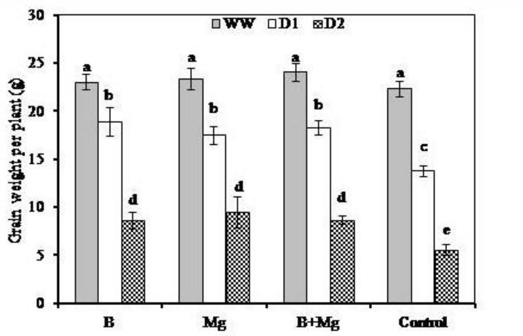

Figure 1. Foliar fertilizer x drought interaction effect on grain weight per plant. Columns with the same letter are not significantly different at $p < 0.05$ using LSD. Error bars show standard errors, n = 3.

4. Discussion

In this study, foliar application was effective in improving transpiration rate of wheat under drought. Similar findings were obtained by [9]. The response of micronutrint application to various abiotic stresses depends on the crop, growth stage and concentration of the nutrient solution [13]. The key mechanisms affecting the ability of micro-and macro-nutrients to alleviate the effects of drought stress include enhancing water uptake and transport, regulating stomatal behavior and transpirational water loss [14]. Our results showed that wheat transpiration at anthesis drought was lower approximately 14% than at tillering drought. This may due to a higher water uptake of larger root biomass at anthesis time. Similarly, [15] found that transpiration rates during the anthesis were higher than during the vegetative phase. Therefore, the soil water supply is more rapidly exhausted at anthesis drought.

Foliar application by combined boron and magnesium had increased total chlorophyll content by SPAD at anthesis drought. These results are consistent with other studies [16, 17] who indicated that Mg had a main role in chlorophyll formation, activation of enzymes, and it may increase plant resistance to water stress. Similarly, foliar application by B increased total chlorophyll content at late growth stages of winter wheat [9]. Thus, these findings indicated the prominence of foliar application by combined boron and magnesium to reduce the harmful effects of drought stress that often occur during anthesis.

In the current study, foliar fertilizer significantly increased RWC of wheat under drought conditions. Similar results were obtained by [18, 19] who found that the foliar application of macro and micro-nutrients improved RWC for some crops. Higher RWC under combined boron and magnesium might be due to higher chlorophyll formation during the drought, whereas the increase in RWC by application of foliar boron might be due to leaf membrane stability and higher resistance against abiotic stresses [20, 7].

Our results also indicated significant differences between both wheat varieties in terms of yield and yield components due to a difference in genetic makeup of variety. It is well documented that wheat varieties grown under drought conditions demonstrate natural genetic difference in traits related to drought tolerance [21]. Our study demonstrated that the foliar application increased grain yield of durum wheat under different drought conditions may due to crucial role of such fertilizers in enhancement of photosynthesis, transpiration rate, pollen viability, number of grains per spike and higher concentrations of these nutrients in the grain. Similar results were obtained by [9, 22]. Our findings were also in agreement with results of [9] who found that grain yield of winter wheat was not improved by foliar applications in the absence of drought. Furthermore, the foliar application of B and Mg was more effective at anthesis drought for improving the grain yield. These results were similar to findings of [23] who found that the foliar application of potassium was the most effective at anthesis stage. However, [22] found that booting stage was the best time for boron application to get higher grains production.

In conclusion, drought stress at either tillering or anthesis growth stage inhibits physiological, growth and yield parameters of durum wheat varieties. Yield reduction was greater during anthesis drought than during tillering. Therefore, exogenous application of B and Mg on wheat under drought alleviated the negative effects of water deficit. Results of this pot experiment revealed that foliar application of B and Mg had enhanced leaf transpiration rate and relative water contents, which in turn improved crop yield of wheat. However, the foliar application of B and Mg in combination performed similar as in single nutrient. The results from this study show the significance of foliar application at anthesis stage for improvement wheat yield under drought conditions. Further study is required to examine the effect of foliar application and drought on wheat yield and growth under field conditions.

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