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EFFECT OF IRON AND BORON FOLIAR FERTILIZATION ON YIELD AND YIELD COMPONENTS OF WHEAT

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ABSTRACT

Field experiments were conducted to investigate the effect of foliar application of two micronutrients (Fe, B and Fe + B) on grain yield and yield components of wheat (*Triticum aestivum* L.) "Alex" cultivar at different growth stages. The experiments were carried out during the growing seasons 2012-13 and 2013-14 in Banat's University of Agricultural Sciences and Veterinary Medicine, Timisoara, Romania. The experiments were performed in randomised complete block design with three replications. Ten treatments with 1000 ppm Fe, 500 ppm B and 1000 ppm Fe + 500 ppm B were applied in these experiments at individual growth stage (BBCH 21 or BBCH 41) and at both growth stages (BBCH 21 + BBCH 41). Among the treatments, two years average showed that foliar application of Fe + B at both stages of growth (T10) produced highest number of grains per spike (50), thousand grain weight (41.50 g), biological yield (12190 kg ha^{-1}), harvest index (42.50%) and grain yield (5180 kg ha^{-1}). This treatment increased the mentioned traits by 25.40%, 19.36%, 12.45%, 17.86% and 32.55% over control respectively.

Key words: foliar spraying; Fe-DTPA; boric acid; wheat growth stage; micronutrients.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an essential cereal crop, basis of staple food and thus the most important crop in food security potential. More of the arable land area is wrapped by wheat than by any other food crop. Wheat production is the third major cereal production in the world, following maize and rice (FAO, 2013).

Wheat is the second most important cereal crop in Romania. It was grown in 2012-2013 on an area of 1.988 million ha with the total production 5.215 million metric tons, and average yield of 2.623 t ha^{-1} (NIS, 2013). Between the various aspects accountable for relatively low yields of wheat crop in the country, one can mention poor fertility of many soils, drought, increasing use macronutrients and low use micronutrients leading to an imbalance of soil chemicals, etc.

Nutrients deficiency is major problem facing crop production globally, especially in eastern European countries. So, a balanced fertilization program with considering both macro and micronutrients in plant nutrition is very important in obtaining high yields of high quality. The role of macro and micro nutrients as a key in crop nutrition is important for achieving higher yields (Arif et al., 2006).

Micronutrients have a very important role in crop growth and development, as well as crops yield. Few studies and a little information are available about the effect of micronutrients on yield and yield components of wheat in Romania and it is not documented well up to date. In fact, their necessary function in plant nutrition and increasing soil productivity makes their importance ever greater (Malvi, 2011). The responses of plants to fertilizers differ significantly due to soil physical and chemical properties and climatic condition (Steven, 2000).

Foliar application of micronutrients is an alternative when nutrient deficits cannot be corrected by applications of fertilizers to the soil, so it is helpful when the roots cannot

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provide necessary nutrients (Babaeian et al., 2011; Mostafavi, 2012). Application of micronutrients to soil could create a major problem of soil pollution. While people are worried about the environment, plant leaves can uptake nutrients better than in the case of soil application of fertilizers (Bozorgi et al., 2011; Fernandez et al., 2013).

Wheat is not sensitive to Fe and B deficiency, but several studies have mentioned that applying Fe and B as single or shared with other micronutrients to soil and/or foliar application significantly improved growth, yield and yield components (Seadh et al., 2009; Tahir et al., 2009; Wrobel, 2009; Khan et al., 2010; Ali, 2012; Ahmad and Irshad, 2011; Nadim et al., 2013; Rawashdeh et al., 2014; Rawashdeh and Sala, 2015).

In Eastern Europe, especially in Romania, few studies and little information are known about the effect of foliar application of micronutrients on yield and yield components of wheat. So this study aimed to study the impact of foliar application of Fe and B single or together on yield and yield components of wheat at two growth stages under field condition.

We demonstrated the importance of the micronutrients application through foliar spraying on wheat yield and yield components. In this study we found that foliar application of Fe and B at both growth stages is important for improving wheat performance. These findings may help farmers to maximize wheat grain yield by adding micronutrients.

MATERIAL AND METHODS

Experimental site

Field experiments were carried out at Didactic Station in Banat's University of agricultural Sciences and Veterinary Medicine, “King Michael I of Romania”, Timisoara, Romania, which is located between 45°46' N latitude, 21°25′ E longitude, with an altitude of 85 m above sea level.

Climate conditions

The meteorological data for the period of growing seasons from October till June (2012-13 and 2013-14) were available as records of regional meteorological centre Banat-Crisana, Timisoara. The mean monthly meteorological data of rainfall (mm), relative humidity (%), and temperature (°C), recorded during the growing seasons of experimental site, are presented in Table 1.

Table 1. Monthly mean of rainfall (mm), relative humidity (%), and maximum and minimum temperature (°C) at the experimental site during 2012-13 and 2013-14 seasons*

Month	Rainfall		Relative humidity		Temperature			
					Maximum		Minimum	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
October	69.4	55.3	81	80	32.8	26.8	-2.1	-1.6
November	19.2	52.7	85	84	21.1	21.1	-0.4	-1.9
December	57.0	1.2	91	86	9.2	15.7	-17.3	-7.7
January	54.3	41.7	88	87	13.1	15.3	-10.2	-7.3
February	37.1	16.7	83	79	17.2	20.1	-5.9	-7.7
March	104.2	13.4	80	70	18.6	23.0	-6.1	-1.9
April	34.1	41.3	68	74	32.2	23.7	0.8	2.1
May	97.3	146.8	67	74	31.4	29.4	6.7	1.8
June	47.5	57.7	74	64	35.5	34.0	9.8	9.2
Total	520.1	426.8						

*Source: Regional Meteorological Centre Banat-Crisana, Timisoara.

Soil sampling and analysis

Soil samples were taken randomly by a soil auger from 10-12 representative places of the experimental field area. The samples were taken at a depth 0-25 cm from soil surface before sowing and mixed carefully to prepare one composite sample. Air dried samples were passed through a 2 mm sieve to obtain a more homogeneous soil sample and to analyse the important chemical and physical soil properties using standard analytical methods (Ryan et al., 2001). Soil chemical and physical properties are presented in (Table 2).

Table 2. Soil chemical and physical properties of the experimental site during growing seasons 2012-13 and 2013-14

Mechanical analysis	Units	2013-13	2013-14
Sand	%	27	27
Silt	%	28.3	27.8
Clay	%	44.7	45.2
Texture Class		clay	clay
Chemical analysis			
pH		6.73	6.98
EC	dS/m	0.48	0.53
Ca^{++}	ppm	58.0	62.8
Mg^{++}	ppm	13.2	12.0
Cl^{-}	ppm	88.75	84.49
SO_4^{--}	ppm	70.56	92.64
N	%	0.168	0.202
Available P	ppm	11.23	14.58
Available K	ppm	171.13	167.60
Available Fe (DTPA extraction)	µg/kg	3.59	3.04
Available Zn (DTPA extraction)	µg/kg	0.66	1.58
Available Mn (DTPA extraction)	µg/kg	14.3	7.68
Available Cu (DTPA extraction	µg/kg	0.62	0.88
B (colorimetric method)	µg/kg	0.20	0.31

Treatments and experimental design

Micronutrients foliar application of Fe in form Fe-DTPA (Fe 6%) and B in form boric acid (B 17%) and time of application treatments involved: T1 – control (no Fe and no B application), T2 – 1000 ppm Fe at individual growth stage (BBCH 21), T3 – 1000 ppm Fe at individual growth stage (BBCH 41), T4 – 1000 ppm Fe at both growth stages (BBCH 21 + BBCH 41), T5 – 500 ppm B at individual growth stage (BBCH 21), T6 – 500 ppm B at individual growth stage (BBCH 41), T7 – 500 ppm B at both growth stages (BBCH 21 + BBCH 41), T8 – 1000 ppm Fe + 500 ppm B at individual growth stage (BBCH 21), T9 – 1000 ppm Fe + 500 ppm B at individual growth stage (BBCH 41), T10 – 1000 ppm Fe + 500 ppm B at both growth stages (BBCH 21 + BBCH 41). Foliar solutions were applied with a hand held spray bottle at the rate of 1.2 L $plot^{-1}$ on plant foliage. Tween-20 at one ml per litre as surfactant was mixed with the foliar solutions to increase adhesion of solution with plant foliage. A buffer zone of 2.0 m spacing was given between plots.

Nitrogen (N) was applied in two doses. First dose of nitrogen along with full dose of phosphorus (P) and potassium (K) were applied for all treatments at 4 weeks after sowing in the form of complex 15:10:10 N:P:K, respectively at the rate of 360 kg/ha. Second dose of the nitrogen in the form of urea was applied at the stem elongation stage at a rate 100 kg/ha. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Seeds were sown through drills at a 15 cm distance between rows. A seed rate 270 kg ha^{-1} of Alex wheat cultivar was used. The size of each plot was constructed with an area of 10 m (length) by 3 m (width). A buffer zone of 2 m spacing was given between plots.

Plant sampling

At maturity stage (BBCH 89), plant was harvested in one square meter area selected randomly, selected at three locations in each plot then mean value was recorded to one square meter. To avoid border effect 0.2 m of every side in each plot was not considered for harvesting. Plants were harvested manually and plants were tied in package and dried in sun for 3 days in respective plots. The tied packages of particular plot were weighted on weight balance for biological yield. The plant was threshed manually to record the number of grain per spike, grain and straw yields of harvested area then transformed into hectare basis. The data regarding to thousand grain weight was measured by taking three random samples from each plot and thousand grains were counted with the help of digital seed counter and then weighed using electronic balance. Mean values were recorded as thousand grain weight (g). Harvest index (HI) was calculated as following formula (Alqudah and Schnurbusch, 2014):

HI=(Economic yield/Biological yield) × 100%

Statistical analysis

The recorded data for yield and yield components were subjected to statistical analysis by using the analysis of variance (ANOVA) through MSTAT-C program (MSTAT-C., 1989). Differences between treatment means were compared by Least Significant Different (LSD) at 0.05 probability.

RESULTS AND DISCUSSION

Number of grains per spike

Two years average showed that foliar application of Fe, B and Fe + B at individual growth stages growth stages (BBCH 21 or BBCH 41 and at both growth stages (BBCH 21 + BBCH 41) by the concentration 1000 ppm Fe, 500 ppm B and 1000 ppm Fe + 500 ppm B increased significantly number of grains per spike over the control (Table 3). The maximum number of grains per spike was observed in treatment number ten (T10) where Fe + B were applied together at both growth stages (BBCH 21 + BBCH 41) (25.40% increase over control). Data showed that minimum number of grains per spike was observed in control. These results are in agreement with (Ali, 2012; Tahir et al., 2009; Ahmad and Irshad, 2011), who reported significant increase in number of grains per spike with foliar application of Fe and B single or shared with other micronutrients.

Table 3. Effect of foliar application of micronutrients (Fe, B and Fe + B) at different growth stages on the number of grains per spike (no.) of wheat during growing seasons 2013-2014

Treatment*	2012-2013	2013-2014	Mean	Increase in number of grains per spike over control (%)
T1	39.43h**	41.03g	40.23I	
T2	40.57g	42.50f	41.53H	3.24
T3	41.17g	44.33de	42.75G	6.26
T4	43.93f	44.67d	44.30EF	10.12
T5	44.77ef	43.56e	44.17F	9.78
T6	46.93d	46.67c	46.80D	16.33
T7	49.20b	48.53b	48.87B	21.46
T8	45.27e	45.02d	45.15E	12.22
T9	48.10c	47.43c	47.77C	18.73
T10	50.17a	50.73a	50.45A	25.40
LSD at p=0.05	0.8730	0.9190	0.8746	

*T1= Control (no Fe and B application); T2= Fe 1000 ppm application at individual growth stage (BBCH 21); T3= Fe 1000 ppm application at individual growth stage (BBCH 41); T4= 1000 ppm application at both growth stages (BBCH 21 + BBCH 41); T5= B 500 ppm at individual growth stages (BBCH 21); T6= B 500 ppm at individual growth stage (BBCH 41); T7= B 500 ppm at both growth stages (BBCH 21 + BBCH 41); T8= Fe 1000 ppm + B 500 ppm at individual growth stage (BBCH 21); T9= Fe 1000 ppm + B 500 ppm at individual BBCH 42 and T10= Fe 1000 ppm + B 500 ppm at both growth stages (BBCH 21 + BBCH 41).

**Means in the same column with different letters differ significantly at 0.05 probability level according to LSD.

Thousand grain weight (g)

The data regarding to 1000-grain weight (Table 4) is significant affected by foliar application of Fe, B and Fe + B at different growth stages. Mean two years values indicated that the maximum 1000-grain weight was observed in treatment (T10) where Fe + B were applied at both growth stages (BBCH 21 + BBCH 41) (19.36% increase over control). This treatment had significant difference with all treatments. The minimum 1000-grain weight was observed in control. Ali (2012), Tahir et al. (2009), Arif et al. (2006), Ahmad and Irshad (2011) also reported that foliar application of Fe and B increased significantly 1000-grain weight in wheat respectively.

Table 4. Effect of foliar application of micronutrients (Fe, B and Fe + B) at different growth stages on 1000-grain weight (g) of wheat during growing seasons 2013-2014

Treatment	2012-2013	2013-2014	Mean	Increase in 1000-grain weight over control (%)
T1	34.09j	35.45h	34.77H	
T2	35.87h	37.20ef	36.53F	5.06
T3	37.24e	37.49de	37.37E	7.48
T4	39.64b	41.74b	40.69B	17.03
T5	35.10i	36.13gh	35.62G	2.44
T6	36.68f	37.19ef	36.93EF	6.21
T7	38.28c	40.22c	39.25C	12.88
T8	36.15g	36.61fg	36.38F	4.63
T9	37.89d	38.23d	38.06D	9.46
T10	40.25a	42.74a	41.50A	19.36
LSD at p=0.05	0.2544	0.7594	0.5678	

Means in the same column with different letters differ significantly at 0.05 probability level according to LSD.

Biological yield (kg ha^{-1})

The data on biological yield exposed significant increase with foliar application of Fe, B and Fe + B at different growth stages (Table 5). The mean data of the two years showed that the maximum biological yield obtained by the foliar application of Fe + B at both growth stages (BBCH 21 + BBCH 41) (12.45% increase over control), while minimum biological yield was recorded by control. These results agreed with (Hosinkhani et al., 2013) who found that biological yield significantly increased when plant sprayed by Fe at stem elongation stage. Babaeian et al. (2012) found that biological yield of barley increased 21.59% as comparison to control due to the application of Fe. Foliar application of Fe lead to 80% increase of biological yield of safflower compared to control. Rehman et al. (2012) found that biological yield of wheat increased over control when B supply at various growth stages. Khan et al. (2010) confirmed that the application of mixture of micronutrients increased biological yield of wheat.

Harvest index (%)

Foliar application of micronutrients (Fe, B and Fe + B) at different growth stages significantly increased harvest index. Two years average, data in (Table 6) showed that the maximum harvest index was observed in (T10) where Fe + B were sprayed at BBCH 21 + BBCH 41 (17.86% increase over control). The minimum harvest index was observed where Fe and B were not sprayed (control). These results are in agreement with (Khan et al., 2010; Shahrokhi et al., 2012; Hosinkhani et al., 2013) in addition (Tahir et al., 2009; Rehman et al., 2012) who found that harvest index of wheat increased by application Fe and B single or joint with other micronutrients.

Table 5. Effect of foliar application of micronutrients (Fe, B and Fe + B) at different growth stages on biological yield (kg ha^{-1}) of wheat during growing seasons 2013-2014

Treatment	2012-2013	2013-2014	Mean	Increase in biological yield over control (%)
T1	10820i	10850h	10840I	
T2	11060h	11210f	11140G	2.77
T3	11110h	11050g	11080H	2.21
T4	11540e	11600d	11570D	6.73
T5	11410f	11280e	11340E	4.61
T6	11830c	11620d	11730C	8.21
T7	12040b	11950b	11990B	10.61
T8	11230g	11320e	11280F	4.06
T9	11670d	11740c	11710C	8.03
T10	12250a	12130a	12190A	12.45
LSD at p=0.05	52.21	48.03	48.34	

Means in the same column with different letters differ significantly at 0.05 probability level according to LSD.

Table 6. Effect of foliar application of micronutrients (Fe, B and Fe + B) at different growth stages on harvest index (%) of wheat during growing seasons 2013-2014

Treatment	2012-2013	2013-2014	Mean	Increase in harvest index over control (%)
T1	35.94i	36.16i	36.05H	
T2	36.72h	37.62g	37.17G	3.11
T3	37.53g	37.24h	37.39G	3.72
T4	39.26e	39.62e	39.44D	9.40
T5	38.66f	38.00f	38.33E	6.32
T6	41.30c	40.23d	40.76C	13.07
T7	41.78b	41.39b	41.58B	15.34
T8	37.67g	38.17f	37.92F	5.19
T9	40.45d	40.83c	40.64C	12.73
T10	42.78a	42.21a	42.49A	17.86
LSD at p= 0.05	0.2365	0.2712	0.2395	

Means in the same column with different letters differ significantly at 0.05 probability level according to LSD.

Grain yield (kg ha^{-1})

Data on grain yield indicated significant increase for foliar application of micronutrients (Fe, B and Fe + B) at different growth stages over control (Table 7). Mean data of the two years showed that the maximum grain yield was recorded when plant received Fe + B at both growth stages (BBCH 21 +BBCH 41) (32.55% increase over control). Minimum grain yield was achieved in control (T1). These results are in agreement with the findings by (Khan et al., 2010; Zeidan et al., 2010; Ali, 2012; Shahrokhi et al., 2012; Ali et al., 2013; Hosinkhani et al., 2013; Nadim et al., 2013) who found that the grain yield of wheat increased due to the application of Fe nutrient single or shared with other micronutrients. Also (Korzeniowska, 2008; Tahir et al., 2009; Khan et al., 2010; Nadim et al., 2013) reported that grain yield of wheat increased due to the application of B single or shared with other micronutrients.

Table 7. Effect of foliar application of micronutrients (Fe, B and Fe + B) at different growth stages on grain yield (kg ha^{-1}) of wheat during growing seasons 2013-2014

Treatment	2012-2013	2013-2014	Mean	Increase in grain yield over control (%)
T1	3890j	3925i	3908H	
T2	4063i	4219g	4141G	5.96
T3	4171h	4116h	4143G	6.01
T4	4530e	4596e	4563D	16.76
T5	4409f	4284f	4346E	11.21
T6	4887c	4673d	4780C	22.31
T7	5030b	4946b	4988B	27.64
T8	4232g	4321f	4276F	9.42
T9	4720d	4794c	4757C	21.72
T10	5242a	5118a	5180A	32.55
LSD at p= 0.05	44.00	48.25	43.66	

Means in the same column with different letters differ significantly at 0.05 probability level according to LSD.

Significant relationships (R^2=0.99, and R^2=0.99) between grain yield (kg ha^{-1}) and harvest index (%) during 2013 (a) and 2014 (b) respectively were also observed with respect to foliar application with Fe, B and Fe + B at individual growth stage (BBCH 21 or BBCH 41) and at both growth stages (BBCH 21 + BBCH 41) (Figure 1) Increasing grain yield for one unit causes enhancement in harvest index at the same rate and vice versa. Increase yield and yield components in this study when we applied (T10) can be explained by essential roles of Fe in plant growth and development, including chlorophyll synthesis, respiration, chloroplast development and enzyme activity (Miller et al., 1995; Eskandari, 2011), and due to the important of role of B in cell wall structure, membrane stability, sugar transportation, and phenol, carbohydrate, nucleic acid and IAA (Indole Acetic Acid), carbohydrate metabolism and in grain setting of wheat (Brown et al., 2002; Tahir et al., 2009).

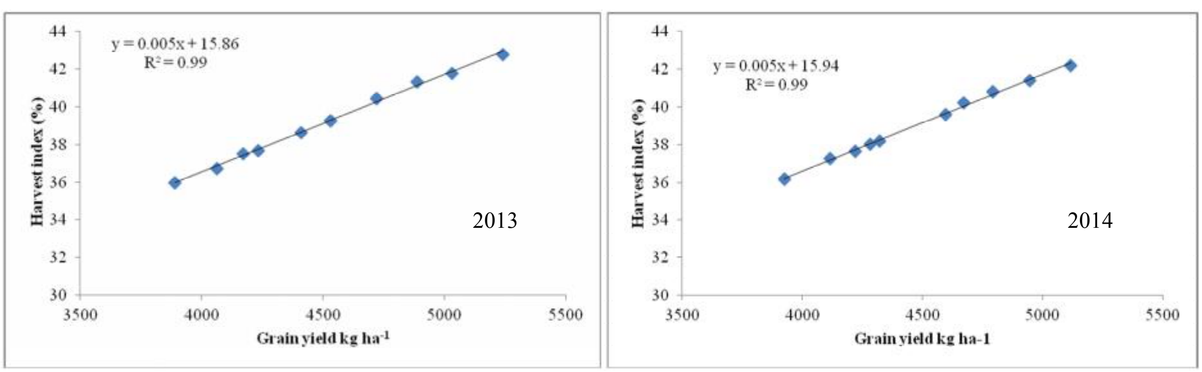

Figure 1. Relationship between grain yield and harvest index during 2013 and 2014

CONCLUSION

The current study showed that foliar application by 1000 ppm of iron and 500 ppm of boron at individual growth stage (BBCH 21 or BBCH 41) and at both growth stages (BBCH 21 + BBCH 41) significantly influenced on grain yield and all studied yield components of wheat. The highest number of grains per spike, thousand grain weight, biological yield, harvest index and grain yield was obtained in foliar application of 1000 ppm Fe + 500 ppm B at two growth stages (T10). Lastly, the results from this study also indicated the importance of micronutrient in improving grain yield and an in-depth analysis on large-scale is a worthwhile target for increasing grain yield in cereals.

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