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Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat

Hekmat Narimani[1], Mohamad Mehdi Rahimi[2], Asadollah Ahmadikhah[3*] and Behrooz Vaezi[4]

[1]Department of Agronomy, Yasooj Azad University, Yasooj, Iran
[2]Department of Agronomy and Plant Breeding, Yasooj Azad University, Yasooj, Iran
[3]Department of Plant Breeding and Biotechnology, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[4]Dryland Agricultural Research Institute, Gachsaran, Iran

ABSTRACT

In order to study the effect of foliar spray of microelement fertilizers Fe, Zn and Cu on yield and yield components of durum wheat (cv. Dehdasht) an experiment was conducted as strip split plots in randomized completely block design with 3 replications. Treatments were spraying time as main factor (at two levels including 2 weeks before flowering and 50% flowering) and microelement fertilizer as subfactor (at 8 levels including N_1=Fe, N_2=Zn, N_3=Cu, N_4=Fe+Zn, N_5=Fe+Cu, N_6=Zn+Cu, N_7=Fe+Zn+Cu and N_8= no spraying). Analysis of variance showed that spraying time was significant only for test weight at 5% level. However, fertilizer effects were significant for most of studied traits. Means comparison revealed that all fertilizer treatments imposed positive effects on spike length and kernel protein content, but Zn had highest positive effect on them (13.4% and 9.6% compared to check, respectively). All fertilizer treatments imposed positive effects on test weight, but Cu had highest positive effect on it (6.1% compared to check). Also, all fertilizer treatments imposed positive effects on economic yield, but Fe+Cu had highest positive effect on it (34.1% compared to check). Although all fertilizer treatments imposed positive effects on fertile tiller number, but Cu+Zn had highest positive effect on it (61.6% compared to check). This treatment, also, had highest positive effect on 1000-kernel weight and spike number per unit area, and highest negative effect on sterile floret number (9.2, 17.3 and -18% compared to check, respectively). Fe+Cu+Zn treatment had highest positive effect on plant height, fertile floret number and kernel number per spike (15.1, 17.6 and 14.3% compared to check, respectively). If only one micronutrient was to be utilized, Zn is obviously the best choice for improvement of yield and its components. Since all fertilizer treatments had positive effects on most of important traits, it can be suggested the utilization of Fe+Zn+Cu treatment in the form of foliar spray in culture of durum wheat.

Key words: Durum wheat- Microelements- Yield- Yield components.

INTRODUCTION

Micronutrient deficiency is widespread in many Asian countries due to the calcareous nature of soils, high pH, low organic matter, salt stress, continuous drought, high bicarbonate content in irrigation water, and imbalanced application of NPK fertilizers. Some of the adverse effects of micronutrient deficiency-induced stress in plants include low crop yield and quality, imperfect plant morphological structure (such as fewer xylem vessels of small size), widespread infestation of various diseases and pests, low activation of phytosiderophores, and lower fertilizer use efficiency [8].

Qualitative and quantitative plant products can only be achieved if they are combined with proper plant nutrition. Besides the three macro elements (N, P, K) essential microelements are inevitable. Because of their function in the enzyme activity we have to give priority to the essential microelements copper and zinc in the nutrient supply of soil and plants. Their lack greatly influences both the quantity and the quality of plant products. Durum wheat has an especially sensitive response to these microelements. Agricultural soils usually show iron, copper and zinc deficiency. The average zinc content of the earth's crust is about 70 mg/kg, and its copper content about 55 mg/kg. Only a very small part of them (about 1 %) is in a form that is absorbable by plants [20].

The deficiency of micronutrients may either be primary, due to their low total contents or secondary, caused by soil factors that reduce their availability to plants [17]. Copper as an essential micronutrient for normal growth and metabolism of plants is well documented [16, 18]. The lack of these microelements can be restored through the soil or the foliage [20, 21]. Plants leaves ensure nutrient uptake for the development of plants [15]. Photosynthesis and the regulation of transpiration are the primary tasks of foliage. Because of their structure, leaves can uptake nutrients under certain conditions and to a certain extent only [20]. The advantage of nutrient uptake through the leaves is that it gets very quickly and directly to the leaf cells, where they are utilized.

Iron and zinc are essential elements for human nutrition [5]. Worldwide, cereals are a main staple for humans, but unfortunately, the concentrations of bioavailable Zn and Fe in grains are rather low and antinutrients such as phytic acid reduce the absorption of Fe and Zn into the body. The nutritional value of grains may be enhanced by increasing accumulation without reducing the availability of the metals or by increasing their bioavailability [4].

The role of essential microelements copper and zinc was proved in forming of more than 200 enzymes [19]. Lack of copper hinders nitrogen uptake and protein synthesis. It plays an important role in transpiration metabolism and electron transport. Copper plays a role in the redox processes in cells, and zinc in H-transportation reactions [15]. Micronutrient deficiency can greatly disturb plant yield and quality, and the health of domestic animals and humans [1, 9, 22]. The role of microelements in maintaining balanced plant physiology is becoming clearer every day as a result of studies on their reactions and the disturbances caused by their deficiency. Micronutrients are essential elements for life [8]. Micronutrients also play key roles in the release of carbon dioxide, and in optimizing the function of vitamin A and the immune system [13].

Kumar *et al.* [7] concluded that Cu fluxes and it's interactions with other micronutrients (Fe, Mn and Zn) affect the growth and yield of wheat plants. Application of Cu in excess amount may induce the deficiency of other micronutrients and adversely affect the yield. Experiments of foliar treatments were carried out with ion-exchanged zeolite on winter wheat for three years. The experiments were launched on small plots of calcareous Danube alluvial soil. On average of three years copper treatments were effective, if yield increase was set as a goal. As a result of zinc-zeolite the increase of raw protein was more favourable than that of copper-zeolite treatment [15].

Extensive research on the effects of micronutrient fertilizers on crop yield and quality has been conducted during the past decade [12]. Results of a broad-based study conducted in 815 irrigated wheat growing regions of Iran between 1995 and 1996 showed that addition of each micronutrient (Fe, Zn, Cu, and B) or a combination of Fe + Zn + Cu + B to NPK fertilizer increased grain yield. The highest yield was obtained by adding all the micronutrients to NPK fertilizer [10]. A 22-site study showed that NPK+ micronutrients increased significantly protein content of wheat kernel from 11.66% to 12.01% [8].

Micronutrient deficiency limits plant growth and affects crop yield, especially in calcareous soil. The results of many researches revealed that the application of balanced fertilization significantly increased grain yield. Field tests of more than 2500 different experiments have shown that micronutrients have a significantly positive effect on crop yield and quality. Studies of several researches have shown that micronutrients also ensure the efficient use of macronutrients [1, 2, 8, 9, 11]. The effect of micronutrients Fe, Cu and Zn alone or in combination with each other little was studied on durum wheat (*Triticum durum*). Therefore, our objective was to study the effect of above micronutrient on yield and yield components of durum wheat.

MATERIALS AND METHODS

Experiment was conducted in Kohgilooyeh, southwest of Iran, 2009-2010, in a strip split plot trial in randomized completely block design with 3 replications. Micronutrients were diluted in water (3 kg chelat ha^{-1}) and sprayed on foliage of durum wheat cv. Dehdasht (*Triticum durum*). Treatments were spraying time as main factor [at two levels including 2 weeks before flowering (max. tillering) and 50% flowering] and microelement fertilizer as sub-factor [at 8 levels including N_1=Fe, N_2=Zn, N_3=Cu, N_4=Fe+Zn, N_5=Fe+Cu, N_6=Zn+Cu, N_7=Fe+Zn+Cu and N_8= no spraying]. Several quantitative and qualitative traits were measured at desirable time or after harvest, including plant height (cm), peduncle length (cm), tiller number per plant, spike length (cm), thousand-kernel weight (g), grain number per spike, total number of florets per spike, fertile floret number per spike, sterile floret number per spike, grain yield (kg ha^{-1}), test weight (kg), economic yield (kg ha^{-1}), biological yield (kg ha^{-1}), spike number per unit area, harvest index(%), ash content (%), protein content (%) and fat content (%). Statistical analyses and mean comparisons were conducted using MSTATC software and graphs were drawn in Excel spreadsheet environment.

RESULTS AND DISCUSSION

Results of analysis of variance (ANOVA) for different traits are shown in Table 1. As seen, effect of spraying time was significant only in the case of test weight at 5% level, and in the case of grain number per spike, grain number per unit area and total floret number per spike it was significant at 10% level, indicating that spraying time had not a considerable effect on most of studied traits. However, micronutrient treatments had a significant effect on most of important traits including tiller number, 1000-kernel weight, spike length, grain number per spike and protein content (at 5% level) and plant height, total floret number per spike, sterile floret number per spike and ash content (at 1% level), indicating that durum wheat cv. Dehdasht differentially respond to micronutrient treatments.

Table 1A. Results of analysis of variance for 13 traits

S.O.V	d.f	Tiller number	Plant height	Total floret number	Fertile floret number	Sterile floret number	Thousand kernel weight
Replication	2	975.6	91.1	1.79	417.45	423.3	304.18
Spray time	1	527.6	567.2	3.20†	363.7	813.12	430.2
E(a)	2	152.1	758.18	0.26	473.4	876.1	633.5
Micronutrient	7	861.4*	104.82**	0.73	377.46**	658.9**	029.11*
E(b)	14	366.1	226.14	0.66	867.5	146.1	918.3
Spray time× micronutrient	7	606	291.5	0.29	297.6	851.1	754.8
E(c)	14	229.1	641.11	0.61	472.6	903	71.7

*†, * and ** show significance at 10%, 5% and 1% level of probability. E(a), E(b) and E(c) indicate errors of main plots, sub-plots and interaction effect, respectively.*

Table 1B.

S.O.V	d.f	Spike length	Grain number per spike	Protein content	Ash content	Test weight	Economic yield	Spike per m^2
Replication	2	1.358	4.371	6.136	0.006	19.22	2.77	10847.52**
Spray time	1	1.268	16.685†	0.442	0.060†	54.19*	0.56	352.08†
E(a)	2	0.391	1.253	0.662	0.007	2.88	0.15	31.02
Micronutrient	7	0.573*	11.163*	1.011*	0.156**	12.44†	0.53	868.37†
E(b)	14	0.175	2.762	0.33	0.33	4.87	0.30	359.31
Spray time× micronutrient	7	0.437*	0.621	2.027†	0.72	10.81**	0.52†	410.08
E(c)	14	0.131	4.760	0.88	0.34	2.12	0.21	835.24

Effect of spraying time

Spraying time had a significant effect only on test weight at 5% level, although had a weaker effect (at 10% level) on total floret number, grain number per spike, spike number per unit area and ash content (Table 1). In table 2 the means of different traits at two spraying time was compared. As seen, spraying at maximum tillering increased the mean of total floret number, grain number per spike, spike number per unit area. However, spraying at 50% flowering increased mean of test weight and ash content.

Table 2. Comparison between the effects of two time of foliar spraying of micronutrients

Spraying time	Test weight	Flower/spike	Grain/spike	Spicke/m2	Ash(%)
Max. tillering	79.883^B	3.867^A	33.237^A	283.667^A	1.770^B
50% flowering	82.008^A	3.350^B	32.058^B	278.250^B	1.841^A
S.E	0.346	0.105	0.229	1.137	0.17

Means with common letters have no significant differences at 5% level.

Main effect of microelements

Micronutrient treatments had significant effects on tiller number, 1000-kernel weight, spike length, grain number per spike and protein content at 5% level, and had significant effects on plant height, total floret number per spike, sterile floret number per spike and ash content at 1% level (Table 1).

Tiller number and plant height

Effect of micronutrients on fertile tiller number and plant height was illustrated in Figure 1. As seen, all the micronutrients had positive effects on these traits compared to control (N_8). Although were not observed significant differences between effect of all the treatments, in the case of tiller number N_6 treatment (Cu+Zn) and in the case of plant height N_7 treatment (Fe+Cu+Zn) showed highest effect, 16.6% and 15.5% relative to control, respectively.

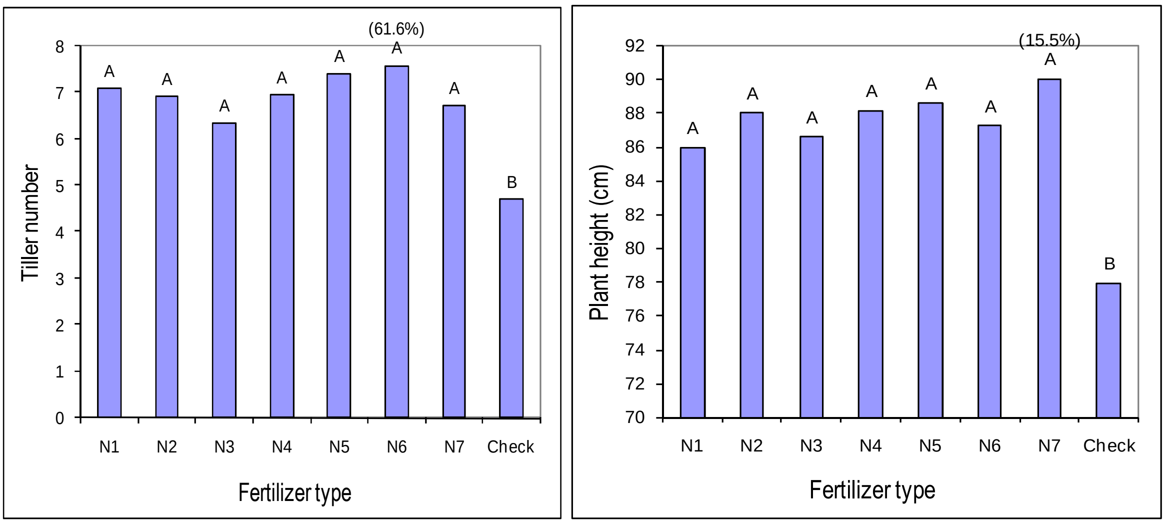

Figure 1. Graphical illustration for comparison of the effect of different micronutrients on tiller number and plant height

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Note: means with common letters have no significant differences at 5% level. Value of increase/decrease in the mean of a given trait (in per cent) was shown above the column of a treatment with highest effect (relative to check).

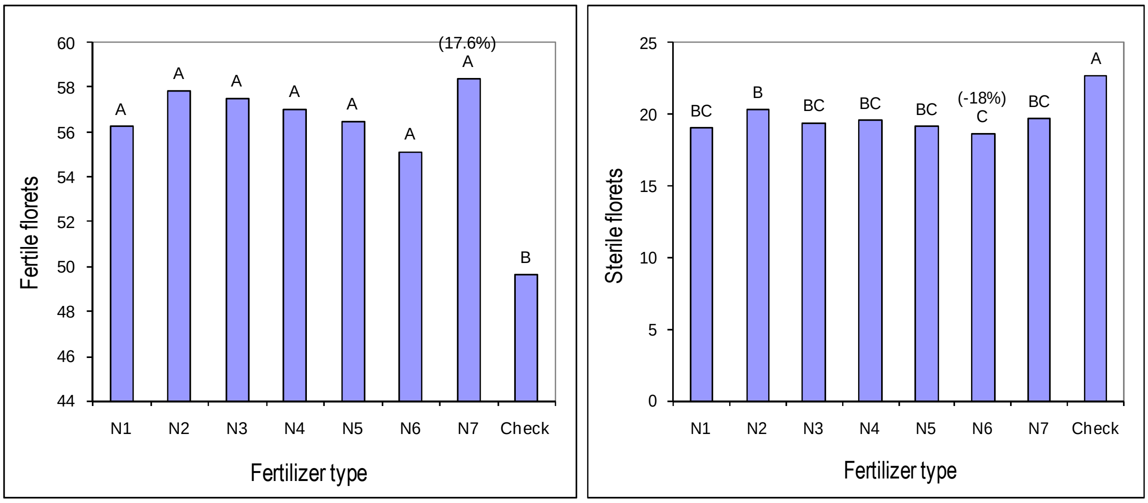

Figure 2. Graphical illustration for comparison of the effect of different micronutrients on fertile floret and sterile floret number per spike

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Note: means with common letters have no significant differences at 5% level. Value of increase/decrease in the mean of a given trait (in per cent) was shown above the column of a treatment with highest effect (relative to check).

Fertile florets and sterile florets

Effect of micronutrients on fertile floret and sterile floret number per spike was shown in Figure 2. As seen, all the micronutrients had positive effects on former trait and negative effect on later one compared to control (N_8). Although were not observed significant differences between effect of all the treatments, in the case of fertile floret number N_7 treatment (Fe+Cu+Zn) and in the case of sterile floret number N_6 treatment (Cu+Zn) showed highest effect, 17.6% and -18.0% relative to control, respectively.

Thousand-kernel weight and spike length

Effect of micronutrients on thousand-kernel weight and spike length was illustrated in Figure 3. As seen, all the micronutrients had positive effects on these traits compared to control (N_8). Although were not observed significant differences between effect of all the treatments (except for N_1 treatment in the case of former trait), in the case of thousand-kernel weight N_7 treatment (Fe+Cu+Zn) and in the case of spike length N_2 treatment (Zn) showed highest effect, 9.2% and 13.4% relative to control, respectively.

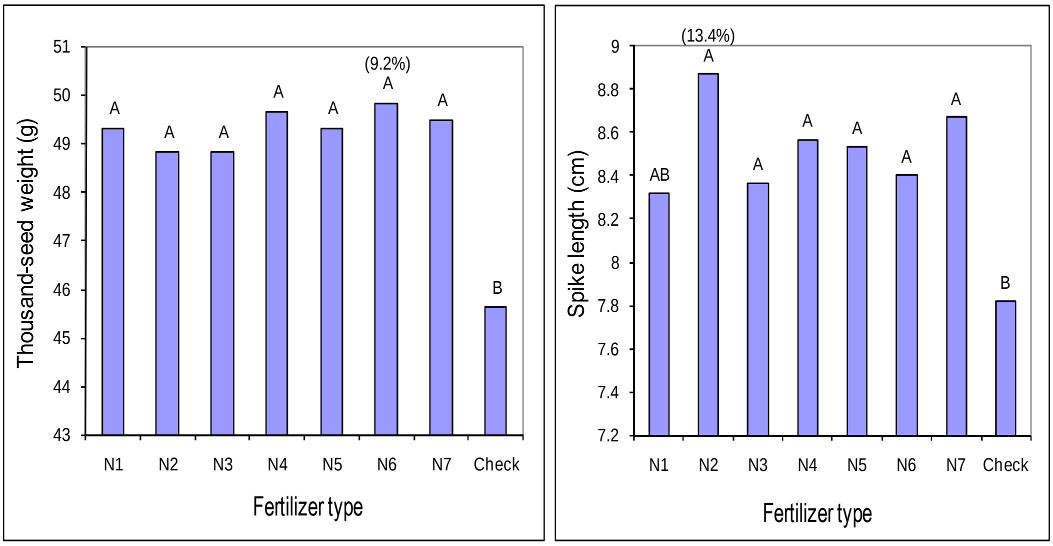

Figure 3. Graphical illustration for comparison of the effect of different micronutrients on thousand-kernel weight and spike length

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Note: means with common letters have no significant differences at 5% level. Value of increase/decrease in the mean of a given trait (in per cent) was shown above the column of a treatment with highest effect (relative to check).

It was commonly believed that the thousand-kernel weight index was genetically determined, and that nutrient management would not affect this parameter in wheat. This notion was tested in a greenhouse and fields between 1996 and 1998 [12]. The results of these researches revealed that the thousand-kernel weight increased from 44.0 g to 48.4 g pot^{-1} (10% increase) due to balanced fertilization, in the greenhouse experiment. The field experiment also showed an increase in mean thousand-kernel weight from 38.49 g to 38.94 g due to balanced fertilization. The effect of balanced fertilization on the mean thousand-kernel weight index value of different wheat cultivars tested ranged between -4.5-3.2% [12].

Grain number per spike and ash content

Effect of micronutrients on grain number per spike and ash content was illustrated in Figure 4. As seen, all the micronutrients had positive effects on these traits compared to control (N_8). Although were not observed significant differences between effect of all the treatments, in the case of grain number per spike N_7 treatment (Fe+Cu+Zn) and in the case of ash content N_1 treatment (Fe) showed highest effect, 14.3% and 36.7% relative to control, respectively.

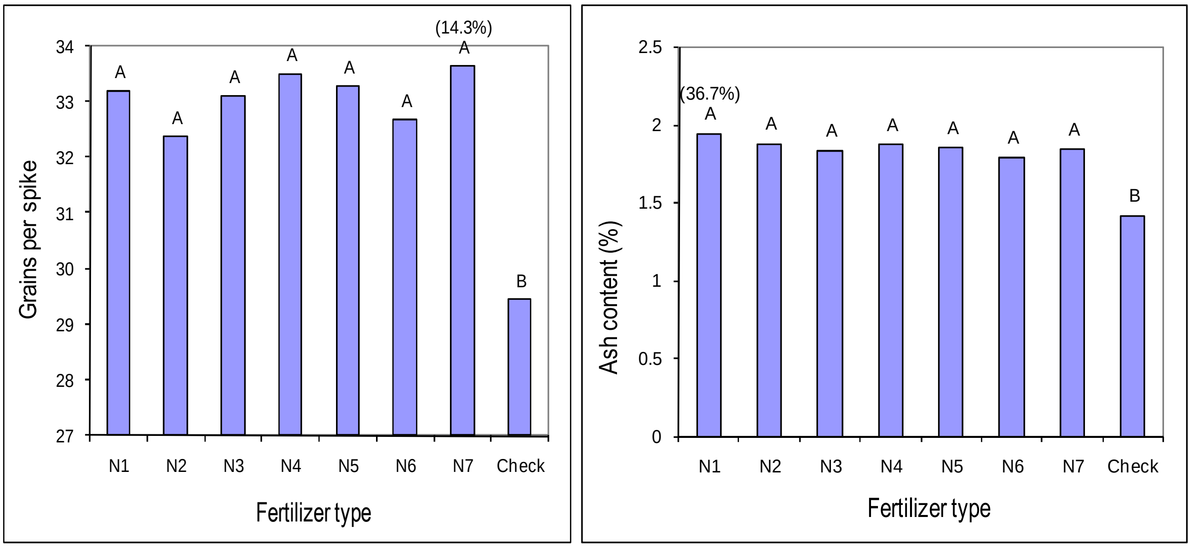

Figure 4. Graphical illustration for comparison of the effect of different micronutrients on grain number per spike and ash content

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Note: means with common letters have no significant differences at 5% level. Value of increase/decrease in the mean of a given trait (in per cent) was shown above the column of a treatment with highest effect (relative to check).

Protein content and economic yield

Effect of micronutrients on protein content and economic yield was illustrated in Figure 5. As seen, all the micronutrients had positive effects on these traits compared to control (N_8). Although were not observed significant differences between effect of most treatments, except for N_1, N_3 and N_4 on protein content, N_2 treatment (Zn) showed highest effect (9.6%) relative to check. In the case of economic yield, only $N_{4\text{-}6}$ treatments showed significant differences compared to other treatments including check. However, N_5 treatment (Fe+Cu) showed highest positive effect (34.1%) compared to check.

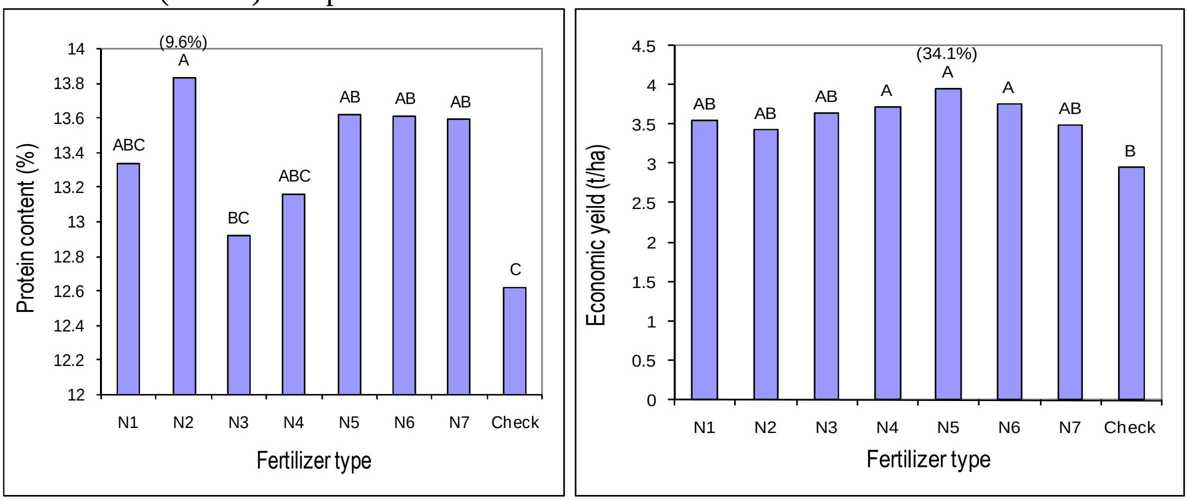

Figure 5. Graphical illustration for comparison of the effect of different micronutrients on protein content and economic yield

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Note: means with common letters have no significant differences at 5% level. Value of increase/decrease in the mean of a given trait (in per cent) was shown above the column of a treatment with highest effect (relative to check).

Sharma *et al.* [3] observed an increased protein content and yield in their experiments. The same results achieved Peterson et al. [14], Han and Shepherd [6]. They reported that higher copper and zinc content resulted in higher protein content. A 22-site study showed that NPK+ micronutrients increased significantly protein content of wheat kernel from 11.66% to 12.01% [8]. The results by Malakouti et al. [12] revealed that due to the use of micronutrients grain yield showed an increase of 17% in the greenhouse experiment. The field experiment also showed a mean yield increase from 4353 kg ha^{-1} to 4640 kg ha^{-1} (6.6% increase), due to balanced fertilization.

Spray time × micronutrient interaction

Foliar spraying at different times (maximum tillering and 50% flowering) had a significant effect on test weight and spike length at 1% and 5% level, respectively (Table 1). The effect of different micronutrients at maximum tillering stage on test weight and spike length traits has been compared in Table 3. As seen, all the treatments had positive effects on these traits as compared to check. However, N_5 (Fe+Cu) treatment showed highest positive effect on test weight (82.0 vs. 77.61 kg), and N_2 (Zn) treatment showed highest positive effect on spike length (9 vs. 7.76 cm).
The effect of different micronutrients at 50% flowering stage on test weight and spike length traits has been compared in Table 3. As seen, all the treatments had positive effects on these traits as compared to check. However, N_3 (Cu) treatment showed highest positive effect on test weight (83.33 vs. 77.33 kg), and N_4 (Fe+Zn) treatment showed highest positive effect on spike length (8.80 vs. 7.72 cm).

Table 3. Comparison of micronutrient effects at maximum tillering stage on different traits at 5% level.

Treatment	Test weight		Spike length (cm)	
	Max. tillering	50% flowering	Max. tillering	50% flowering
N1	80.33^{BC}	81.33^{ABC}	8.20^{BC}	8.43^{ABC}
N2	80.00^{BC}	82.67^{AB}	9.00^{A}	8.73^{AB}
N3	81.67^{ABC}	83.33^{A}	8.47^{AB}	8.27^{BC}
N4	80.33^{BC}	82.33^{AB}	8.33^{AB}	8.80^{AB}
N5	82.00^{ABC}	80.67^{ABC}	8.33^{AB}	8.73^{AB}
N6	81.67^{ABC}	82.33^{AB}	8.13^{BC}	8.67^{AB}
N7	79.33^{CD}	81.67^{ABC}	8.67^{AB}	8.67^{AB}
N8 (check)	77.61^{D}	77.33^{D}	7.76^{C}	7.72^{C}
S.E	0.841		0.209	

Treatments were N1=Fe, N2=Zn, N3=Cu, N4=Fe+Zn, N5=Fe+Cu, N6=Zn+Cu, N7=Fe+Zn+Cu and N8= no spraying. Means with common letters have not significant differences at 5% level.

Taking altogether, our results indicate more important role of Zn for better performance of durum wheat, because in 9 out of 13 traits studied here Zn-containing treatments showed a positive effect (either as a single treatment or in combination with 2 micronutrients Fe and Cu) on given traits. After Zn, Cu-containing treatments showed more essential role, and Fe played a weaker role. Other researchers also showed that among micronutrients, Zn deficiency is the most detrimental to effective crop yield [8, 9, 12].

CONCLUSION

Our results in accordance to Malakouti [9] suggest that if only one micronutrient was to be utilized in wheat culture, Zn is obviously the best choice for improvement of yield and its components. If economic issues are not a case, we suggest utilization of the combined treatment of Fe+Zn+Cu as foliar treatment in durum wheat culture.

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