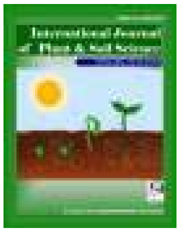

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Effect of Combined Application of Different Micronutrients on Productivity and Quality of Sugar Beet Plants *(Beta vulgaris* L.)

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Authors' contributions

Authors cooperate together in all the steps of the experiment until it is in the final version.

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ABSTRACT

The experiments were conducted throughout two successive winter seasons 2010/2011 and 2011/2012 at Belquas, Dakahlia Governorate, Egypt. The aim of this work was to investigate the effect of foliar application with different micronutrients with excluding one element each treatment and its addition times on the productivity and quality of sugar beet plants. The treatments were six combinations of micronutrients, T0 (spraying with water),T1 (Fe+Zn+Mn+B), T2 (T1-Fe), T3 (T1-Zn), T4 (T1-Mn), T5 (T1-B) and two application times (once after 60 days from sowing or twice after 60 and 90 days from sowing) at 50ppm for each in the form of (Zinc sulphate, Manganese sulphate and Boric acid) and 100ppm in the form of Iron sulphate. Results indicated that, T1 recorded the highest values for yield characters i.e. root, top and sugar yields as well as root weight and dimensions as compared with other treatments followed by T2. Moreover, the results concluded that T1 treatment produced the maximum sucrose %, purity %, recoverable sugar % and white sugar yield followed by T2 in both seasons, this proving that Fe was the least effective microelement on productivity and quality traits of sugar beet. On the other hand, T3 and T4 recorded the lowest values of all yield and yield components and this may be due to the role of Zn and Mn in plant growth as well as their effect as metal components of some enzymes. Furthermore, Zn and B followed by Mn positively affected the impurities content i.e. K, Na and amino N % as well as sucrose loss to molasses, so

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the absence of Zn or B have more impact on sugar beet quality. The obtained results showed that foliar application with micronutrients twice (60 and 90 days) after sowing significantly increased root, top and recoverable sugar yield and improved sucrose % and purity % in both seasons. Generally, it could be concluded that spraying micronutrients mixture twice (Fe+Zn+Mn+B) produce the highest productivity and quality of sugar beet under the environmental conditions of Dakahlia Governorate.

Keywords: Sugar beet; foliar application; iron ; zinc ; manganese; boron; yield; quality.

1. INTRODUCTION

Sugar beet (*Beta vulgaris L.*) is considered the second source for sugar production in Egypt and in many countries all over the world. The Egyptian government encourages sugar beet growers to increase the cultivated area with sugar beet to increase sugar production and decrease the gap between sugar production and consumption. There are several advantages favoring sugar beet as a suitable crop in Egypt. The crop is annual grows during the winter season, with a relatively short duration period and allows for growing a summer crop during the same year. Proper plant nutrition is an important factor for improving productivity and quality of agricultural production. Boron is the most important trace element needed by sugar beet because without an adequate supply the yield and quality of roots is very depressed [1]. Root fresh weight, sucrose %, root and top yields significantly increased by increasing boron levels [2,3]. Thus, application of boron fertilizer to sugar beet cultivars significantly increase the root yield and yield components and also increased recoverable sugar percent and sugar yield, while decreased Na and K in root juice. Since the impurities decreased, therefore the juice purity % increased. Micronutrients often act as co-factors in enzyme activating and participate in redox reactions, photosynthesis and respiration. It has essential role in promoting cell wall formation, carbohydrate metabolism, and has been associated with sugar translocation process [4] In agricultural development programs role of micronutrients is very important to increase crop yield and quality. So balanced and efficient use of micronutrients fertilizers such as manganese (Mn), boron (B), zinc (Zn), and iron (Fe) can improve agricultural production and quality [5]. A research work by [6] stated that sugar beet crop has high requirements for boron (B) and it is required for all plant growth. Adequate B nutrition is critical for high yields and quality of crops. They added that boron increases the rate of transport of sugars which are produced by photosynthesis in mature plant leaves to actively growing regions and also in developing fruits. In this concern, [7] stated that micronutrients such as iron, manganese and zinc have important roles in plant growth and yield of aromatic and medicinal plants. A work by [8] also stated that application of 50ppm boron significantly improve the parameters of the yield of roots and above ground and nutrient contents and balance ratio of sugar beet. Moreover, [9] showed that nutrient treatments had significant effect on grain yield, 1000 grain weight, spike weight and biological yield in barley. The aim of this work was to investigate the effect of foliar application with different micronutrients with excluding one element each treatment and its addition times on the productivity and quality of sugar beet plants.

2. MATERIALS AND METHOD

The experiment were conducted throughout two successive winter seasons 2010/2011 and 2011/2012 at Belquas, Dakahlia Governorate, Egypt. The experiment included twelve treatments where as follow: six combinations of micronutrients, T_0 (spraying with water),T_1

(Fe+Zn+Mn+B), T_2 (T_1-Fe), T_3 (T_1-Zn), T_4 (T_1-Mn), T_5 (T_1-B) at 50ppm for each in the form of (Zinc sulphate, Manganese sulphate and Boric acid) and 100ppm in the form of Iron sulphate and two application times (once after 60 days from sowing or twice after 60 and 90 days from sowing). The experimental design was a split–plot design with four replicates. The main plots were occupied by the number of spraying with micronutrients treatments while the combinations of different micronutrients were distributed in sub-plots. Sub- plot area was $21/m^2$ (6 ridges 7m long and 50cm. apart).Seeds of sugar beet (*Beta vulgaris* L.) cv. Raspoly were sown in hills 20cm a part on 1st and 3rd October 2010 and 2011, respectively. Plants were thinned to one plant per hill after 30 days from sowing. Phosphorus at the rate of 31 kg P_2O_5 / fed. In the form of super phosphate (15.5% P_2O_5) was added before sowing. Nitrogen fertilizer was added at the recommended rate of 84Kg N / fed. In the form of urea (46% N) in two equal doses, the first dose was added at thinning and the second one was added after 30 days later. Potassium at the rate of 25kg K_2O/fed. In the form of potassium sulphate (48%K_2O) was added after thinning. The other agronomic practices were done as recommended. The soil of the experiments was clay loam texture. Chemical analysis of soil samples at 0 and 30cm depth in experimental sites before soil preparation is presented in Table 1 according to methods described by [10].

Table 1. Chemical analysis of experimental soils in both seasons

Season	pH	EC dsm^{-1}	O.M%	$CaCO_3$%	P	K	Na	Mg	Fe	Mn	Zn	Cu	B
					mg / 100 g				ppm				
2010/11	8.38	0.99	1.93	2.23	4.16	40.14	79.20	187.3	8.25	4.40	1.03	2.24	0.33
2011/12	8.17	1.26	2.10	2.50	3.51	43.38	68.14	209.0	7.50	4.50	1.79	2.56	0.38

At harvest time (195 days from sowing) ten guarded plants were taken at random from each plot in the two seasons to determine root dimensions (length and diameter cm) and fresh root weight (kg). The plants were harvested from the four middle rows of each plot to determine the top and root yields ton/fed. Fifteen roots were chosen randomly to determine quality and impurities content. Sucrose percentage as described by [11]. Total Soluble Solids (TSS %) was determined by using digital refractometer. Juice purity percentage was estimated using method of [12]. Recoverable sugar % was calculated according to [13] given as;

$$RS\%=[(Pol\%-0.29)-0.343(K+Na)-0.093\ \alpha \text{ amino N}] \qquad (1)$$

The sucrose loss to molasses was evaluated based on [13] whereas [K, Na and amino-N in meq /$100g^{-1}$ beet];

$$SM\%=0.343\ (K+NA)+(0.093\ \alpha \text{ amino N})+0.31) \qquad (2)$$

The recoverable sugar yield was calculated according to the following equation: Recoverable sugar % x root yield. Potassium and Sodium were measured in the root dry weight at harvest time. Using the Flame photometer and the blue number method, α amino nitrogen was also calculated by double beam filter photometry [14]. Data of two seasons were statistically analyzed according to [15], and the combined analysis was done according to [16], then the treatments means were compared using LSD test at 5% of probability.

3. RESULTS AND DISCUSSION

3.1 Effect of Foliar Application with Micronutrients and Its Addition Time on

3.1.1 Yield and yield components

Data in Table 2 showed significant positive effect on root dimension and root weight. Spraying micronutrients twice after 60 and 90 days from sowing significantly increase root characters with root length (41.82cm), root diameter (15.72cm) and root weight (1.49kg) compared with spraying one after 60 days from sowing with root length (38.96cm), root diameter (15.72cm) and root weight (1.39kg). The increase in root dimensions and weight are attributed to the numbers of increasing cells due to the increasing concentration of the micronutrients especially Iron, Boron, Zinc and Manganese. These results are in agreement with those of [17,18] and [19]. Also, the obtained results indicated that yields of root, top and white sugar were significantly affected by the number of spraying with micronutrients. Addition of micronutrients twice gave the highest yields of root, top and white sugar (32.22, 14.90 and 5.49ton/fed) respectively. These results are in agreement with those obtained by [19]. This positive effect recorded is because sugar beet plants have high requirements for microelements such as B, Zn, Mn and Fe since these elements have essential roles in plant growth. It has been published [2] that adequate B and Zn nutrition is critical for high yields and quality of crops. According to [2], root fresh weight significantly increased by increasing boron levels. A work by [6] stated that Boron is required for all plant growth of sugar beet. The positive effect of Fe, B, Zn and Mn on plants may be due to their effect as metal components of some enzymes or regulatory for others. Moreover, they have an essential role in plant metabolism [7]. Results in Table 2 indicated that all micronutrients treatments had a significant positive effect on yield and yield components compared with control treatment (spraying with water). Application mixture of all micronutrients (T_1 (Fe+Zn+Mn+B)) super passed other treatments effect followed by T_2 (T_1–Fe) on root length and yields of root, top and white sugar per fed, this proving that Fe has the lowest positive effect on productivity and quality traits of sugar beet . The lowest values of root length (38.88 and 39.88cm) and root yield (30.93 and 31.12ton/fed) top yield (14.15 and 13.88ton/fed) and white sugar yield (5.08 and 5.19ton/fed) were recorded by application micronutrients without Mn and Zn (T_4) and (T_3), respectively. This means that when excluding Mn or Zn in the micronutrients treatments brings about negative effect on the quantity of sugar beet. This is because Zinc and Manganese are essential elements for crop production and optimal size of fruit, Also Zn is required in the carbonic enzymes which are present in all photosynthetic tissues, and are required for chlorophyll biosynthesis. Also excluding Boron (T_5) from mixture of the micronutrients resulted in the lowest values of root diameter (14.43cm), root weight (1.39kg). This is because Boron is essential for providing sugars which are needed for root growth plant. In addition, Boron is by far the most important of the trace elements needed in sugar beet crop because without an adequate supply, the yield and quality of roots is very depressed [3] and [1]. A work by [6] also stated that sugar beet crop has high requirements for B, and is required for all plant growth and adequate of it is critical for high yield of crops.

3.1.2 Effect of interaction

Concerning the interaction effects between spraying times and foliar spraying with micronutrient treatments on yield and yield components data in Table 3 indicated that spraying micronutrient solution T_1 (Fe+Zn+Mn+B) twice (after 60 and 90 days from sowing) gave the largest and tallest root per plant, and the highest values of top yield and white sugar yield (15.90 and 5.89ton/fed) respectively, followed by T_2 (T_1-Fe). While the lowest values of root, top and white sugar yields recorded by T_3 (T_1-Zn) and T_4 (T_1-Mn), When spraying once (after 60 days from sowing). These results are in agreement with those of [19] that reported that fertilized plants by 95Kg N/Fed and twice sprayed with micronutrients was significantly increased top, root and sugar yields. The negative effect resulted from the absence of either Zn or Mn may be due to their effects as metal components of some enzymes or regulatory of others. Moreover, they have an essential role in plant metabolism. Work by [20,7] and [21] showed that zinc has an important role on most enzymes structure such as dehydrogenises, aldolase and is affective in energy production and crebs cycle.

3.2 Effect of Foliar Application with Micronutrients and Its Addition Time on

3.2.1 Quality parameters and impurities content

Data presented in Table 4 showed clearly that the effect of number of spraying by micronutrients was significant on purity % and recoverable sugar %, while insignificant effect on sucrose %, sucrose loss to molasses (S.M%), and impurities content i.e. K, Na and α Amino nitrogen contents. Significant increase in purity % and recoverable sucrose % when plants sprayed twice due to increasing in sucrose % and decreasing impurities contents and sucrose loss to molasses % at the same condition. On contrast, K, Na and α amino nitrogen contents were decreased in these treatments. Also in Table 4 indicated that application different combined with micronutrients had a significant positive effect on quality traits i.e. sucrose %, purity % and recoverable sugar % in comparison with untreated plants (T_0). Foliar spraying with different micronutrients elements that led to a positive increase in sucrose, purity and recoverable sugar percentages are reported by [2,3] and [21]. The work by [6] also stated that adequate B is critical for high yields and quality of crops, boron increases the rate of transport of sugars which are produced by photosynthesis in mature plant leaves to actively growing regions and also in developing fruits. In addition, [22] cleared that spraying solution with four elements (Fe,Zn,Mn,Cu) significantly increase yield components and improve quality in barley plant. When spraying with micronutrients without B (T_5) the quality parameters are decreased followed by (T_4) while impurities i.e. K, Na and α amino nitrogen percentages were increased, also sucrose loss to molasses was increased. On the other hand, spraying without Fe (T_2) has the lowest positive effect on juice quality of roots. This means that sugar beet has high requirements of B and Zn for improving yield quality [3,6]. Spraying with complete micronutrients elements recorded the highest values of sucrose, juice purity and recoverable sucrose percentages (20.95, 84.61,17.56) respectively followed by spraying micronutrients without Fe (T_3).On contrast, Na, K, and α Amino nitrogen contents were gradually decreased under the same conditions.

Table 2. Effect of foliar application with micronutrients and its addition time on yield and yield component

Treatments	Root length (cm)	Root diameter (cm)	Root weight (kg)	Root yield (Ton)	Top yield (Ton)	White Sugar yield (Ton)
Micronutrients addition times						
60 day	38.96	14.67	1.39	31.17	14.18	5.17
60 & 90 day	41.82	15.72	1.49	32.22	14.90	5.49
LSD at 5%	1.15	0.43	0.03	0.37	0.28	0.12
Micronutrient treatments						
T_0=(spraying with water)	38.18	14.00	1.27	29.97	13.30	4.67
T_1 =(Fe+Zn+Mn+B)	41.51	14.43	1.39	32.51	15.35	5.71
T_2 =(T1-Fe)	41.21	15.62	1.49	32.01	14.76	5.46
T_3 =(T1-Zn)	39.88	14.90	1.40	31.12	13.88	5.19
T_4 =(T1-Mn)	38.88	15.81	1.50	30.93	14.15	5.08
T_5 =(T1-B)	40.45	14.43	1.39	31.91	14.55	5.23
LSD at 5%	0.39	0.18	0.04	0.24	0.23	0.1

Table 3. The interaction effect between application of micronutrients and addition time on yield and yield component

Treatments	Root length (cm)		Root diameter (cm)		Root weight (kg)		Root yield (Ton)		Top yield (Ton)		White sugar yield(Ton)	
	60 day	60 & 90 day	60 day	60 & 90 day	60 day	60 & 90 day	60 day	60 & 90 day	60 day	60 & 90 day	60 day	60 & 90 day
T_0=(spraying with water)	37.80	38.10	14.20	14.38	1.30	1.28	30.20	30.88	13.25	13.40	4.75	4.90
T_1 =(Fe+Zn+Mn+B)	39.93	43.10	15.15	16.30	1.46	1.59	31.76	33.25	14.80	15.90	5.53	5.89
T_2 =(T_1-Fe)	39.93	42.50	14.80	16.33	1.43	1.53	31.54	32.47	14.41	15.10	5.31	5.61
T_3 =(T_1-Zn)	38.15	41.60	14.48	15.30	1.34	1.44	30.60	31.65	13.66	14.10	5.02	5.35
T_4 =(T_1-Mn)	37.60	40.15	14.18	14.98	1.31	1.38	30.47	31.39	13.84	14.46	4.92	5.24
T_5 =(T_1-B)	39.18	41.73	14.73	15.68	1.44	1.52	31.49	32.32	14.16	14.93	5.09	5.37
LSD at 5%	0.55		0.25		NS		NS		0.32		0.10	

Table 4. Effect of foliar application with micronutrients and its addition time on quality parameters and impurities content

Treatments	Sucrose %	Potassium %	Sodium %	α Amino nitrogen	Purity %	Recoverable sugar %	Sucrose loss to molasses
Micronutrients addition times							
60 day	20.17	6.25	2.05	4.39	82.41	16.59	3.56
60 & 90 day	20.49	6.22	1.97	4.18	83.08	17.05	3.5
LSD at 5%	NS	NS	NS	NS	0.1	0.22	0.06
Micronutrient treatments							
T_0=(spraying with water)	19.20	6.40	2.11	4.58	81.25	15.57	3.66
T_1 =(Fe+Zn+Mn+B)	20.95	6.11	1.88	3.86	84.61	17.56	3.41
T_2 =(T_1-Fe)	20.56	6.20	2.01	4.13	83.17	17.06	3.52
T_3 =(T_1-Zn)	20.19	6.22	2.01	4.52	82.55	16.66	3.55
T_4 =(T_1-Mn)	19.98	6.30	2.09	4.45	81.90	16.41	3.59
T_5 =(T_1-B)	19.96	6.33	2.05	4.47	81.49	16.39	3.59
LSD at 5%	0.26	0.16	0.07	0.23	0.75	0.25	0.07

Table 5. The interaction effect between application of micronutrients and addition time on quality and Impurities Content of sugar beet

Treatments	Sucrose %		Potassium %		Sodium %		α Amino nitrogen		Purity %		Recoverable sugar %		Sucrose loss to molasses	
	60 day	**60 & 90 day**	**60 day**	**60 & 90 day**	**60 day**	**60 & 90 day**	**60 day**	**60 & 90 day**	**60 day**	**60 & 90 day**	**60 day**	**60 & 90 day**	**60 day**	**60 & 90 day**
T_0=(spraying with water)	19.40	19.47	6.40	6.38	2.20	2.14	4.67	4.65	81.67	81.99	15.73	15.83	3.70	3.66
T_1 =(Fe+Zn+Mn+B)	20.78	21.13	6.18	6.05	1.90	1.86	3.82	3.91	84.24	84.98	17.40	17.72	3.43	3.38
T_2 =(T_1-Fe)	20.46	20.67	6.20	6.20	2.04	1.98	4.30	3.96	83.04	83.30	16.83	17.29	3.54	3.51
T_3 =(T_1-Zn)	19.93	20.46	6.17	6.27	2.00	2.01	4.61	4.44	82.40	82.69	16.40	16.91	3.54	3.57
T_4 =(T_1-Mn)	19.86	20.10	6.34	6.26	2.18	2.01	4.56	4.33	81.43	82.36	16.14	16.68	3.66	3.52
T_5 =(T_1-B)	19.82	20.11	6.35	6.30	2.11	1.99	4.66	4.28	80.93	82.05	16.15	16.62	3.64	3.55
LSD at 5%	NS		NS		0.11		0.24		0.23		0.07		0.11	

3.1.3 Effect of interaction

Juice quality and impurities content of sugar beet plant are affected by foliar micronutrients and its addition time. Data in Table 5 indicated that purity and recoverable sugar (R.S.) percentages were significantly affected by the interaction between foliar spraying micronutrients and its application times. Data in Table 5 indicated the highest values of purity and recoverable sugar (R.S) percentages when plants sprayed twice with mixture of all micronutrients and the lowest R.S. % was noticed when plants sprayed with water (untreated plant). Also, data showed that the lowest purity percentages was noticed when plants sprayed once with micronutrient without boron (T_5) followed by without Zn (T_4). This means that sugar beet plants have high requirements of B and Zn [6]. The work by [1] stated that B is the most important trace element needed by sugar beet, without B supply the yield and quality of roots is very depressed. The same Table, data showed that impurities content such as K, Na, α amino nitrogen and sucrose loss to molasses (S.M%) were significantly affected by interaction between foliar spraying and number of spraying except K%. The highest values of these traits were obtained when plants sprayed with water (T_0), while spraying twice with complete micronutrients significantly reduce impurities content and increase sucrose % and purity %. These results are in agreement with those obtained by [5]. On the other hand, [19] pointed out that spraying with water significantly increase sugar percentages, while purity percentage was not affected by interaction between N level and number of sprayings.

4. CONCLUSION

Applying solution of complete micronutrients (Fe+Zn+Mn+B) twice after 60 and 90 days from sowing recorded the highest values of all characteristics of quantity and quality of sugar beet plants compared to untreated plants (spraying with water). On the other hand, spraying once after 60 days from sowing with excluding Mn and Zn gave the lowest values of root characters and yields of root, top and white sugar. Moreover, excluding B recorded the lowest values of quality characters such as sucrose, purity and recoverable sugar contents. In general, it can be concluded that Zn and B has an important roles in increasing productivity and improving quality of sugar beet plants. While Fe element was the lowest positive effect. Generally, it could be concluded that spraying micronutrients mixture twice (Fe+Zn+Mn+B) at 60 and 90 days from sowing produce the highest productivity and quality of sugar beet under the environmental conditions of Dakahlia Governorate, Egypt.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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