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Influence of Iron Levels and Foliar Application Times on Productivity and Quality of Sugar Beet

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ABSTRACT

A field trial was performed at Tag El-Ezz Research Station, Governorate of Dakahlia, Egypt, in 2015/2016 & 2016/2017 seasons to find out the impact of levels and times of foliar application of iron fertilizer on productivity and quality of sugar beet cv. Sultan. The experiment was arranged in design of strip-plot with three replicates during both seasons. Levels of iron foliar application (untreated "without spraying ", spraying solution of Fe-EDTA at the levels of 500, 750 and 1000 ppm) put in the vertical-plots. The horizontal plots were devoted to five times of foliar application (60, 75, 90, 105 and 120 days after sowing "DFS"). We can summarize the given results as follows:- The greatest averages of all considered traits were achieved when spraying plants with solution of Fe-EDTA (1000 ppm). The second best level of Fe foliar fertilizer was 750 ppm and followed by foliar spraying plants with 500 ppm Fe during both seasons. Adversely, control treatment gave the lowest averages of all considered traits in the two seasons. -Foliar spraying plants with Fe-EDTA after 90 DFS attained the greatest values of all considered traits and followed by spraying with Fe-EDTA after 105 DFS, 120 DFS, then 75 DFS and lastly 60 DFS ranked secondly during the two seasons. It can be concluded that foliar spraying plants of sugar beet with the solution of Fe- EDTA (1000 ppm concentration) after 90 days from sowing to gave the upper limits of yields and quality under climate and nature of agricultural lands in Dakahlia Governorate, Egypt.

Keywords: Sugar beet, iron foliar application levels, iron foliar application times, yields, quality.

INTRODUCTION

Sugar beet is a specially type of *Beta vulgaris* L. which grown for sugar production. It is one of main sugar crops in Egypt as well as many countries all over the world with sugar cane (*Sacchurum officinarum* L.). The importance of sugar beet to agriculture is not only confined to sugar production, but also, used to produce many of products.

Micronutrients, such as transition metals like Fe is necessary element in favor of growth and development of the living plants. These micronutrients are found in most redox reactions besides its essential role in cellular processes, proteins, enzymes structural and catalytic enzyme activities (Hall and Williams, 2003).Thereby, using optimum level and time of foliar application of iron (Fe) fertilizer are among factors that enhance sugar beet growth and productivity. Yet, micronutrients fertilizers (like Fe) soil application in the cultivation may not meet the crop prerequisite for growth and nutrient use, therefore the alternative effective method is to apply Fe as a foliar spraying, which can be a cheaper, more environmentally-friendly(Shalaby, 1998).

Iron deficiency is a disorder affecting crops in numerous areas of the world, mainly connected with high pH, calcareous soils that make soil Fe unavailable for plants (Abadía *et al.*, 2011). Iron deficiency has a large economic impact, because crop quality and yield can be severely compromised (El-Jendoubi *et al.*, 2011). Fe nutrient deficiency affects photosynthesis through, Fe stress alters chloroplast ultra structure and protein and lipid composition of thylakoid membranes; it reduces electron transport capacity in thylakoids; and it diminishes noncyclic ATP formation and leaf ATP levels (Nishio *et al.*, 1985 and Arulanantham *et al.*, 1990). Shafika and El-Masry (2006) deduced that root growth, quality parameters, root and sugar yields/fad were significantly increased due to spraying via micronutrients mixture (Zn, Mn and Fe). Hussein, Manal (2011) showed that spraying with solution of micronutrients mixture (B + Zn + Mn + Fe) at the level of 2cm/L/400L water/fad significantly increased root length and diameter, weight of fresh roots, sucrose %, yields of root and sugar per faddan as compared with without micronutrients (control treatment). Mamyandi *et al.* (2012) stated that Nano-iron spraying time significantly affected root diameter and length. Moreover Fahad *et al.* (2014) reported that iron deficiency impairs many plant physiological processes because it is involved in chlorophyll and protein synthesis. Abdelaal *et al.* (2015) revealed that spraying with B, Fe, Zn and Mn as mixture at the concentration of 1.5 L/fed recorded the highest fresh weight of roots, diameter of roots, sucrose percent, root and sugar yields/fed. While, foliar application of B, Fe, Zn and Mn at the concentration of at 2 L/fed gave tallest root. Masri and Hamza (2015) revealed that increasing level of micronutrients mixture up to 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm considerably improved fresh weight of roots, root and sugar yields as well as total soluble solids (TSS), sucrose, purity and extractable sucrose percentages during both seasons. Rassam *et al.* (2015) recommended that fertilizing sugar beet plants by spraying 2 L/ha of the micronutrients mixture (Fe, Zn, Mn, Cu and B) at 45, 75 and 105 days after sowing to produce the highest productivity and quality of sugar beet.

Therefore, this study aimed to determine the effect of iron levels and times of foliar application on productivity and quality of sugar beet cv. Sultan under climate and nature of agricultural lands in Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

This investigation was executed in Tag El-Ezz Research Station (latitude of 30.56^0 N and longitude of 31.35^0 E), Dakahlia, Egypt, throughout 2015/2016 and 2016/2017 seasons to determine the impact of levels and times of foliar application of iron fertilizer on productivity and quality of sugar beet cv. Sultan.

In each season, the experiment was arranged in design of strip-plot with three replicates. Levels of iron foliar application *i.e.* without spraying (control treatment), spraying solution of Fe-EDTA at the levels of 500, 750 and 1000 ppm were put in the vertical-plots. The Fe-EDTA fertilizer (13 % Fe) was obtained from

Bio-Tec Fertilizers and Biocides Co. The horizontal plots were allocated with times of foliar application *viz.* T_1 (60 days from sowing "DFS"), T_2 (75 DFS), T_3 (90 DFS), T_4 (105 DFS) and T_5 (120 DFS).

Each plot consisted of 5 ridges, which 60 cm width and length of 3.5 (10.5 m^2). Soil samples were in use at random from the investigational field area (0-30 cm from soil surface) and ready for in cooperation mechanical and chemical analyses (Table 1).

Table 1. Mechanical and chemical properties of soil at the investigational site in 2015/2016 and 2016/2017 seasons.

Variables	2015/2016	2016/2017
A: Mechanical analysis		
Coarse sand (%)	5.8	6.0
Fine sand (%)	33.1	33.5
Silt (%)	25.4	25.3
Clay (%)	35.7	35.2
$CaCo_3$ (%)	2.48	2.51
Soil texture class	Clay loam	Clay loam
B: Chemical analysis		
Soil reaction pH	7.7	7.5
EC (dS m^{-2}) in soil water extraction (1:5) at 25^{0}C	2.4	2.2
Organic matter (%)	1.83	1.96
Available N (ppm)	32.4	36.1
Available P (ppm)	7.3	7.8
Exchangeable K (ppm)	228	236
Available Mn (ppm)	10.0	11.0
Available Fe (ppm)	7.0	7.5
Available Zn (ppm)	0.80	0.86

Two ploughing, leveling, compaction, division and after that divided to the experimental units were done. Calcium super phosphate (15.5 % P_2O_5) was applied throughout soil preparation (150 kg/fad).

Sugar beet seeds were hand sown using dry sowing method (3-5 seeds/hill) on one side of the ridge (20 cm between hills) at 5thand 10thof October in the first and second seasons, respectively. Nitrogen fertilizer at the rate of 80 kg N/fad as urea (46.5%) applied in 2 equivalent doses, the 1st was applied later than thinning (30 DFS) and the 2nd done before the 2nd irrigation (60 DFS). Potassium sulphate (48 % K_2O) at the rate of 50 kg/fad was applied before the second irrigation. Other cultural practices, except the factors under study for growing sugar beet were done as recommendations of Sugar Crops Research Institute.

Studied characters:

After 210 DFS (harvest time), 5 plants chosen in randomly from the external ridges of each plot to decide; root and foliage fresh weights, length and diameter of roots. In fresh juice of roots, total soluble solids (TSS %) was measured using Hand Refractometer. According to the method of Carruthers and Oldfield (1960), sucrose percentage (%) was determined Polarimetrically. Percentage of apparent juice purity (%) was determined as a ratio between sucrose % and TSS % of roots (Carruthers and Oldfield, 1960).

At harvesting time, plants produced from the two inner ridges of each plot were collected and cleaned, then roots and tops were separated and weighted (kg), after that converted to calculate root and top yields (t/fad). Sugar yield/fad was calculated by multiplying root yield by sucrose percentage.

All recorded data were statistically analyzed as the technique of ANOVA for the strip- plot design (Gomez and Gomez, 1984) using "MSTAT-C " program. Least significant difference (LSD) method at 5 % level of probability was used to compare the differences among means of treatments (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

1- Iron foliar application levels effect:

The obtained results showed that yield components and quality traits (root and foliage fresh weights/plant, root length and diameter, total soluble solids "TSS" and sucrose as well as apparent purity percentages) were significantly influenced by iron foliar application levels *i.e.* without, 500, 750 and 1000 ppm during both seasons (Tables 2 and 3). The maximum averages of yield components and quality traits were achieved when foliar spraying sugar beet plants with solution of Fe (1000 ppm concentration) as Fe-EDTA during both seasons. Spraying plants with solution of Fe (750 ppm concentration) was the second rank and followed by the level of 500 ppm concerning its effect on all studied traits during both seasons. Conversely, the lowest means of yield components and quality traits were resulted from without Fe spraying in every season.

Table 2. Root and foliage fresh weight/plant, root length and diameter of sugar beet as affected by levels and times of foliar application of iron fertilizer during 2015/2016 and 2016/2017 seasons.

Characters Treatments	Root fresh weight (g/plant)		Foliage fresh weight (g/plant)		Root length (cm)		Root diameter (cm)	
Seasons	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017
A- Levels of iron foliar application:								
Without	823.4	830.4	420.5	210.7	26.25	25.23	11.92	10.99
500 ppm	850.2	858.4	441.2	430.0	26.50	25.83	12.40	11.08
750 ppm	906.0	897.8	443.5	438.8	28.00	27.20	13.50	11.23
1000 ppm	970.3	937.4	459.1	472.4	28.56	27.46	13.58	12.30
LSD at 5%	38.0	31.4	10.7	12.2	0.95	1.01	0.89	0.78
B- Times of iron foliar application:								
T_1- 60 DFS	815.6	774.6	391.0	386.8	24.77	25.88	12.24	10.30
T_2- 75 DFS	904.8	922.5	443.2	457.8	28.88	27.00	13.03	11.43
T_3- 90 DFS	1008.6	1002.8	502.4	483.2	29.72	27.72	14.23	12.74
T_4- 105 DFS	940.0	949.1	468.2	476.1	28.88	27.38	13.98	12.11
T_5- 120 DFS	875.1	840.3	434.8	431.2	26.16	26.16	12.32	11.11
LSD at 5%	23.7	20.8	9.2	10.7	0.87	0.98	0.71	0.69
C- Interaction:								
A × B	*	*	NS	*	*	*	NS	NS

Table 3. Total soluble solids (TSS), sucrose and apparent juice purity percentages in sugar beet roots as affected by levels and times of foliar application of iron fertilizer during 2015/2016 and 2016/2017 seasons.

Characters	TSS (%)		Sucrose (%)		Apparent purity (%)	
Treatments Seasons	2015/ 2016	2016/ 2017	2015/ 2016	2016/ 2017	2015/ 2016	2016/ 2017
A- Levels of iron foliar application:						
Without	22.05	22.10	17.55	17.45	79.59	78.95
500 ppm	22.24	22.38	17.99	17.92	80.78	80.02
750 ppm	22.48	22.41	18.49	18.21	82.21	81.28
1000 ppm	23.12	22.93	18.98	18.85	82.26	82.28
LSD at 5%	0.44	0.43	0.41	0.38	1.25	1.36
B- Times of iron foliar application:						
T_1- 60 DFS	21.58	22.05	16.9	16.84	78.35	76.39
T_2- 75 DFS	22.67	22.28	18.71	18.33	82.69	82.15
T_3- 90 DFS	23.85	23.77	20.48	19.77	85.98	83.21
T_4- 105 DFS	23.04	22.60	19.10	18.56	82.94	82.21
T_5- 120 DFS	21.91	22.15	17.24	18.16	78.74	81.95
LSD at 5%	0.38	0.32	0.39	0.31	1.15	1.10
C- Interaction:						
A × B	*	NS	*	*	NS	NS

Data in table 4 show that the Iron foliar application levels (without, 500, 750 and 1000 ppm) significantly affected sugar beet yields (root, top and sugar yields/fad) during both seasons. The highest yields of sugar beet were produced from spraying sugar beet plants with solution of Fe (1000 ppm concentration) as Fe-EDTA during both seasons. While, spraying plants with solution with concentration of 750 ppm Fe-EDTA ranked secondly after highest level of Fe and followed by the level of 500 ppm concerning its effect on yields during both seasons. Conversely, the lowest means of yields were resulted from without Fe spraying in every season. It could be noticed that spraying plants with solution of Fe (1000 ppm concentration) caused increases amounted with 3.74, 4.88 and 12.02 % in root yield/fad, 3.73, 13.13 and 15.21 % in top yield/fad and 6.93, 10.48 and 31.89 % in sugar yield/fad as compared with foliar spraying by 750 and 500 ppm Fe-EDTA and control treatment over both seasons, respectively.

The increase in yield components, quality and yields caused by using the highest level of iron as foliar fertilizer (1000 ppm) may be ascribed to some of iron can be stored in the leaves as a ferric phosphorprotein and phytoferritin, which serves as a reserve for developing plastids and hence for photosynthesis. Also, the reduction of nitrite to ammonia depends on iron, as nitrite reductase itself comprises a haem protei, called sirohaem and a non-haem component containing iron and sulphur (Marschner, 1995). Abd El-Hai *et al.* (2007) stated that ferrous at 2 and 3 g/L significantly increased photosynthetic pigments, which increased carbohydrate contents, in turn improve yield components. In addition, the role of iron in chloroplast ultra- structure, protein and lipid composition of thylakoid membranes, in addition Fe enhance electron transport capacity in thylakoidsand ATP formation (Nishio *et al*., 1985 and Arulanantham *et al*., 1990), consequently enhance establishment, growth, yields and quality of sugar beet (Shafika and El-Masry, 2006 ; Hussein, Manal, 2011 ; Abdelaal *et al*., 2015 ; Masri and Hamza, 2015 and Rassam *et al*., 2015).

Table 4. Root, top and sugar yields/fad of sugar beet as affected by levels and times of foliar application of iron fertilizer during 2015/ 2016 and 2016/2017 seasons.

Characters	Root yield (t/fad)		Top yield (t/fad)		Sugar yield (t/fad)	
Treatments Seasons	2015/ 2016	2016/ 2017	2015/ 2016	2016/ 2017	2015/ 2016	2016/ 2017
A- Levels of iron foliar application:						
Without	26.805	26.110	12.093	12.795	4.196	4.305
500 ppm	28.501	28.020	12.741	12.605	5.127	5.021
750 ppm	28.670	28.470	13.513	14.130	5.301	5.184
1000 ppm	29.527	29.751	14.494	14.179	5.604	5.608
LSD at 5%	0.358	0.401	0.287	0.293	0.389	0.173
B- Times of iron foliar application:						
T_1- 60 DFS	27.166	27.328	12.733	13.174	4.591	4.602
T_2- 75 DFS	28.672	28.800	13.900	13.573	5.365	5.279
T_3- 90 DFS	30.361	30.256	14.572	14.206	6.218	5.982
T_4- 105 DFS	29.690	29.640	13.944	13.911	5.671	5.501
T_5- 120 DFS	28.609	27.711	12.767	13.326	4.932	5.032
LSD at 5%	0.278	0.292	0.261	0.271	0.247	0.160
C- Interaction:						
A × B	*	*	*	*	*	*

2- Iron foliar application times effect:

Times of iron foliar application exhibited significant influence on yield components and quality traits (root and foliage fresh weights/plant, root length and diameter, total soluble solids "TSS", sucrose and apparent purity percentages) during both seasons as shown in Tables 2 and 3. It can be observed that foliar spraying sugar beet plants once with solution of Fe-EDTA after 90 days after sowing (DFS) was more effective than other studied times of application (60, 75, 105 and 120 DFS) in increasing yield components and quality traits and gave the top values of them during both seasons. Foliar spraying sugar beet plants once with Fe-EDTA after 105 DFS ranked secondly after 90 DFS with regard in effect on yield components and quality traits and followed by foliar spraying sugar beet plants once with Fe-EDTA after 120 DFS and then 75 DFS during both seasons. Whilst, spraying plants once with Fe-EDTA after 60 DFS gave the lowest means of yield components and quality traits during both seasons.

Root, top and sugar yields/fad significantly influenced as a result of times of iron foliar application exhibited during both seasons (Table 4). Foliar spraying sugar beet plants once with solution of Fe-EDTA after 90 days after sowing (DFS) was gave the highest values of root (30.361 and 30.256 t/fad), top (14.572 and 4.206 t/fad) and sugar (6.218 and 5.982) yields in the first and second seasons, respectively. The second best times of iron foliar application was spraying once with Fe-EDTA after 105 DFS with regard in effect on yields and followed by foliar spraying sugar beet plants once with

Fe-EDTA after 120 DFS and then 75 DFS during both seasons. Whilst, spraying plants once with Fe-EDTA after 60 DFS gave the lowest means of yields during both seasons.

This increase in yield components, quality and yields of sugar beet by foliar spraying once with solution of Fe-EDTA after 90 DFS may be attributed to the fact that sugar beet plants at the age of 90 DFS reached to maximum vegetative growth and the beginning of root formation, which needs more macro and micro nutrients especially Fe at this time, which give positive responses, therefore improve growth, yields and quality of sugar beet. These findings are in agreement with those stated by Mamyandi *et al*. (2012).

3- Interaction effect:

With regard to the interaction between both studied factors (iron levels and times of foliar application), most of them were statistically significant. Therefore, the author will discus only some of them concerning root, top and sugar yields/fad.

The interaction between iron levels and times of foliar application exhibited significant effect on root, top and sugar yields/fad in the two growing seasons. The highest values of root (31.360 and 31.283 t/fad), top (15.050 and 14.333 t/fad) and sugar (6.555 and 6.072 t/fad) yields/fad were resulted from spraying beet plants once with solution of Fe-EDTA (1000 ppm) after 90 DFS in the first and second seasons, respectively, as illustrated in Tables 5, 6 and 7, respectively. The second best interaction treatment concerning root yield/fad was foliar spraying sugar beet plants once with solution of Fe-EDTA (1000 ppm concentration) after 105 DFS during both seasons. Meanwhile, the second greatest interaction treatment concerning top and sugar yields/fad was foliar spraying sugar beet plants once with solution of Fe-EDTA at the level of 750 ppm after 90 DFS in every season. In contrast, without Fe spraying (control treatment) resulted in the lowest means of root, top and sugar yields/fad in the two growing seasons.

Table 5. Root yield (t/fad) of sugar beet as affected by the interaction between levels and times of iron foliar application during 2015/2016 and 2016/2017 seasons.

Levels of iron foliar application	Times of iron foliar application 60 DFS	75 DFS	90 DFS	105 DFS	120 DFS
			2015/2016		
Without			26.805		
500 ppm	27.117	28.200	29.390	29.283	28.183
750 ppm	27.180	28.533	30.333	29.317	28.300
1000 ppm	27.200	29.343	31.360	30.470	29.283
LSD at 5%			0.411		
			2016/2017		
Without			26.110		
500 ppm	26.400	28.100	29.283	29.200	27.050
750 ppm	27.167	28.167	30.200	29.350	27.533
1000 ppm	27.767	30.133	31.283	30.370	29.200
LSD at 5%			0.516		

Table 6. Top yield (t/fad) of sugar beet as affected by the interaction between levels and times of iron foliar application during 2015/2016 and 2016/2017 seasons.

Levels of iron foliar application	Times of iron foliar application 60 DFS	75 DFS	90 DFS	105 DFS	120 DFS
			2015/2016		
Without			12.093		
500 ppm	12.233	13.533	14.233	13.733	12.467
750 ppm	12.433	13.767	14.433	13.867	12.700
1000 ppm	13.033	14.400	15.050	14.233	13.633
LSD at 5%			0.317		
			2016/2017		
Without			12.795		
500 ppm	13.033	13.533	14.050	13.733	13.183
750 ppm	13.133	13.567	14.233	13.867	13.293
1000 ppm	13.357	13.620	14.333	14.133	13.500
LSD at 5%			0.322		

Table 7. Sugar yield (t/fad) of sugar beet as affected by the interaction between levels and times of iron foliar application during 2015/2016 and 2016/2017 seasons.

Levels of iron foliar application	Times of iron foliar application 60 DFS	75 DFS	90 DFS	105 DFS	120 DFS
			2015/2016		
Without			4.196		
500 ppm	4.317	4.838	5.947	5.378	4.447
750 ppm	4.649	5.160	6.167	5.610	4.934
1000 ppm	4.679	5.583	6.555	6.033	5.204
LSD at 5%			0.650		
			2016/2017		
Without			4.305		
500 ppm	4.482	5.001	5.421	5.154	4.717
750 ppm	4.571	5.230	5.903	5.385	5.036
1000 ppm	4.764	5.456	6.072	5.812	5.353
LSD at 5%			0.618		

CONCLUSION

It could be stated that maximizing sugar beet productivity and quality could be achieved by foliar spraying plants once after 90 DFS with the solution of Fe- EDTA (1000 ppm concentration) under the environmental conditions of Dakahlia Governorate, Egypt.

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تأثير مستويات ومواعيد الرش الورقى بالحديد على إنتاجية وجودة محصول بنجر السكر

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أُقيمت تجربة حقلية بمحطة البحوث الزراعية بتاج العز (دائرة عرض 30.56º شمالاً وخط الطول 31.35 º شرقاً) بمحافظة الدقهلية خلال الموسمين 2016/2015 و 2017/2016 لدراسة تأثير مستويات ومواعيد الرش الورقى بالحديد على الإنتاجية وجودة بنجر السكر (صنف سلطان). نفذت التجربة في تصميم الشرائح المتعامدة فى ثلاث مكررات خلال الموسمين حيث تم وضع أربعة مستويات من الرش الورقى بالحديد (معاملة المقارنة "بدون رش"، الرش بمحلول الحديد بتركيز 500، 750 و 1000 جزء في المليون) فى الشرائح الرأسية . كما تم تخصيص الشرائح الأفقية لخمسة مواعيد الرش الورقى بالحديد (60، 75، 90، 105 و 120 يوما بعد الزراعة). ويمكن تلخيص أهم النتائج التي تم الحصول عليها على النحو التالي: - أوضحت النتائج أن أعلى القيم لجميع الصفات المدروسة (وزن الجذر الطازج/ النبات، وزن العرش الطازج / النبات، طول الجزر، قطر الجزر) النسبة المئوية للمواد الصلبة الذائبة الكلية ، السكروز والنقاوة الظاهرية ، محصول الجذر ، العرش والسكر للفدان نتجت من الرش الورقى لنباتات بنجر السكر بمحلول الحديد عند مستوى 1000 جزء في المليون. بينما ثانى أفضل معاملة كانت عند الرش الورقى بمحلول الحديد عند مستوى 750 جزء في المليون يليها الرش الورقى بمحلول الحديد عند مستوى 500 جزء في المليون. في حين نتجت أقل القيم لجميع الصفات المدروسة من معاملة الكنترول في كلا الموسمين. - أدى موعد الرش الورقي لنباتات بنجر السكر مرة واحدة بمحلول الحديد بعد 90 من الزراعة الحصول على أعلى القيم لجميع الصفات المدروسة ، تبعها الرش الورقى بعد 105 يوم من الزراعة ثم 120 يوم من الزراعة ثم 75 يوم من الزراعة وأخيرا 60 يوم من الزراعة في كلا الموسمين. توصى الدراسة بالرش الورقي لنباتات بنجر السكر مرة واحدة بعد 90 يوما من الزراعة بمحلول الحديد بتركيز 1000 جزء في المليون والذى أدى إلى تعظيم إنتاجية ونوعية بنجر السكر في ظل الظروف البيئية لمحافظة الدقهلية بمصر.