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Additional Chelated Iron and Organic Amendment Influence on Yield and Quality of Sugar Beet under Various Plant Populations

Makhlouf, B. S. I. *; M. E. M. Ibrahim and A. K. Eanar

Agron., Res. Dept., Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt

ABSTRACT

A field experiment was executed at Kalabsho, Dakahlia Province, Egypt in a sandy loam soil, during 2018/2019 and 2019/2020 seasons, to study the influence of humic acid levels (without, 7.5 and 15 l/fed) and chelated iron levels (without, 0.5 and 1.0 g/l) on sugar beet grown under three hill spaces (15, 20 and 25 cm). A split-split plot design was used. The results cleared that increasing hill spaces from 15 and/or 20 cm to 25 cm had a substantial increase in leaf area index in both seasons, and sugar lost to molasses (SLM) in the 1st one, whereas, extractable sugar%, quality index, sugar and root yields/fed were markedly reduced, in both seasons. Raising humic acid level from 7.5 to 15 l/fed had an appreciable increment in net assimilation rate (NAR),extractable sugar%, sucrose%, root and sugar yields/fed, in both seasons, and quality index in the 1st one, meanwhile, SLM was not affected. The maximum values and statistical increases were detected in root dimensions, photosynthetic pigments, NAR, sucrose%, extractable sugar%, quality index, sugar and root yields/fed, and low impurities content and SLM, when chelated iron concentration was raised to 1.0 g/l. Effects of the significant interactions among the studied factors on the recorded traits were discussed. Under the present work conditions, sowing sugar beet on 15cm and/or 20cm between hills, soil drench with humic acid at 15 l/fed and spraying foliage with 1.0 g Fe-EDDHA/l, can be recommended to get the highest root and sugar yields/fed and the best quality traits.

Keywords: Plant populations, iron, humic acid, quality, sandy loam soil, sugar beet, yield.

INTRODUCTION

Many factors affect the optimum number of sugar beet (*Beta vulgaris* L.) plants such as the availability of nutrients, sunlight and water, potential plant size and length of the growing season. Plant density has been recognized as major factors in determining the degree of competition between plants (Sadre, 2012). Thus, there is a need to use the optimum plant density, which is expected to bring about a maximize yield when all other inputs of production have been adequately met (Khaiti, 2012). Therefore, plant densities, organic and microelements fertilizers are among the factors that improve sugar beet productivity and quality. Bhullar *et al.* (2010) found that the plant populations of 100000 plants/ha (20cm hill spaces) produced the lowest root diameter and highest root length and yields of sugar and root. Shalaby *et al.* (2011) showed that sharp increases in root fresh weight, sucrose%, root and sugar yields/fed with increasing distance between hills from 15 to 25 cm. In comparison to 16000, 24000, 32000, and 40000 plants/fed, Hozayn *et al.* (2013) deduced that plant population of 36000 plants/fed increased root, top, and sugar yields/fed, in addition to the highest values for most of the quality parameters. Abdou *et al*. (2014) cleared that sowing beets 25cm between hills increased root yield, gross sugar, and white sugar significantly. El-Geddawy and Makhlouf (2015) mentioned that sucrose% and sugar yield/fed appreciably increased with 20cm between hills, while, the impurities decreased. According to Ragab and Rashed (2016), sowing beets on 15cm between hills yielded the highest sucrose percent, top, root and sugar yields. Leilah *et al.* (2017) stated that sowing beet plants on in both sides of mastaba 80cm width at 35cm distance between hills (30000 plants/fed) resulting statistical increment in root weight, sucrose% and purity%. Root dimensions, root fresh weight/plant, sugar and root yields/fed all responded positively and continuously to increasing hill spacing up to 25 cm, according to Sadek *et al.* (2019). However, an insignificant difference among sowing hills *i.e.*15, 20 and 25 cm were found in their influence on impurities content, purity% and sucrose%. Varga *et al.* (2021) found that the highest values of LAI, root and white sugar yields/ha were obtained when the beet plant densities were 140000 and 100000 plants/ha, in the 1st and 2nd season, respectively, than 60000 plants/ha.

Humic acid as an organic amendment plays an important role and effect on the process of the functions of cell membrane by stimulating nutrients uptake, respiration, chlorophyll content, photosynthesis, biosynthesis of DNA, absorption of ions and intensify of system of enzyme as well as control the activity of H^+ and ATP in plasmalema and tonoplast (Fathy *et al.*, 2009, Khaled and Fawy, 2011 and Seydabadi and Armin, 2014). In comparison to the control treatment, Rassam et al. (2015) exhibited that applying humic acid at 2.5 and/or 5 l/ha caused a significant increment in sucrose, refined sugar, root and refined sugar yields, and a reduction in molasses forming substances content. El-Gamal *et al.* (2016) remarked that foliar spraying with 25 g/l of humic acid produced the maximum values of leaves area, relative growth rate, crop growth rate and sugar and top yields/fed. El-Hassanin *et al.* (2016) cleared that foliar spraying with humic substances at level 0.5% appreciably affected the content of impurities, sucrose, extractable sugar and purity percentages, decreasing sugar lost in molasses%, while markedly increased top, root and sugar yields, as compared to untreated one. Enan *et al.*

* **Corresponding author.**
E-mail address: basemssee@gmail.com

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(2016) deduced that application of humic acid at 15 l/fed increased root diameter and fresh weight/plant, leaf area index (LAI), potassium content, gross sugar% and root, top and sugar yields/fed, significantly. Wilczewski *et al.* (2018) stated that soil application of humic substances can improve sugar beet yield and, consequently, increase the biological yield of sugar from storage roots.

Iron element deficiency leads to altered chloroplast ultra structure and protein and lipid composition of thylakoid membranes; it decreases electron transport capacity in thylakoids; and it reduces noncyclic ATP formation and leaf ATP levels, all of which influence photosynthesis and many plant physiological processes (Nishio *et al*., 1985, Arulanantham *et al*., 1990 and Fahad *et al*., 2014). Hence, crop quality and yield can be severely compromised (El-Jendoubi *et al*., 2011). Hussein (2011) showed that spraying beets with solution of micronutrients mixture (B+Zn+Mn+Fe) at 2 cm/l "400 liters water/fed" significantly increased root dimensions and fresh weight, sucrose%, yields of root and sugar, comparing to without addition of micronutrients. Makhlouf *et al.* (2015) stated that treating beets with trace-element have a considerable influence on the metabolic activities and in turn exert increases in its sugar content. Abd El-All and Makhlouf (2017) indicated that the progressive increase in iron concentrations on beet foliage up to 1.0 g/l produced a significant positive increase in root dimensions and fresh weight/plant, LAI, photosynthetic pigments, sucrose and extractable sugar percentages, root and top yields/fed, meanwhile, the lowest impurities was obtained. Ibrahim (2017) cleared that foliar beet canopy with 1000 ppm Fe attained the greatest value of root dimensions, purity%, sucrose%, yields of root and sugar/fed, followed with 750 and 500 ppm Fe. In this respect, the chemical composition of the plant during the vegetation season, the content of sucrose in the roots, and plant production were all affected by foliar fertilization with Fe, Cu, and Mn in combination with pre-sowing seed stimulation (Prośba-Białczyk *et al*., 2017).

Therefore, this study was carried out to find out the optimal plant densities, humic acid and iron levels to produce the maximum yields of root and sugar with the best quality parameters of sugar beet crop grown under the environmental conditions of Dakahlia Province.

MATERIALS AND METHODS

Two field experiments were executed at Kalabsho, Dakahlia Province, Egypt (Lat. 31.14° N, Long. 31.22° E and elevation 15 m above sea level) in a sandy loam soil, during 2018/2019 and 2019/2020 seasons, to study the application effect of humic acid as an organic amendment to the soil, and foliar application with iron on productivity and quality of sugar beet grown under different hill spaces. The present study included 27 treatments, which were the combinations between three hill spaces (15, 20 and 25 cm), three humic acid levels (without, 7.5 and 15 l/fed "fed = 0.42 ha^{-1}") and three iron concentrations (without, 0.5 and 1.0 g Fe-EDDHA"6%"/l "300 liters of water/fed"). Humic acid treatments were added through drip irrigation system twice, after thinning (4-6 true leaf stage) and 15 days later. Humic product, liquid humic acid 12%, was obtained from the Central Laboratory for Organic Agric., ARC, Giza, Egypt). Iron levels were sprayed on sugar beet foliage twice, at 60 and 75 days from sowing date. A randomized complete block design in a split-split plot arrangement with three replications was conducted. Hill spaces were allocated in the main plots. The sub plots were occupied by humic acid treatments; meanwhile iron levels were distributed in the sub-sub plots. The sub-sub plot area was 19.2 m^2 including 4 ridges, 8 m long and 60 cm apart. Sugar beet variety Faten (multi-germ seeds) was sown in the 2nd week and the 1st week of November in the first and second seasons, respectively, while harvesting was done 7-month later. The preceding crop was sorghum. Single calcium super-phosphate (15% P_2O_5) was added at 30 kg P_2O_5/fed during land preparation. Nitrogen fertilizer was applied at 120 kg N/fed as ammonium nitrate "33.5% N" in 4 equal doses, the 1st dose was added after thinning and the other ones were applied later on, at two-week interval. Potassium fertilizer was added at 48 kg K_2O/fed as potassium sulfate "48% K_2O" in 3-equal dose; the 1st one was applied with the 2nd N-dose and the other ones were added with the other N doses. The other agricultural practices were completed as suggested by Sugar Crops Res. Inst., ARC, Egypt.

Soil samples were collected from the experimental sites at a depth of 30 cm from soil surface before sowing, to determine its physical and chemical properties according to Jackson (1973) and Black *et al.* (1981) as shown in Table 1.

Table 1. Soil physical and chemical properties of the experimental sites

2018/2019 season								
Particle size distribution			Soil texture	Available nutrients (mg/kg soil)			EC	pH
Sand%	Silt%	Clay%		N	P	K	(ds/m)	(1:2.5)
82.4	13.3	4.3	Sandy loam	24.21	4.52	160.20	1.26	8.11
Soluble cations and anions (meq/l)								Fe
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}		SO_4^{--}	(ppm)
2.73	2.40	5.11	1.11	0.40	8.48		2.47	0.30
2019/2020 season								
Particle size distribution			Soil texture	Available nutrients (mg/kg soil)			EC	pH
Sand%	Silt%	Clay%		N	P	K	(ds/m)	(1:2.5)
81.7	13.1	5.2	Sandy loam	25.73	4.68	163.61	1.34	8.01
Soluble cations and anions (meq/l)								Fe
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}		SO_4^{--}	(ppm)
3.01	2.38	4.99	1.64	0.46	9.0		2.56	0.31

The recorded data:

After 100 days from sowing, a representative sample of ten plants was randomly taken from the guarded ridges of each sub-sub plot to determine the following traits:

1. Leaf area index (LAI) = leaf area per plant (cm^2) / plant ground area (cm^2), according to Watson (1958).

Where;

Plant leaf area was determined using the "disk method" in 50 leaf disks of 1.0 cm diameter.

2.Net assimilation rate (NAR) $= \dfrac{(W_2 - W_1)(\log_e A_2 - \log_e A_1)}{(T_2 - T_1)(A_2 - A_1)}$ g/m^2/day (Radford`s (1967).

Where:

W_1, A_1 and W_2, A_2, respectively refer to dry weight and leaf area of plant at sampling time T_1 and T_2 (30-day interval).

3. Photosynthetic pigments (mg/g fresh leaf) were determined as described by Wettestien (1957).

Chlorophyll a = 9.784 (A 662) – 0.99 (A 644)

Chlorophyll b = 21.426 (A 644) – 4.65 (A 662)

Carotenoids = 4.695 (A 440) – 0.268 (chl. "a" + chl. "b")

Where;

A = optical density at the wave length indicate.

At harvest, ten plants were randomly collected from the middle ridges of each sub-sub plot to determine the following characteristics:

1. Root length and diameter (cm).
2. Sucrose% was determined using "Saccharometer" according to the method described in A.O.A.C. (2005).
3. Impurities content (K, Na and α-amino N) in root were estimated as described by Cooke and Scott (1993).

Sucrose% and impurities content were determined in the Quality Control Laboratory at Dakahlia Sugar Company, Bilkas, Dakahlia Governorate, Egypt.

6. Sugar lost to molasses% (SLM) = 0.14 (Na + K) + 0.25 (α–amino N) + 0.5 (Deviller, 1988).
7. Extractable sugar% (ES) = sucrose% - SLM - 0.6 (Dexter *et al.*, 1967).
8. Quality index = (extractable sugar x 100) / sucrose% (Cooke and Scott, 1993).
9. Top and root yields were determined on sub-sub plot weight (kg) and converted to tons/fed.
10. Sugar yield/fed (ton) was calculated by multiplying root yield/fed (ton) by extractable sugar%.

The collected data were statistically analyzed as according to Gomez and Gomez (1984) by using "MSTAT-C" computer software package. Least significant of difference (LSD) method was used to test differences between means at 5% level of probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Leaf area index, photosynthetic pigments, net assimilation rate, root dimensions and root yield:

Data in Table 2 clarified that root diameter and leaf area index (LAI) substantially and positively responded to increase hill spaces from 15 to 25 cm, meanwhile, root length significantly decreased, in both seasons. The variance between sowing hills on 20 and 25 cm was insignificant in their impact on LAI and net assimilation rate (NAR) in the two seasons and root diameter in the 1st one. The pronounced effect of the wider hill spaces due to the distinct effect of the wider hill spaces on root fresh weight/plant, the wider the hill space, the heavier, the individual root fresh weight/plant. In this regard, wider spacing results in better root growth and no competition for sunlight or nutrients (Fadilah and Akbar, 2015). Also, the distinct effect of 20 and 25 cm distances on LAI is mainly due to the favorable climatic conditions especially the light intensity which accelerated vegetative growth, formation of good canopy capable to increase LAI. Conversely, Varga *et al.* (2021) found that the highest LAI was obtained with the higher plant densities *i.e.* 140000 and 100000 plants/ha than 60000 plants/ha. Chlorophyll "a", carotenoids and NAR were significantly differed by the different hill spaces, in the 2nd season, whereas, chlorophyll "b" was insignificantly affected in both seasons.

Table 2. Leaf area index, photosynthetic pigments, net assimilation rate, root dimensions and root yield/fed (ton) as affected by hill spaces, humic acid and iron levels in 2018/2019 and 2019/2020 seasons

Treatments	Leaf area index		Photosynthetic pigments (mg/g.f.w.) Chlorophyll a		Chlorophyll b		Carotenoids		NAR		Root length (cm)		Root diameter(cm)		Root yield /fed (ton)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Hill spaces																
15 cm	2.79	3.20	3.80	4.28	2.03	2.00	0.95	1.24	2.75	3.11	30.49	27.32	10.89	9.58	26.92	25.44
20 cm	3.37	3.61	4.57	4.42	2.13	2.43	1.05	1.33	3.02	3.41	28.09	25.99	11.80	11.38	25.68	24.90
25 cm	3.53	3.63	4.29	4.40	2.16	2.52	1.31	1.29	3.05	3.66	24.56	23.63	13.16	12.59	22.53	22.38
LSD at 0.05	0.19	0.26	NS	0.11	NS	NS	NS	0.06	NS	0.31	1.31	2.31	1.68	0.38	1.53	1.43
Humic acid levels																
Without	3.06	3.27	3.84	4.12	1.75	2.03	0.96	1.12	2.76	3.15	25.96	23.86	11.31	10.70	24.19	23.69
7.5 l/fed	3.20	3.44	4.16	4.32	2.14	2.25	1.17	1.30	2.93	3.37	28.06	26.13	11.76	11.15	24.73	24.27
15 l/fed	3.44	3.73	4.66	4.67	2.43	2.68	1.17	1.43	3.12	3.66	29.13	26.96	12.79	11.71	26.21	24.77
LSD at 0.05	0.09	0.20	0.34	0.06	0.29	0.22	0.19	0.06	0.11	0.21	0.98	0.39	0.94	0.46	1.26	0.36
Fe-EDDHA levels																
Without	3.03	3.15	4.09	4.32	1.95	2.17	1.00	1.10	2.83	3.27	26.17	23.99	11.56	10.90	24.42	23.78
0.5 g/l	3.31	3.59	4.20	4.37	2.09	2.27	1.10	1.36	2.90	3.38	28.24	26.20	11.93	11.25	24.97	24.18
1.0 g/l	3.37	3.71	4.37	4.41	2.28	2.51	1.21	1.40	3.07	3.52	28.73	26.76	12.36	11.41	25.74	24.76
LSD at 0.05	0.08	0.16	0.10	0.04	0.11	0.16	0.09	0.06	0.11	0.08	0.52	0.42	0.20	0.18	0.59	0.54

NAR: net assimilation rate (g/m2/day), 1st: first season, 2nd: second season, NS: insignificant.

These increments may be attributed to the favorable light intensity which stimulated vegetative growth and allowed to absorb the largest amount of solar energy, which reflected on the photosynthetic pigments formation, thus increase the products and efficiency of photosynthesis process and net assimilation rate. Meanwhile, sowing plants on narrow distance led to shading of the leaves to each other. Sowing beets on 15 and/or 20 cm between hills gave higher root yield/fed than 25 cm apart. These results are in harmony with that reported by Hozayn *et al.* (2013) and Ragab and Rashed (2016). Decreasing the distance between hills from 25 cm to 15 and 20 cm led to significant increments in root yield/fed reached 4.39 and 3.15 tons, in the 1st season, corresponding to 3.06 and 2.52 tons, in the 2nd one, respectively. The pronounced effect of the narrow and/or mid hill spaces on the final weight of root yield/fed may be attributed to the increases in number of plants/fed, as compared to the wider space, which gave the heavier individual root fresh weight/plant but with the lower number of plants/fed.

Regarding humic acid influence, soil application with humic acid had a significant effect on LAI, photosynthetic pigments, NAR, root dimensions and root yield, in both seasons. The maximum and substantial values were obtained with adding 15 l humic acid/fed, resulting in a statistical increment of 0.24 and 0.29 for LAI, 1.03 and 0.56 cm in root diameter, 1.07 and 0.83 cm in root length/plant, 0.19 and 0.29 in NAR, and 5.98% (1.48 tons) and 2.06% (0.50 tons) for root yield/fed, in the 1^{st} and 2^{nd} season, successively, as compared to that gained by adding 7.5 l humic acid/fed. These results are in agreement with Enan *et al.* (2016) and Wilczewski *et al.* (2018). Increased vegetative growth can be attributed to humic acid's positive effect on both plants and soil in increasing microbial activity and improving soil effectiveness in nutrient uptake as a chelating agent, as well as bio-stimulation of plant growth, which improves vegetative characteristics, nutritional status, and leaf pigments, which are positively reflected on the final root yield.

Increasing chelated iron concentration to 1.0 g/l had a statistical increment amounted to 0.56 cm/plant in root length in the 2^{nd} season, 0.43cm for root diameter in the 1^{st} one, corresponding to 0.17 and 0.14 in NAR, and 0.77 tons (3.08%) and 0.58 tons (2.40%) for root yield/fed, in the 1^{st} and 2^{nd} seasons, consecutively, as compared to that given 0.5 g/l, meanwhile, LAI was increased without significant. These results are in line with Fahad *et al.* (2014) and Ibrahim (2017). Spraying beet canopy with 1.0 g chelated iron/l tended to positive and statistical increments in photosynthetic pigments in both seasons, except for carotenoids in the 2^{nd} one, compared to that gained by 0.5 g/l. Each the two iron levels surpassed the check treatment. These results are in agreement with Abd El-All and Makhlouf (2017). This result may be back to that the iron acts as a catalyst in the manufacture of the chlorophyll molecule and assists in the absorption of other elements (Pandev *et al*., 2016), which positively reflected on the rate of photosynthesis products.

Quality parameters and sugar yield:

Data in Table 3 indicated that the differences between hill spaces substantially affected sucrose%, extractable sugar%, quality index and sugar yield, in both seasons, as well as, potassium and sodium contents and sugar lost to molasses% (SLM) in the 1^{st} one, meanwhile, α-amino N content was not affected. Sadek *et al.* (2019) obtained similar tendency concerning α-amino N. Increasing hill spaces from 20 to 25 cm had a marked increment in K and Na contents and SLM, in the 1^{st} season, corresponding to significant decreases in sucrose%, extractable sugar%, quality index and sugar yield, in both seasons. This finding could be ascribed to that, the wider space between hills allowed more growth for roots and consequently high moisture content in turn low extractable sugar%. Sowing beets on 15cm and/or 20cm between hills statistically surpassed the wider hill space *i.e.* 25cm in sugar yield/fed. Decreasing the distance between hills from 25 cm to 15 and 20 cm led to a significant increment in sugar yield/fed by 1.00 and 1.04 tons, in the 1^{st} season, corresponding to 0.96 and 0.97 tons, in the 2^{nd} one, respectively. This may be due to that the narrower and mid hill spaces attained the highest sucrose% and lowest SLM (Table 3), thereby; the best extractable sugar% was achieved. Similar results were recorded by El-Geddawy and Makhlouf (2015) and Ragab and Rashed (2016).

Table 3. Sucrose%, impurities of juice (meq/100 g beet), sugar lost to molasses%, quality index, extractable sugar% and sugar yield/fed (ton) as affected by hill spaces, humic acid and iron levels in 2018/2019 and 2019/2020 seasons

Treatments	Sucrose%		Impurities of juice (meq/100 g beet) K		Na		α-amino N		SLM%		Quality index		Extractable sugar%		Sugar yield/fed (ton)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Hill spaces																
15 cm	18.07	19.66	3.74	3.82	1.65	1.39	1.09	1.00	1.53	1.48	88.23	89.42	15.94	17.58	4.31	4.52
20 cm	18.94	20.03	3.37	3.75	1.53	1.33	1.03	0.96	1.44	1.45	89.21	89.76	16.90	17.98	4.35	4.53
25 cm	16.88	17.89	3.80	4.05	1.80	1.42	1.19	1.15	1.58	1.55	87.08	87.96	14.70	15.74	3.31	3.56
LSD at 0.05	0.90	0.45	0.10	NS	0.19	NS	NS	NS	0.06	NS	0.62	0.76	0.89	0.46	0.36	0.36
Humic acid levels																
Without	17.38	18.67	3.38	3.59	2.08	1.71	1.06	1.02	1.53	1.50	87.75	88.77	15.25	16.57	3.71	3.98
7.5 l/fed	17.92	19.23	3.76	3.89	1.58	1.42	1.11	1.03	1.53	1.50	88.14	89.07	15.79	17.13	3.92	4.21
15 l/fed	18.59	19.68	3.78	4.14	1.33	1.00	1.15	1.06	1.50	1.48	88.69	89.41	16.49	17.60	4.34	4.41
LSD at 0.05	0.29	0.21	0.08	0.27	0.12	0.16	NS	NS	NS	NS	0.46	0.39	0.32	0.22	0.22	0.07
Fe-EDDHA levels																
Without	17.04	18.65	3.90	4.04	1.89	1.47	1.24	1.19	1.62	1.57	86.97	88.37	14.82	16.48	3.64	3.97
0.5 g/l	18.26	19.21	3.74	3.84	1.70	1.37	1.10	0.98	1.54	1.47	88.30	89.20	16.12	17.14	4.04	4.19
1.0 g/l	18.60	19.72	3.27	3.74	1.40	1.29	0.97	0.94	1.40	1.44	89.27	89.66	16.60	17.68	4.29	4.43
LSD at 0.05	0.30	0.24	0.17	0.12	0.10	0.10	0.15	0.11	0.04	0.04	0.28	0.25	0.30	0.24	0.12	0.11

SLM: sugar lost to molasses, 1st: first season, 2nd: second season, NS: not significant

Raising humic acid level from 7.5 to 15 l/fed increased potassium content and appreciably raised sucrose%, extractable sugar% and sugar yield/fed, in both seasons, and quality index, in the 1^{st} one, whereas, sodium content decreased. On the contrary, the variances in the values of α-amino N content and SLM did not reach the level of significance, in both seasons. These observations may be due to the increasing in available N and K in the soil by application of humic acid compare with untreated plants. Increasing humic acid levels from 7.5 to 15 l/fed had a significant increase by 0.67 and 0.45 for sucrose% in the 1^{st} and 2^{nd} seasons, respectively, corresponding to 0.55 in quality index, in the 1st one. Soil application with humic acid at 15 l/fed produced a statistical increase in sugar yield/fed amounted to 10.71% (0.42 ton) and 4.75% (0.20 ton) for sugar yield/fed, in the 1st and 2nd seasons, successively, as compared to that given 7.5 l/fed. These finding are in line with those reported by Enan *et al.* (2016). This result may be referred to that humic substances cause darkening of the soil color, which helps in absorbing the sun's energy, which reflects in enhancement of leaf area/plant, the efficiency of photosynthesis process and NAR (Table, 2), which in turn was reflected on the final sugar storage in roots.

In Table 3, the results elucidate that there were significant differences in impurities contents, SLM, sucrose%, quality index, extractable sugar% and sugar yield due to the applied concentrations of Fe-fertilizer, in both seasons. The increased additions of iron levels were accompanied by a significant and gradual increase in sucrose%, extractable sugar%, quality index and sugar yield/fed, in both seasons, corresponding to reduction in impurities content and SLM. This result may be referred to the role of iron as a mediator in the formation of chlorophyll (Table 2), which maximizes the efficiency of photosynthesis and sugar content, which plays a principal role in the values of quality index (Table 3). Spraying beet canopy with 1.0 g chelated iron/l caused a significant increase reached 0.48 and 0.54 in extractable sugar%, corresponding to 0.25 ton (6.19%) and 0.24 ton (5.73%) for sugar yield/fed, in the 1st and 2nd seasons, successfully, as compared to that gained with 0.5 g/l. The increments in these traits may be back to the role of microelements in improving leaf area/plant (Table 2), therefore increasing NAR, finally turn to increases sugar storage in roots. These observations are in line with those mentioned by Abd El-All and Makhlouf (2017) and Ibrahim (2017).

Significant interaction effect between hill spaces and humic acid levels:

The interaction between hill spaces and humic acid levels statistically affected potassium content and sucrose% in the 1st season, root length and chlorophyll "a" in the 2nd one, as well as net assimilation rate in both seasons (Table 4). Data stated that marked variances between 7.5 and 15 l humic acid/fed in sucrose% and root length, were found when beet was sown on 20 and/or 25 cm apart between plants. Insignificant increments in sucrose% were noticed with increasing humic acid level to 7.5 l/fed under sowing hills on 20 or 25 cm, while the substantial increase in this trait was recorded under 15cm apart between hills. The increase in the applied dose of humic acid from zero to 15 l/fed under the different plant populations was accompanied by a gradual and statistical increase in chl. "a", in the 2nd season. Raising the humic acid levels from zero to 15 l/fed resulted in a sharp and gradual increase in NAR, as the plants were planted on 15 cm hill distances. However, the same humic acid levels under the 20 and/or 25 cm hill spaces led to an increase in net assimilation rate but without significant effect. Under sowing beets on 20cm between hills, soil application of humic acid at 15 l/fed gave the highest and significant values of sucrose% and the lowest potassium content, as compared to that gained by the same level of humic acid under the other two spaces. These observations may indicated that sowing beet on 20cm hill space with a specific dose of essential nutrients provided by humic acid reduced competition between plants and provided better conditions for plant growth, as well as, improved absorption of solar energy, which will positively reflects on efficiency of photosynthesis and thus the sugar content.

Table 4. Significant interaction effect between hill spaces and humic acid levels on some traits of sugar beet in 2018/2019 and/or 2019/2020 seasons

Hill spaces	Humic acid levels	Root length (cm)	Chlorophyll a (mg/g fresh leaf)	Net assimilation rate ($g/m^2/day$)		K (meq/100 g beet)	Sucrose %
		2nd season	2nd season	1st season	2nd season	1st season	1st season
15 cm	Without	25.89	3.94	2.29	2.58	3.34	17.58
	7.5 l/fed	27.79	4.13	2.67	3.13	3.97	18.32
	15 l/fed	28.29	4.77	3.27	3.62	3.93	18.30
20 cm	Without	23.73	4.19	2.93	3.26	3.16	18.24
	7.5 l/fed	26.76	4.44	3.04	3.40	3.49	18.70
	15 l/fed	27.49	4.64	3.08	3.58	3.47	19.87
25 cm	Without	21.94	4.23	3.05	3.61	3.64	16.33
	7.5 l/fed	23.84	4.38	3.08	3.59	3.81	16.73
	15 l/fed	25.11	4.60	3.00	3.77	3.93	17.59
LSD at 0.05		0.68	0.11	0.19	0.36	0.14	0.50

Significant interaction effect between hill spaces and chelated iron levels:

The presented data in Table 5 elucidate that, the interaction between hill spaces and chelated iron levels had a sharp effect on root diameter, leaf area index, chlorophyll "a" and net assimilation rate in the 1st season, sucrose% and extractable sugar%, in the 2nd one, in addition to quality index and sugar yield/fed, in both seasons. Sowing beet plants on 15 and 20 cm apart between hills, statistical and gradual increments were detected in sugar yield/fed in both seasons, as well as, quality index in the 1st one, when chelated iron level was gradually raised from zero up to 1.0 g/l. Significant variances in root yield/fed were observed between spraying beet canopy with 0.5 and 1.0 g chelated iron/l when beets were sown on 20cm between hills, meanwhile, there was no significant difference under the other plant densities. Chlorophyll "a", leaf area index and net assimilation rate, as well as sucrose and extractable sugar percentages were appreciably responded to increase chelated iron levels from 0.5 to 1.0 g/l, when sugar beets were sown on 15 cm apart between hills. However, the difference between the two chelated iron levels in their influence on the previously-mentioned traits was not significant under sowing on 20 cm and/or 25 cm distance between plants. The interaction between spraying the foliage of sugar beet plants with 1.0 g chelated iron/l and sowing on 15 and/or 20 cm between hills resulted in the highest values of sugar yield/fed but without significant between them, meantime, each outperformed at a distance of 25 cm apart. Sowing beets on 15 and 20 cm along with spraying of 1.0 g chlated iron/l produced a significant increase reached 0.92 and 0.59 tons in the 1st season, corresponding to 0.61 and 0.67 tons in sugar yield/fed, successively, compared to the control treatment (without addition of chlated iron).

Table 5. Significant interaction effect between hill spaces and chelated iron levels on some traits of sugar beet in 2018/2019 and/or 2019/2020 seasons

Hill spaces	Fe-EDDHA levels	RD(cm)	LAI	Chl.b	NAR	S%	Quality index		RY/fed(ton)	ES%	Sugar yield/fed (ton)	
		1st	1st	2nd	1st	2nd	1st	2nd	2nd	2nd	1st	2nd
15 cm	Without	10.71	2.54	1.75	2.50	19.28	86.78	88.92	24.45	17.14	3.80	4.23
	0.5 g/l	10.78	2.83	1.94	2.70	19.37	88.33	89.31	25.60	17.30	4.40	4.47
	1.0 g/l	11.18	3.01	2.33	3.03	20.32	89.40	90.03	26.26	18.29	4.72	4.84
20 cm	Without	11.20	3.11	2.17	2.95	19.13	88.25	88.87	24.26	17.00	4.07	4.19
	0.5 g/l	11.82	3.50	2.46	2.97	20.33	89.09	90.05	24.55	18.31	4.32	4.52
	1.0 g/l	12.39	3.51	2.65	3.13	20.64	90.22	90.31	25.91	18.64	4.66	4.86
25 cm	Without	12.78	3.43	2.59	3.05	17.53	85.66	87.20	22.64	15.29	3.04	3.50
	0.5 g/l	13.18	3.59	2.42	3.03	17.95	87.38	88.13	22.40	15.82	3.40	3.58
	1.0 g/l	13.52	3.58	2.56	3.06	18.20	88.07	88.50	22.12	16.11	3.50	3.59
LSD at 0.05		0.35	0.15	0.27	0.20	0.41	0.49	0.43	0.94	0.41	0.21	0.19

RD: root diameter, LAI: leaf area index, Chl.: chlorophyll (mg/g fresh leaf), NAR: net assimilation rate (g/m2/day), S: sucrose, ES: extractable sugar, 1st: first season, 2nd: second season.

Significant interaction effect between humic acid and chelated iron levels:

Data showed that the interaction between humic acid and chelated iron levels appreciably affected sodium content in root, quality index and extractable sugar% in the 1st season, as well as, chlorophyll "b" and carotenoids in the 2nd one, Table 6. Under the different humic acid levels, increasing chelated iron up to 1.0 g/l attained a significant increment in quality index and extractable sugar%, in the 1st season and carotenoids in the 2nd one, as compared to the check treatment (without addition of chelated iron). However, the difference between 0.5 and 1.0 g chelated iron/l in their effect on chlorophyll "b" and carotenoids failed to reach the level of significance. Raising chelated iron level to 0.5 g/l + 7.5 and/or 15 l humic acid/fed had no significant reduce in sodium content, in the 1st season. This result may be referred to that the stimulatory effects of humic substances have been directly correlated with increasing of some micronutrients uptake such as Fe, Zn and Mn (Chen and Aviad 1990). Furthermore, humic acid enhances soil characteristics by increasing cation exchange capacity, chelating of elements, and increasing nutrient availability to plants (Ahmad *et al*., 2020), therefore, foliar spraying with 1.0 g chelated iron/l was more distinguished for the need of the plant.

Table 6. Significant interaction effect between humic acid and chelated iron levels on some traits of sugar beet in 2018/2019 and/or 2019/2020 seasons

Humic acid levels	Fe-EDDHA levels	Carotenoids (mg/g fresh leaf)		K meq/100 g beet	Na meq/100 g beet	Quality index%	Extractable sugar%
		1st season	2nd season	1st season	1st season	1st season	1st season
Without	Without	0.93	0.85	3.65	2.50	86.27	14.13
	0.5 g/l	0.97	1.23	3.61	2.10	87.75	15.45
	1.0 g/l	0.99	1.28	2.88	1.65	89.10	16.18
7.5 l/fed	Without	0.99	1.16	3.92	1.71	86.92	14.59
	0.5 g/l	1.14	1.37	3.76	1.58	88.43	16.23
	1.0 g/l	1.40	1.37	3.59	1.44	89.00	16.55
15 l/fed	Without	1.07	1.29	4.13	1.47	87.63	15.72
	0.5 g/l	1.20	1.47	3.86	1.41	88.68	16.67
	1.0 g/l	1.25	1.53	3.34	1.10	89.69	17.07
LSD at 0.05		0.16	0.10	0.29	0.18	0.49	0.51

Significant interaction effect among hill spaces, humic acid and chelated iron levels:

As for the 2nd order interaction effect, the collected data elucidate that the interaction among hill spaces, humic acid and chelated iron levels substantially affected chlorophyll "a", quality index, extractable sugar% and sugar yield/fed, in the 1st season, as well as root length in the 2nd one (Table 7). The results showed that there was a significant and positive response in quality index and sugar yield/fed when chelated iron level was raised from 0.5 to 1.0 g/liter associated with application of humic acid at the rate of 15 liters/fed under sowing beet plants on a distance of 15 and/or 20 cm between hills, whereas the effect did not reach the level of significance when sugar beet was sown on 25 cm apart between plants under the same conditions. The results confirmed that the considerable increases in root length, extractable sugar%, quality index and sugar yield/fed, were found as a result of raising the concentrations of Fe- level from zero to 1.0 g/l under the different humic acid levels and plant populations. Data cleared that the difference between 0.5 and 1.0 chelated iron/l with feeding sugar beet plants by the various levels of humic acid in their effect on chlorophyll "a" and carot, was insignificant, except for chl.a when beets were fed with 7.5 l/fed from humic acid under sowing on 15 cm apart between hills. The highest significant values of sugar yield per feddan were achieved when sowing sugar beet plants on15 and 20 cm distance between hills along with feeding them by humic acid at a rate of 15 l/fed and spraying them with chelated iron at a rate of 1.0 g/liter, while sowing beets on 25cm between plants led to a decrease in sugar yield/fed amounted to 24.43 and 28.96 %, respectively.

Table 7. Significant interaction effect among hill spaces, humic acid and chelated iron levels on some traits of sugar beet in 2018/2019 and/or 2019/2020 seasons

Hill spaces	Humic acid levels	Fe-EDDHA levels	Chl. a 1st season	Carot. 2nd season	RL (cm) 2nd season	QI% 1st season	ES% 1st season	SY/fed (ton) 1st season
15 cm	Without	Without	3.12	0.58	23.33	85.81	13.88	3.15
		0.5 g/l	2.90	1.22	27.10	87.98	15.82	4.20
		1.0 g/l	3.55	1.24	27.23	89.63	16.67	4.62
	7.5 l/fed	Without	3.45	1.19	26.60	87.32	15.29	4.09
		0.5 g/l	3.71	1.35	27.70	88.40	16.33	4.49
		1.0 g/l	3.87	1.33	29.07	88.93	16.87	4.68
	15 l/fed	Without	4.67	1.28	26.73	87.15	15.29	4.16
		0.5 g/l	4.60	1.44	28.83	88.61	16.22	4.50
		1.0 g/l	4.34	1.51	29.30	89.65	17.10	4.87
20 cm	Without	Without	4.23	0.99	22.27	87.49	15.20	3.75
		0.5 g/l	4.20	1.22	24.30	88.85	16.34	4.06
		1.0 g/l	4.30	1.31	24.63	89.78	17.01	4.29
	7.5 l/fed	Without	4.27	1.11	25.40	87.88	15.39	3.75
		0.5 g/l	4.54	1.38	27.17	89.15	17.10	4.11
		1.0 g/l	4.74	1.45	27.70	90.09	17.49	4.52
	15 l/fed	Without	4.72	1.31	25.93	89.25	17.62	4.72
		0.5 g/l	4.95	1.54	28.17	89.25	17.59	4.79
		1.0 g/l	5.17	1.62	28.37	90.76	18.31	5.18
25 cm	Without	Without	3.88	0.98	20.33	85.38	13.31	2.91
		0.5 g/l	4.10	1.26	22.57	86.25	14.21	3.08
		1.0 g/l	4.27	1.30	22.93	87.76	14.87	3.36
	7.5 l/fed	Without	4.15	1.18	22.40	85.34	13.09	2.89
		0.5 g/l	4.28	1.37	24.57	87.62	15.25	3.32
		1.0 g/l	4.39	1.34	24.57	87.86	15.31	3.46
	15 l/fed	Without	4.28	1.29	22.87	86.24	14.28	3.32
		0.5 g/l	4.56	1.44	25.43	88.13	16.21	3.80
		1.0 g/l	4.68	1.47	27.02	88.54	15.79	3.68
LSD at 0.05			0.31	0.17	1.25	0.85	0.89	0.36

Chl.: chlorophyll (mg/g fresh leaf), Carot.: carotenoids (mg/g fresh leaf), RL: root length, QI: quality index, ES: extractable sugar, SY: sugar yield.

CONCLUSION

Under conditions of the present work, it was found that sowing sugar beet plants on 15 and/or 20 cm apart between hills, soil drench with humic product (liquid humic acid 12%) at a rate of 15 liters/fed along with spraying canopy by 1.0 g Fe-EDDHA"6%"/l, can be recommended to produce the optimal root and sugar yields/fed and the best quality traits of sugar beet.

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تأثير إضافة الحديد المخلبي والمُحسِّن العضوي علي محصول وجودة بنجر السكر تحت كثافات نباتية مختلفة

باسم صبحي إبراهيم مخلوف ، محمد الغريب محمد إبراهيم و أمين كمال عينر
قسم بحوث المعاملات الزراعية - معهد بحوث المحاصيل السكرية - مركز البحوث الزراعية – الجيزة – مصر

أجريت تجربة حقلية في منطقة قلابشو - محافظة الدقهلية خلال موسمي 2019/2018 و 2020/2019 لدراسة تأثير اضافة ثلاثة مستويات من حمض الهيوميك (بدون ، 7.5 و 15 لتر/فدان)، وثلاثة تركيزات للرش الورقي بالحديد المخلبي (بدون ، 0.5 و 1.0 جم/لتر) علي محصول وجودة بنجر السكر المُنزرع تحت ثلاث مسافات زراعة بين الجور (15 ، 20 و 25 سم). استُخدِم تصميم القطع المنشقة مرتين في ثلاث مكررات. أوضحت النتائج أن زيادة مسافات الجور من 15 و/أو 20 سم إلى 25 سم أدت إلى زيادات معنوية في دليل مساحة الأوراق في كلا الموسمين ، ونسبة السكر المفقود في المولاس في الموسم الأول ، في حين انخفضت نسبة السكر المستخلص ، دليل الجودة وحاصلي السكر والجذور/فدان في كلا الموسمين. ادي رفع مستوى حمض الهيوميك من 7.5 إلى 15 لتر/فدان الي زيادة معنوية في صافي معدل التمثيل الضوئي، نسبة السكروز والسكر المستخلص وحاصلي الجذور والسكر/فدان في كلا الموسمين والجودة في الموسم الاول، بينما لم تتأثر نسبة السكر المفقود في المولاس. ادت زيادة تركيز الحديد المخلبي إلى 1.0 جم/لتر الي تحقيق اعلي قيم وزيادة معنوية للصبغات الضوئية في الأوراق، صافي معدل التمثيل الضوئي، نسبة السكروز والسكر المستخلص ودليل الجودة وحاصلي الجذور والسكر/فدان، وانخفاض في نسبة الشوائب والسكر المفقود في المولاس. تم مناقشة تأثير التفاعلات المعنوية بين عوامل الدراسة علي الصفات المدروسة. تحت ظروف هذا البحث، يمكن التوصية بزراعة نباتات بنجر السكر على مسافة 15 سم أو 20 سم بين الجور، واضافة حمض الهيوميك للتربة بمعدل 15 لتر/فدان والرش الورقي بالحديد المخلبي بتركيز 1.0 جم/لتر للحصول على أعلى حاصل من الجذور والسكر/فدان وأفضل صفات جودة.