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Revisiting of chemical fertilizers by using suitable plant growth regulators and nano fertilizer

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Abstract

A key challenge for sustainable intensification of agriculture is to produce increasing amount of food and feed with minimal mineral fertilizers usage for reducing greenhouse gas emissions and decreasing the excessive utilization of undesirable plant growth regulators like gibberellins. The current study was focus on the use of plant growth regulators (gibberellic acid and proline) in presence of two sources of boron (B–NPs and boric acid) to reduce the consumption of mineral fertilizers, minimize the hazard effect of using plant growth regulators and increasing the yield productivity and quality of sugar beet plants.

An experimental field was conducted at Giza Agricultural Experimental Station, Giza, Egypt, on sugar beet plants (*Beta vulgaris* L. *var.* Sara poly). Plants applied with gibberellin and proline as foliar application at three rates of zero (control), 100 and 200 mg l^{-1}, 100 and 75% from full dose of macronutrients with boron sources at 0.48 B kg $acre^{-1}$ as recommended dose.

The obtained data showed that the foliar applications of gibberellin (GA_3) at rate of 100 mg l^{-1} and proline at 200 mg l^{-1} were the most effective for plant yield, growth parameters under study, sucrose yield and macronutrients uptake may be those due to increased N use efficiency, especially at sub-optimal macro nutrient fertilizers. Regard to boron sources, boron-NPs had positive effects on all parameters under study due to sugar transport, cell membrane synthesis, nitrogen fixation, indole acetic acid metabolism, respiration, cell wall structure, carbohydrate metabolisms, root growth and functional characteristics and development. Moreover, obtained data revealed that the applied mineral fertilizers at rate of 75% from recommended dose was more response than that applied at rate of 100 % as a recommended dose. On the other hand, obtained data also showed that 75% applied from macronutrients fertilizers when accompanied with proline at 200 mg l^{-1} and B-NPs was more responses and effects on all plant characteristics and quality compared to the other treatments under study.

Keywords:

Proline, GA_3, Boric acid, B-NPs, mineral fertilizers, growth parameters, yield productivity, quality and sugar beet.

Introduction:

Meeting human needs within the ecological limits of our planet calls for continuous reflection on and designing of agricultural technologies and practices. There is growing consensus that nutrient mining is leading to declining soil productivity and increasing the consumption of mineral fertilizers. So, using of plant growth regulators and nano technology has to be exploited to enhance and increase nutrients uptake.

Sugar beet (*Beta vulgaris* L.) is considering the second sugar crop for sugar production in Egypt after sugar cane. Recently, sugar beet crop has been an important position in Egyptian crop rotation as a winter crop not only in fertile soils, but also in poor, saline, alkaline and calcareous soils. It could be economically grown in newly reclaimed soils (El-Hawary, 1999). Improving sugar beet yield and quality are the main goals of the governmental policy to increase sugar production to cover gap between sugar consumption and production. Approximately 66 % of local needs from the white sugar are produced locally from sugar beet and sugar cane while, the rest (34 %) is imported. Increasing production from unit area and water by using fertilization and agricultural practices are considered one of the important national targets to minimize gap between sugar consumption and production, fertilizer is considered as a limiting factor for obtaining high yield and quality (Hozayn *et al.*, 2013).

Plant hormones are a structurally unrelated collection of small molecules derived from various essential metabolic pathways. These compounds are important regulators of plant growth and mediate responses to both biotic and abiotic stresses. In general these compounds are present at very low concentrations and act either locally, at or near the site of synthesis, or in distant tissues. It is including (but is not limited to) abscisic acid (ABA), indole-3-acetic acid (IAA or auxin), brassinosteroids (BRs), cytokinin, gibberellic acid (GA), ethylene, jasmonic acid (JA) and salicylic acid (Santner *et al.,* 2009).

The GAs is a large family of tetracyclic, diterpenoids growth regulators. This hormone has a particularly interesting role in modern agriculture. It was originally isolated in 1938 as a metabolite from the rice fungal pathogen *Gibberella fujikuroi* (Yamaguchi, 2008).

Proline is a proteogenic amino acid and accumulates both under stress and non-stress conditions as a beneficial solute in plants. Recent discoveries point out that proline plays an important role in plant growth and differentiation across life cycle. It is a key determinant of many cell wall proteins that plays important roles in plant development. The role of extensins, arabino galactan proteins and hydroxyproline- and proline-rich proteins as important components of cell wall proteins that play pivotal roles in cell wall signal transduction cascades, plant development (Kishor *et al.,* 2015).

Boron is by far the most important of the micronutrients needed by sugar beet. Boron deficiently depressed the yield and quality of sugar beet. Soil application, as well as, a foliar spray of boron is equally effective, hence the root fresh weight, sucrose %, root and top yields significantly increased by increasing boron levels (Mekdad, 2015).

Nanotechnology helps agricultural sciences and reduce environmental pollution by production of chemical fertilizers by using the nano particles and nano capsules with the ability to control or delayed delivery, absorption and more effective and environmentally friendly and production of nano-crystals to increase the efficiency of application with lower dose. Nanotechnology is seen as an important technology for future agriculture production. It refers to a size range of 1 to 100 mm. Nanotechnology is the technology that manipulates or self-assembles individual atoms, molecules or molecular clusters into structures to create materials and devices with new or vastly different properties (Nair *et al.,* 2010). The core of nanotechnology is, size and control. The smaller size, higher specific surface area and reactivity of nanofertilizers as compared to bulk fertilizers may increase the solubility, diffusion and availability to plants and hence enhance crop productivity. Nanotechnology has provided the feasibility of exploring nanoscale or nanostructured materials as fertilizer carrier or controlled release vectors for building of the so-called smart fertilizers as new facilities to enhance the nutrient use efficiency and reduce the cost of environmental pollution (Chinnamuthu and Boopathi, 2009).

The objective of this study was to evaluate the response of sugar beet yield and yield component to foliar application of plant growth regulators and boron sources with reducing the mineral fertilizers to 75% of recommended dose, also, comparing between plant response for gibberellin and proline.

Materials and Methods:

Two experimental fields were carried out on sugar beet *(Beta vulgaris var.* Sara poly*)* plants on in a clay texture at agriculture research station of El Giza, Giza Governorate, Egypt (30° N, 31°: 28 E at an altitude 19 meters above sea level) during two agricultural successive seasons *i.e*. 2017/18 and 2018/19. The study was to evaluate the effects of two type's plant growth regulator gibberellin and proline as foliar application at three rates zero, 100 and 200 mg l^{-1} with two sources of boron (B-NPs and boric acid) at recommended dose 0.48 B kg $acre^{-1}$ applied with 100 and 75% from full dose of macronutrients.

The experiment was laid-out in split- split plot design with three replicates as follows:

a. The main plots were 100 and 75% of NPK from recommended dose. Calcium super phosphate (15.5% P_2O_5) was added at rate 150 and 112.5 P_2O_5 Kg $acre^{-1}$ during the soil preparation. Nitrogen was applied at rate of 75 and 56.5 Kg N $acre^{-1}$ as urea (46.5% N) applied in three equal doses after 21, 45 and 60 days from planting. Potassium sulphate (50% K_2O) at rate of 50 and 37.5 Kg K_2O $acre^{-1}$ was added in two equal doses after 30 and 50 days from planting.

b. The sub plots were applied plant growth regulators *i.e.* GA_3 (Natural Enterprise Co.) and proline (Alfa Aesar Co.) at three rates as a foliar application (Zero, 100 and 200 mg l^{-1}).

c. The sub – sub plots were applied foliar of boron sources boric acid (Aldrich Co.) and B-NPs (Yara Fertiliser Co.) at the recommended dose.

Foliar application of both plant growth regulators and boron were applied after 45 and 60 days from sowing. All agricultural practices for growing sugar beet were done as recommended.

Soil samples collected at depth 0–30 cm was air-dried, ground and sieved with a 2 mm sieve. Some of its properties were analyzed according to (Page *et al.*, 1982). The total N was determined using macro-Kjeldahl method used (Gerhardt model VAP 30 S). Total P was determined colorimetrically using vandomolbadate yellow by UV/Vis spectrophotometer (JENWAY model 6705 UV/Vis), K^+ and Na^+ content were detected by flame photometer (JENWAY model PFP7). Finally, the contents of Ca^{+2}, Mg^{+2}, Fe, Mn, Zn, Cu and B were measured by ICP-AAS spectrophotometer (Agilent Technologies model 8800) (Jackson, 1959; Cottenie *et al.*, 1982), and data obtained Tabulated in Table, 1.

The plant samples were directly transferred to the laboratory, cleaned with distilled water to get free from any adherent dust, then samples were separated into two parts (tops + roots) then weighted fresh, dry weight of top parts and roots were recorded for each sample after drying in oven at 70 ^oC for 24 hours. Moreover, dried material of were ground to a fine powder and kept in stopped glass bottles for more analyses.

Table 1: Some chemical and physical characteristics of initial soil under investigation.

Soil characteristics	Value	Soil characteristics	Value
Particle size distribution (%):		Soluble cations (soil paste, $mmol_c l^{-1}$):	
Sand	26.2	Ca^{+2}	2.35
Silt	29.3	Mg^{+2}	1.20
Clay	44.5	Na^+	6.85
Soil textural class	Clay*	K^+	5.13
Chemical properties:		Soluble anions (soil paste, $mmol_c l^{-1}$):	
pH (1:2.5 soil water suspension)	8.95	CO_3^{-2}	0.00
$CaCO_3$ %	4.82	HCO^{-3}	3.15
Organic matter %	1.53	Cl^-	6.40
EC_e (dS m^{-1}, soil past)	1.69	SO_4^{-2}	5.95
Physical properties:		Available macro- and micronutrients (mg kg^{-1})	
Bulk density, g cm^{-3}	1.20	N	46.34
Sodium adsorption ratio (SAR)	5.15	P	18.56
Exchangeable sodium (ESP)	4.50	K	349.1
Saturation (SP)	70.3	Fe	41.2
CEC** $cmol_c$ kg^{-1}	53.2	Mn	26.1
Moisture content (%):		Zn	2.43
Field capacity	27	B	1.13
Wilting point	16		
Available water	11		

* Using USAD Soil Texture Triangle, after (Twarakavi, N. K. C., Šimůnek, J. and Schaap, 2010).
** CEC= Cation exchange capacity

Samples of plants were wet digested with a mixture of sulphuric and perchloric acids (Piper, 1950), chemical analyses of sugar beet plants were carried out on the samples to determine total nitrogen by using the Kjeldahl method described by (Hesse and Hesse, 1971), phosphorus was determined calorimetrically according to (Schofield and Da Costa, 1935). Potassium was estimated using a flame photometer as described by (Jackson, 1962). Roots yield was determined after 210 days from sowing; plants of sugar beet from each plot were harvest and weighted separately.

Finally, data obtained statistically analyzed by the analysis of variance (ANOVA) using the least significant difference at level at 0.05 according to (Gomez and Gomez, 1984).

Results

The obtained data of both successive seasons were not significantly different; their average was taken into consideration.

a- Sugar beet plants growth parameters

Data in Table, 2 showed that, the effects of gibberellin and proline as a foliar application on leaves, roots fresh weights, root length and root radius at two rates of macronutrient fertilizers under study with boron. Data obtained illustrated that the foliar application of gibberellin at rate of 100 mg l^{-1} accompanied with 75% of macronutrients rate was the most effective for all plant growth parameters of sugar beet followed by proline at rate of 200 mg l^{-1} without significant differences.

Table 2: Effect of two type of growth regulator at different rates with two sources of boron at two rates of macronutrients on yield components of sugar beet plants at harvest stage.

Boron sources (B)	**Macronutrients at 100% of recommended dose**							**Macronutrients at 75% of recommended dose**						
	Control	**Gibberellin (mg l^{-1})**			**Proline (mg l^{-1})**			**Control**	**Gibberellin (mg l^{-1})**			**Proline (mg l^{-1})**		
		100	**200**	**Mean**	**100**	**200**	**Mean**		**100**	**200**	**Mean**	**100**	**200**	**Mean**
Fresh weight of leaves (g plant^{-1})														
Control	517	589	567	558	556	580	551	475	595	524	531	529	575	526
Boric a.	582	638	593	604	603	631	605	492	767	577	612	588	649	576
B-NPs	594	645	614	618	636	657	629	515	919	738	724	625	860	667
Mean	564	624	561	588	598	623	595	494	760	613	622	581	695	606
Fresh weight of root (g plant^{-1})														
Control	988	1209	1134	1110	1172	1277	1146	815	1384	1135	1111	1161	1266	1081
Boric a.	1194	1388	1332	1305	1252	1370	1272	1045	1837	1425	1436	1440	1745	1410
B-NPs	1250	1439	1347	1345	1326	1425	1334	1125	2054	1534	1571	1690	1990	1602
Mean	1144	1345	1271	1253	1250	1357	1251	995	1758	1365	1373	1430	1667	1364
Root length (cm)														
Control	25.0	34.0	31.5	30.2	32.5	36.0	31.2	23.0	35.5	33.5	30.7	27.5	33.5	28.0
Boric a.	27.0	37.0	34.0	32.7	34.5	35.5	32.3	25.5	40.5	36.0	34.0	32.0	37.5	31.7
B-NPs	28.5	39.5	37.0	35.0	36.0	38.5	34.3	27.0	43.0	37.5	35.8	36.5	41.0	34.8
Mean	26.8	36.8	34.2	32.6	34.3	36.7	32.6	25.2	39.7	35.7	33.5	32.0	37.3	31.5
Root radius (cm)														
Control	10.0	11.5	10.3	10.6	10.5	11.0	10.5	9.5	11.9	11.0	10.8	10.0	11.6	10.4
Boric a.	11.0	13.0	12.1	12.0	12.0	12.5	11.8	10.5	13.5	12.3	12.1	11.9	12.7	11.7
B-NPs	11.8	13.5	12.5	12.6	12.0	13.0	12.3	10.9	14.8	13.0	12.9	12.5	13.5	12.3
Mean	10.9	12.7	11.6	11.7	11.5	12.2	11.5	10.3	13.4	12.1	11.9	11.5	12.6	11.5

L.S.D. 0.05

	B	**G**	**R**	**B x G**	**B x R**	**G x R**	**B x G x R**
Fresh wt. of leaves	55	23	15	33	12	21	11
Fresh wt. of leaves	65	45	83	27	44	67	83
Root length	1.0	0.9	1.1	0.8	1.2	0.9	1.3
Root radius	0.4	0.2	0.4	0.3	0.5	0.3	0.4

B = Boron sources; G = Plant growth regulator sources and R = Rate of Plant growth regulator

Regard to boron sources data in Table 2 data showed that the foliar application of nano boron give higher responses in all parameters under study this resulted might be due to the small size of nano boron make its penetration more easily and do its role effectively.

According to data in Table 2 showed the application of macronutrients NPK at full dose was more response for all plant growth parameters under study than that at 75% from the full dose.

Finally, previously data showed that the interaction between macronutrients at 75% accompanied with gibberellin at rate 100 mg l^{-1} and nano boron give the highest response followed by proline at rate of 200 mg l^{-1} for all plant growth parameters under study.

b- Sugar beet roots nutritional status

The obtained data in Table, 3 revealed that the foliar application of plant growth regulators on sugar beet plant was more responded in nutritional status of sugar beet root compared to control (without plant growth regulators). Also, data represented that the application of gibberellin at 100 mg l^{-1} was the most effective one followed by proline at 200 mg l^{-1} without significant difference.

Regard to sources of boron as boric acid and B-NPs, data represented in Table, 3 showed a positive response in nutritional status of sugar beet root compared to the control of both macronutrient rates. Moreover, result showed that the foliar application of nano boron was the most effective source on all parameters under study.

Table 3: Effect of two type of growth regulator at different rates with two sources of boron at two rates of macronutrients on nutritional status of sugar beet root at harvest stage.

Boron sources (B)	Macronutrients at 100% of recommended dose							Macronutrients at 75% of recommended dose						
	Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})			Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})		
		100	200	Mean	100	200	Mean		100	200	Mean	100	200	Mean
Nitrogen content (%)														
Control	4.30	4.69	4.58	4.52	4.45	4.67	4.47	4.18	4.75	4.60	4.51	4.55	4.67	4.47
Boric a.	4.36	4.78	4.63	4.59	4.57	4.72	4.55	4.25	5.46	5.05	4.92	4.81	5.26	4.77
B-NPs	4.52	4.90	4.75	4.69	4.66	4.86	4.65	4.34	5.68	5.32	5.11	5.25	5.45	5.01
Mean	4.39	4.79	4.65	4.61	4.56	4.75	4.56	4.26	5.30	4.99	4.85	4.87	5.13	4.75
Phosphorous content (%)														
Control	0.175	0.248	0.229	0.217	0.228	0.239	0.214	0.163	0.240	0.216	0.206	0.192	0.228	0.194
Boric a.	0.183	0.262	0.236	0.227	0.231	0.257	0.224	0.171	0.275	0.234	0.227	0.239	0.275	0.228
B-NPs	0.190	0.280	0.254	0.241	0.252	0.273	0.238	0.183	0.299	0.248	0.243	0.242	0.281	0.235
Mean	0.183	0.263	0.240	0.229	0.237	0.256	0.225	0.172	0.271	0.268	0.231	0.224	0.261	0.219
Potassium content (%)														
Control	5.22	5.57	5.39	5.39	5.30	5.42	5.31	5.10	5.48	5.40	5.33	5.28	5.37	5.25
Boric a.	5.29	5.61	5.47	5.46	5.45	5.58	5.44	5.20	5.88	5.76	5.61	5.46	5.59	5.42
B-NPs	5.45	5.73	5.55	5.53	5.50	5.65	5.49	5.24	5.99	5.82	5.68	5.66	5.81	5.57
Mean	5.32	5.64	5.47	5.47	5.42	5.55	5.41	5.18	5.78	5.66	5.54	5.47	5.59	5.41

L.S.D. at 0.05

	B	G	R	B x G	B x R	G x R	B x G x R
N	0.12	0.32	0.12	0.71	0.22	0.11	0.32
P	0.09	0.02	0.05	0.09	0.10	0.22	0.08
K	0.12	0.22	0.11	0.90	0.12	0.13	0.14

B = Boron sources; G = Plant growth regulator sources and R = Rate of Plant growth regulator

Respect to macronutrient rates applied, information uncovered that the full dose was better than 75% this outcome might be because of the ideal pace of macronutrients increments photosynthetic procedures, leaf zone creation, leaf region span just as net osmosis rate.

Finally, macronutrients applied at rate 100% with foliar application of gibberellin at rate 100 mg l^{-1} was more effective when accompanied with nano boron in micronutrients content of sugar beet roots compared to other treatments used.

c- Micronutrient contents in sugar beet roots

Data in Table, 4 showed that the foliar application of plant growth regulators was enhanced micronutrients content in sugar beet roots due to the role of plant growth regulators in increasing the cell division, expansion and stem elongation. The obtained data represented also that the application of gibberellin at rate 100 mg l^{-1} was more effective on micronutrient contents followed by proline at 200 mg l^{-1}.

By application of boron sources as boric acid and nano boron (B-NPs) data in Table, 4 showed that the application of B-NPs gave more respond for all micronutrients contents this might be due to nano-fertilizer application promoted the growth, development and antioxidant activity in sugar beet plants and has the potential to improve crop production and plant nutrition.

Table 4: Effect of two type of growth regulator at different rates with two sources of boron at two rates of macronutrients on micronutrients contents of sugar beet plants after 90 days from sowing.

Boron sources (B)	Macronutrients at 100% of recommended dose							Macronutrients at 75% of recommended dose						
	Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})			Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})		
		100	200	Mean	100	200	Mean		100	200	Mean	100	200	Mean
Zinc (mg kg^{-1})														
Control	13.66	15.06	14.88	14.53	15.70	17.35	15.57	12.40	15.01	13.90	13.77	14.92	18.56	15.29
Boric a.	15.48	18.42	17.36	17.09	16.96	19.84	17.43	13.85	20.44	19.60	17.96	18.14	22.40	18.13
B-NPs	17.08	24.92	20.38	20.79	20.62	23.81	20.50	15.54	27.30	21.02	21.29	21.65	26.74	21.31
Mean	15.65	19.47	17.59	17.52	17.76	20.33	17.87	13.93	20.92	18.17	17.67	18.24	22.57	18.25
Cupper (mg kg^{-1})														
Control	0.86	1.30	1.08	1.08	1.21	1.58	1.22	0.75	1.45	1.24	1.15	1.25	1.45	1.15
Boric a.	0.93	1.56	1.44	1.31	1.34	1.61	1.29	0.86	1.74	1.46	1.35	1.34	1.61	1.27
B-NPs	1.32	1.71	1.56	1.53	1.49	1.75	1.52	1.06	1.96	1.52	1.51	1.51	1.93	1.50
Mean	1.04	1.52	1.36	1.31	1.35	1.65	1.35	0.89	1.72	1.41	1.34	1.37	1.66	1.31
Iron (mg kg^{-1})														
Control	24.46	59.42	43.54	42.47	40.72	55.54	40.24	20.40	55.10	42.48	39.99	41.00	53.64	38.35
Boric a.	25.38	61.57	46.22	44.39	54.60	56.39	45.46	23.32	68.80	40.17	44.10	53.68	71.82	49.61
B-NPs	29.94	65.81	47.31	47.69	59.17	61.31	50.14	26.41	85.20	65.40	59.00	62.16	87.42	58.66
Mean	26.59	62.27	45.69	44.85	51.50	57.75	45.28	23.38	69.70	49.35	47.59	52.28	47.63	44.98
Manganese (mg kg^{-1})														
Control	17.70	20.16	18.76	18.87	18.86	20.94	19.17	16.18	22.58	20.44	19.73	21.68	23.08	20.31
Boric a.	19.72	25.48	23.78	22.99	21.98	25.52	22.23	18.42	28.16	25.36	23.98	24.80	27.90	23.71
B-NPs	21.02	27.32	25.02	24.45	24.86	26.94	24.27	19.92	30.78	27.78	26.16	26.76	30.50	25.73
Mean	19.48	24.32	22.52	22.11	21.90	24.47	21.92	18.17	27.17	24.53	23.29	24.41	27.18	23.25

L.S.D. at 0.05

	B	G	R	B x G	B x R	G x R	B x G x R
Zn	0.54	0.32	0.11	0.23	0.15	0.23	0.15
Cu	0.09	0.10	0.08	0.03	0.12	0.03	0.06
Fe	0.23	0.22	0.42	0.24	0.35	0.33	0.41
Mn	1.22	0.91	1.20	0.93	0.15	1.10	1.01

B = Boron sources; G = Plant growth regulator sources and R = Rate of Plant growth regulator.

Regard to macronutrient rates applied, data revealed that the full dose was superior compared to 75% this result may be due to the optimum rate of macronutrients increases photosynthetic processes, leaf area production, leaf area duration as well as net assimilation rate.

Finally, macronutrients applied at rate 75% with foliar application of gibberellin at rate 100 mg l^{-1} was more effective when accompanied with nano boron in micronutrients content of sugar beet roots compared to other treatments used.

d- Yield and sugar yield of sugar beet

Data in Table, 5 revealed that the foliar application of gibberellin at rate 100 mg l^{-1} and proline at 200 mg l^{-1} gave higher response in yield and sucrose yield.

Root yield and sucrose yield of sugar beet plants were affect to application of different boron sources as results obtained in Table, 5. Data showed that the application of B-NPs was more response than boric acid.

Moreover, the interaction between plant growth regulators and boron give higher response in root yield and sucrose yield.

Regard to macronutrient rates applied, data in Table 5 also, represented that the application of 100% macronutrients give better response this is due to the abundant availability of nutrients for prober sugar beet plants growth where the importance of each element during plant life.

Yet, the interaction between all treatments and parameters of sugar beet roots under study gave high values at the combination between applications of macronutrients at rate 75 % with nano boron and gibberellin at rate 100 mg l^{-1} and proline at 200 mg l^{-1} in both yield and sugar yield of sugar beet plants at harvest stage.

Table 5: Effect of two type of growth regulator at different rates with two sources of boron at two rates of macronutrients on yield and sugar yield of sugar beet plants at harvest stage.

Boron sources (B)	Macronutrients at 100% of recommended dose							Macronutrients at 75% of recommended dose						
	Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})			Control	Gibberellin (mg l^{-1})			Proline (mg l^{-1})		
		100	200	Mean	100	200	Mean		100	200	Mean	100	200	Mean
Root yield (Mg ha^{-1})														
Control	57.44	70.34	67.36	65.05	66.10	70.59	64.71	56.11	75.19	70.71	67.34	66.52	71.58	64.74
Boric a.	60.19	77.96	71.82	69.99	68.05	73.19	67.14	57.63	78.49	73.04	69.72	71.11	75.80	68.18
B-NPs	61.94	84.26	76.11	74.10	69.67	75.16	68.92	59.60	87.22	77.76	74.86	71.96	84.57	72.04
Mean	59.86	77.52	71.76	69.71	67.94	72.98	66.93	57.78	80.30	73.84	70.64	69.86	77.32	68.32
Sucrose yield (Mg ha^{-1})														
Control	9.24	11.61	10.89	10.58	10.84	11.75	10.61	8.98	13.27	11.89	11.38	11.28	12.17	10.81
Boric a.	9.92	13.21	11.89	11.67	11.30	12.35	11.19	9.41	14.36	12.34	12.04	12.16	13.11	11.56
B-NPs	10.34	14.62	12.71	12.56	11.70	12.79	11.61	9.78	16.49	13.69	13.32	12.26	15.01	12.35
Mean	9.83	13.15	11.83	11.60	11.28	12.30	11.14	9.39	14.71	12.64	12.25	11.90	13.43	11.57

L.S.D. 0.05	B	G	R	B x G	B x R	G x R	B x G x R
Root yield	0.32	0.15	0.31	0.21	0.11	0.24	0.18
Sucrose yield	0.91	0.11	0.21	0.16	0.22	0.15	0.19

B = Boron sources; G = Plant growth regulator sources and R = Rate of Plant growth regulator

Discussion

Economic conditions in modern agriculture demand high crop yields in order to be profitable and consequently meet the high demand for food that comes with population growth.

The previously data showed that the foliar application of plant growth regulators showed increase in the nutritional status, sucrose yield and productivity of sugar beet at 100 mg l^{-1} of gibberellin and 200 mg l^{-1} of proline This may be due to the gibberellin plays an important role in internode elongation (Ross *et al.*, 1997), stimulates cell division, expansion and increases the use efficiency of nutrients in response to light or dark (De Lucas *et al.*, 2008; Gallego-Bartolomé *et al.*, 2011). Proline, a multifunctional amino acid, besides acting as an excellent osmolyte and stabilizing subcellular structures such as proteins and cell membranes, scavenging free radicals, balancing cellular homeostasis and signaling events and buffering redox potential under stress conditions (Hayat *et al.*, 2012). It could be reflecting on maintaining the nutrient status in roots. This report is in conformity with the increased nitrate content of roots by exogenous application of proline (Alyemeni *et al.*, 2016). Moreover, gibberellin is endogenously synthesized hormone that regulates stem cell elongation. Gibberellin acts through its nucleus-localized receptor, GID1 (Gibberellin-Insensitive Dwarf1), and like auxin, this binding induces degradation of transcriptional repressor proteins, DELLA which have a characteristic conserved motif Asp-Glu-Leu-Leu-Ala, at the amino terminus (Haruta and Sussman, 2017).

Eid and Abou-Leila (2006) reported that the gibberellin application increased the N, P, K, Mg, Fe, Zn, Mn and Cu content of plants, thereby increasing the mineral nutrient status of the plant. The increased nutrient content enhanced photosynthetic potential of leaves, source strength and increased the mineral nutrient levels of plant roots and shoots (Al-Rumaih, Rushdy and Warsy, 2003). Since GA_3 is increasing the efficiency of plants in terms of photosynthetic activity, enhancing nutrients uptake, nutrients translocation and improving its mobilization, thus GA_3 might be increased the yield (Ali *et al.*, 2019). According to (Nilanjan, 2013) who stated that boron nano as fertilizers of embodiments herein a sharp increase in crop yield and quality.

This results was in agreement with (Soad, 2005) who to gibberellin foliar application. Also, the exogenous application of plant growth regulators improve crop productivity and the nutritional quality of crop plants through improved photosynthesis and nutrient uptake and through accumulation within the plant body (Niu *et al.*, 2016). Moreover, proline also functions as a sink for energy to regulate redox potentials (Blum and Ebercon, 1976) as a hydroxyl radical scavenger, solute that protects macromolecules against denaturation (Schobert and Tschesche, 1978), reducing the acidity in the cell (Venekamp *et al.,* 1989) and acts as storage compound and nitrogen source for an after-stress rapid growth (Singh *et al*., 1973).

Also, result attribute to gibberellin is growth promoter which has the ability to increase mitosis in the sub apical regions of apical meristems, stimulating cell divisions in the intercalary meristems and causing elongation of cell, cell division and increasing the length of internode (Thomson *et al.,* 2015). Also, the foliar spray of proline caused an increase in apical meristem and cell division, which improved the plant height (Ali *et al.*, 2013). Plant growth regulators may be employed to improve crop performance in terms of yield and seed nutritional quality through the modulation of plant growth and physiological processes such as the photosynthetic efficiency and nutrient dynamics within the plant body (Anjum *et al.*, 2016).

Regard to the boron sources the obtained data revealed that the foliar application of B-NPs was more response than boric acid this results may be due to (Dewdar *et al.*, 2018) who reported that nanofertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth, nano-fertilizers have great impact on the soil, can reduce the toxicity of the soil and decrease the frequency of fertilizer application. Also, Allen and Pilbeam (2007) emphasized that sugar beet crop has high requirements for boron when adequate boron nutrition is critical for high yield and quality of crops. They also reported that boron increases the rate of transport of sugars from source to sink. Abido (2012) stated that the advantage of boron application may be due to the function of boron in increasing plant metabolism, development and growth. Liu and Lal (2015) who reported that utilization of nanoparticles to plants can be advantageous for development and advancement because of its capacity for more noteworthy absorbance and high reactivity. Additionally, Nanotechnology can be used in crop production to improve growth and increase yield (Reynolds, 2002). Abbas M. Mahmoud (2020) .found that foliar application at 20 ppm of nano silver had the highest figures of fruit yield per gm and fruit yield per kg. Addition of nano silver in foliar application at 20 ppm gave the highest figures of yield characteristics compared with other treatments.

Moreover, macronutrient rates applied the results showed that the application of macronutrients at full dose was more effective than at 75% where, Lošák *et al.*, (2010) confirmed that under various patterns of N supply, plants have shown elaborate reaction in relation to physiological and morphological levels to regulate their development and growth. Pavlíková *et al.*, (2012) reported that phytohormones are strongly connected to nitrogen signaling. These results were confirmed by (Abdelaal, 2015) who stated that shoot and root fresh weight, toot length and root radius significantly decreased as a result of 75% macronutrients compared to the application of full dose. This can result from the nutrient being a raw material for synthesis of a product but also from its involvement in enzymatic activities will lead to increased amount of proteins due to increased activation of enzymes that metabolize carbohydrates for synthesis of amino acids and proteins (Njira and Nabwami, 2015). Also Pavlíková *et al.* (2012) suggested that cytokinin metabolism and translocation were adjusted by N nutritional status in plants. The primary macronutrients play a significant role during the entire plant life by performing various beneficial activities in plant metabolism. Nitrogen is also regarded as the essential component of all proteins and enzymes and further performs in various metabolic processes of energy transformation. Therefore, sufficient amount of N availability in plants is required, because it is one of the major key factors of crop production (Nadeem *et al.*, 2014). Phosphorus plays an important role in an array of cellular processes, including maintenance of membrane structures, synthesis of biomolecules and formation of high-energy molecules. It also helps in cell division, enzyme activation/inactivation and carbohydrate metabolism (Razaq *et al.*, 2017). Potassium has two main functions, it plays an important role in activation of basic enzymes for protein production and sugars, also potassium protects the water content in plants by help in maintain the turgor of the cells which protect vitality of the leaf and consequently, photosynthesis proceeds efficiently (Çalişkan and Çalişkan, 2019).

Conclusion

From the presented study, it might be concluded that the application of 75% macronutrients was the best treatment for plant growth parameters (fresh and dry weigh), micro nutrients content and total yield of roots with yield production of sucrose of sugar beet plants (*Beta vulgaris* L. *var.* Sara poly) when accompanied with nano boron as an nano micronutrient fertilizer source with proline at rate of 200 mg l^{-1} than 100% with boric acid and proline 100 mg l^{-1} and control treatment of sugar beet quality grown in clay soil.

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