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RESEARCH ARTICLE

Impact of gibberellic acid on yield and quality of some sugar beet varieties

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Abstract

A field experiment was conducted in Hafir Shehab El-Din (Dakhalia Governorate), Egypt (latitude of 31.5 N, and longitude of 30.32 E), and elevation of 15 m above sea level) during the 2018/2019 and 2019/2020 growing seasons, to study the impact of gibberellic acid on the yield and quality of some sugar beet varieties. A randomized complete block design (RCBD) using strip-plot arrangement with four replication was used in both growing seasons, where four gibberellic acid concentrations (control= distilled water, 100 ppm, 200 ppm and 300 ppm) occupied the main plots, while the four multi-germ and mono-germ sugar beet varieties namely, Belatos, Hercule, Helsinki and Bersea, allocated in the sub-plots. The plot area was 21 m^2 (1/200 fed.) and consisted of 6 ridges, 7 m length, 0.5 m width and 0.20 m spacing between hills. Seeds were sown in the first week of October, as well as sugar beet was harvested at the age of 210 days. The soil of the experimental site was clay. All studied traits (root fresh weight, sucrose%, root yield and yield/fed.) were highly significantly affected by the two studied factors (gibberellic acid concentrations and sugar beet varieties) in both growing seasons. All studied traits were increased by increasing gibberellic acid concentration and the highest mean values were obtained by 300 ppm gibberellic acid treatment, in both growing seasons, except sucrose % was superior with 200 ppm treatment in the second growing season. The Bersea variety realized the maximum mean values for root fresh weight (kg/plant) and root yield (ton/fed.) in both growing seasons, combined with sucrose% and sugar yield (ton/fed.) in the first growing season only. In contrast, Helsinki and Hercule varieties recorded the maximum values for the sucrose% and sugar yield in the second growing season. Bersea variety and sprayed with 300 ppm gibberellic acid treatment recorded the maximum mean values for fresh root weight (kg/plant) and root yield (ton/fed) in both growing seasons. Moreover, either Helsinki variety with 200 ppm or the Hercule variety with 300 ppm treatments realized the highest mean values for sugar% and sugar yield (ton/fed.) in the second growing season only.

Keywords: Beta vulgaris; Plant growth regulators; Root yield; Sugar yield

Introduction

Sugar beet (*Beta vulgaris*) is considered the most important crop for sugar industry in Egypt and worldwide (Ahmed et al. 2023; Galal et al. 2022a). Sugar beet variety is the basis of sugar beet production (Galal et al. 2022b). Therefore, the imported seeds of sugar beet varieties annually are evaluated across a wide range of locations and years for their productivity and quality characteristics to select the appropriate ones under the different environmental conditions. Because of the unsuitable conditions for seed production in Egypt, beet sugar companies mainly depended upon imported seeds from the production areas in European countries (Abo-Elwafa et al. 2006; Abou-Elwafa wt al. 2013). Selection among the imported sugar beet genotypes is done through three experimental types of experiments, i.e., primary, main and final experiments to select the superior genotypes characterized by high yield and quality. El-Shiekh et al. (2012) revealed that the differences between sugar beet varieties were significantly root, sugar yields/fed. and sucrose %. They added that Farida variety was surpassed in sucrose % and sugar yield (ton/fed.). Enan et al. (2016) indicated that the tested three beet varieties differed significantly in the studied traits.

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They added that Polat variety showed superiority over the other two tested varieties and recorded the highest values of root fresh weight/plant in both growing seasons. Meanwhile, insignificant differences were found between Polat and Henrike varieties in root fresh weight/plant in both growing seasons. Moreover, insignificant differences among varieties were detected in their impact on gross and corrected sugar yields/fed. Aly and Khalil (2017) showed that growing sugar beet at Tamia site resulted in the highest values of root fresh weight/plant, root yield/fed. as well as the percentage of sucrose, corrected sugar and quality index. The variety Oscar Poly was significantly higher in root fresh weight/plant, root yield and sugar yield/fed. Mohamed et al. (2019) indicated that Raspoly, Kawemira and Montibianco varieties were significantly differed on root yields, sugar yields and sugar beet quality in the two tested growing seasons. The highest mean values of sugar beet yield were recording by cv. Montibianco. Gobarah et al. (2019) showed that Ras-Poly variety recorded the highest values of root fresh weight/plant and yield ton/fed., while Dema-poly and Glloria varieties gave a higher sugar yield/fed. and sucrose % in both growing seasons. El-Bakary et al. (2020) showed that root fresh weight, root yield (t/fed.), sucrose and sugar yield/fed. were significantly affected by the different tested varieties. Capel, Sirona and Beta max varieties recorded the highest values of growth, quality and yield of Sugar beet compared to the other varieties.

Enan (2015) indicated that sowing sugar beet using seeds soaked in 150 ppm GA_3 produced significantly higher values of root fresh weight/plant, root and sugar yields/fed. and caused an appreciable increase in root and top dry weight/plant as well as the lowest quantities of sugar lost to molasses in both growing seasons. Azab et al. (2018) tested the effect of three levels of gibberellic acid solutions (50, 100 and 150 mg/L) on two sugar beet cultivars (Farida and Sultan), and results showed that all tested GA_3 treatments statistically improved root yield, sucrose% of sugar beet. El-Kady and El-Mansoub (2020) studied the effect of (gibberellic acid GA_3), at the levels of 0, 100, 200 and 300 ppm concentrations on growth, yield and quality of sugar beet. They summarized increasing growth regulator concentrations from zero up to 100, 200 and 300 ppm increased yield and quality traits of sugar. Leilah and Khan (2021) reported that root fresh weight/plant, and root and top yield/ha were increased with the incremental level of GA_3 concentration. Foliar application of GA_3 significantly decreased quality parameters including sucrose and total soluble solid percentages. Early application of GA_3 (60 DAP) had an active role on sugar beet growth, yield and quality or spraying GA_3 with a concentration of 160 mg/L at 60 DAP is the recommended treatment for raising sugar yield/fed.

Materials and Methods

A field experiment was carried out during the two growing seasons of 2018/2029 and 2019/2020 at Hafir Shehab El-Din (Dakahlia Governorate) Egypt (latitude of 31.5 N, and longitude of 30.32 E and elevation of 15 m above sea level), to study the impact of four gibberellic acid spraying concentrations on some sugar beet varieties in relation to yield and quality attributes of sugar beet crop.

A randomized complete block design (RCBD) using strip-plot arrangement with four replication was used in both growing seasons, where four gibberellic acid treatments distilled water (the solvent as control), 100 ppm, 200 ppm and 300 ppm) arranged horizontally, while four multi-germ and mono-germ sugar beet varieties namely; Belatos, Hercule, Helsinki and Bersea, were allocated vertically. The plot area was 21 m^2 (1/200 fed.) consisted of 6 ridges, 7 m length, 0.50 m width and 0.20 m spacing between hills. Sugar beet seeds were sown at the first week of October and plants were harvested at age 210 days in both growing seasons. All agronomic practices required for growing sugar beet and recommended doses of mineral fertilizers were done. The soil of the experimental site was clay. Chemical and physical properties of the experimental soil was done according to Piper (1955) are shown in Table 1.

Table1. Physical and chemical analysis of the experimental soil

El-Dakahlia experimental site

Growing season	2018/2019	2019/2020	Growing season	2018/2019	2019/2020
Partial soil distribution			Mg**	0.94	1.42
Sand %	21.20	18.20	Na^+	2.75	1.25
Silt %	36.00	33.00	K^+	0.05	0.03
Clay %	42.80	41.80	Anions (meq/l)		
Soil texture	Clay	Clay	HCO^-_3	0.80	0.50
EC (dS/m)	0.92	0.90	Cl^-	2.10	1.63
pH (1:2.5)	8.20	8.10	SO^-_4	1.70	1.90
Organic matter %	1.22	1.18	Available N (mg/kg soil)	39.10	40.35
Cations (meq/l)			Available P (mg/kg soil)	8.50	7.85
Ca**	0.86	1.33	Available K (mg/kg soil)	175	180

The studied traits

The harvest was carried out at 210 days after sowing. A sample of ten plants were randomly selected from the inner ridges of each plot to estimate:

1- Root fresh weight (kg/plant).
2- Sucrose percentage: sucrose content in juice of sugar beet in each treatment was determined in Dakahlia Sugar Company.
3- Root yield/fed. (ton/fed.), which were determined from plot weight (kg) and converted to tons/fed.
4- Sugar yield/fed. (ton/fed.) was calculated according to the following method of Devillers (1988)

Sugar yield/fed. (ton) = root yield/fed. (ton/fed.) x sucrose % / 100

All collected data were analyzed with analysis of variance (ANOVA) procedures using M-State software program. Differences between means were compared by LSD at 5% level of significance (Gomez and Gomez 1984).

Results and Discussion

Root fresh weight (kg)

Data in Table 2 revealed that root fresh weight affected highly significantly by tested sugar beet varieties, gibberellic acid spraying levels and their interaction in both growing seasons. The highest mean values (1.231 and 1.185 kg) followed by (1.221 and 1.175 kg) were recorded by 300 ppm followed by 200 ppm gibberellic acid levels without significant differences between them, while the lowest mean values in this respect (1.174 and 1.128 kg) for root fresh weight were recorded by control treatment in the first and second growing seasons, respectively. The results supported that root fresh weight increased with increasing gibberellic acid concentration. These results are in agreement with those cleared by Enan (2015); El-Kady and El-Mansoub (2020) and Leilah and Khan (2021).

Table 2. Main effects of varieties, gibberellic acid levels and their interaction on root fresh weight (RFW) of sugar beet in 2018/2019 and 2019/2020 growing seasons.

Growing season			2018/2019		
Treatments			Gibberellic acid concentration (GA)		
Varieties (V)	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	1.093	1.162	1.177	1.188	1.155
Hercule	1.162	1.172	1.189	1.200	1.181
Helsinki	1.215	1.235	1.254	1.262	1.242
Bersea	1.227	1.249	1.262	1.275	1.254
Mean	1.174	1.204	1.221	1.231	--
Growing season			2019/2020		
	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	1.046	1.116	1.131	1.141	1.109
Hercule	1.116	1.126	1.142	1.154	1.135
Helsinki	1.169	1.189	1.208	1.218	1.196
Bersea	1.181	1.203	1.218	1.227	1.207
Mean	1.128	1.158	1.175	1.185	--

Statistical tests

Treatments	2018/2019		2019/2020	
	F-test	$LSD_{0.05}$	F-test	$LSD_{0.05}$
GA	**	0.025	**	0.021
V	**	0.023	**	0.019
VxGA	**	0.046	**	0.038

** Indicated highly significant at 1% level of probability.

With respect to varieties (Table 2), the highest mean values (1.254 and 1.207 kg) followed by (1.242 and 1.196 kg) were obtained by Bersea followed by Helsinki varieties without significant differences between them. On the other hand, the lowest mean values (1.155 and 1.109 kg) for root fresh weight were obtained by Belatos variety in the first and second growing seasons, respectively. The variance among sugar beet varieties may be due to the genotype make up. These results in harmony with those reported by Enan et al. (2016); Aly and Khalil (2017) and Gobarah et al. (2019).

As for the interaction between gibberellic acid levels and varieties (Table 2), results declared that the maximum mean values (1.275 and 1.227 kg) followed by (1.262 and 1.218 kg) were gained from Bersea followed by either Helsinki varieties under the highest gibberellic acid concentration (300 ppm) or by Bersea variety under 200 ppm GA, while the minimum records (1.093 and 1.046 kg) for root fresh weight were recorded from Belatos variety sprayed by water (control) in the first and second growing seasons, respectively.

Sucrose %

It would be observed from the recorded data in Table 3 that a highly significant differences in sucrose % were found among the tested treatments of gibberellic acid concentrations, sugar beet varieties and their interaction in both growing seasons. It could be noted that the highest mean values (17.53 and 15.76%) followed by (17.26 and 15.58%) were obtained by (300 and 200 ppm) followed by (200 ppm and 300 ppm) without significant differences between them, while the lowest mean values (16.88 and 14.63) resulted from the control treatment in the first and growing seasons, respectively. Moreover, the sucrose % increased by increasing gibberellic concentration up to 300 ppm in the first growing season and up to 200 ppm in the second growing season. Similar findings were mentioned by Azab et al. (2018) and El-Kady and El-Mansoub (2020). On the contrary, Leilah and Khan (2021) found that sucrose % decreased with increasing gibberellic acid levels.

Data in Table 3 illustrated the superiority of Bersea variety (17.85%) in the first growing season and Hercule variety (16.40%) in the second growing season, while Belatos variety (16.68%) in the first growing season and Bersea variety (13.87) produced the minimum values. The difference among the sugar beet varieties in sucrose % could be due to the variation in the genetic background. These results are in line with those detected by Aly and Khalil (2017); Gobarah et al. (2019); conditions et al. (2019) and El-Bakary et al. (2020).

Here too, the interaction between variety and gibberellic acid concentration levels was shown in Table 3. The highest mean values of sugar percentages 17.82% followed by 17.63% were recorded by Bersea and Hilsinki varieties under 300 ppm gibberellic acid without significant differences between the first growing season as well in the second growing season the highest mean values 16.80 % followed by 16.57 % were recorded by Hercule variety under 300 ppm and 100 ppm, respectively, without significant differences between them.

Table 3. Main effects of varieties, gibberellic acid levels and their interaction on sucrose percent (%) of sugar beet in the 2018/2019 and 2019/2020 growing seasons.

Growing season	2018/2019				
Treatments	Gibberellic acid concentration (GA)				
Varieties (V)	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	16.18	16.53	16.85	17.17	16.68
Hercule	16.55	16.94	17.16	17.50	17.04
Helsinki	17.37	17.33	17.42	17.63	17.44
Bersea	17.43	17.43	17.62	17.82	17.85
Mean	16.88	17.06	17.26	17.53	--
Growing season	2019/2020				
	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	15.64	16.15	16.21	16.34	16.09
Hercule	15.72	16.57	16.49	16.80	16.40
Helsinki	14.07	14.32	15.99	15.22	14.90
Bersea	13.08	13.33	14.33	14.37	13.87
Mean	14.63	15.09	15.76	15.58	--

Statistical tests

Treatments	2018/2019		2019/2020	
	F-test	$LSD_{0.05}$	F-test	$LSD_{0.05}$
GA	**	0.887	**	0.337
V	**	0.132	**	0.235
VxGA	**	0.264	**	0.470

** Indicated highly significant at 1% level of probability.

Root yield (ton/fed.)

The spraying application of gibberellic acid on sugar beet plants exerted a highly significant influence on root yield (ton/fed.) in the two growing seasons (Table 4). There was an increase in root yield as a result of spraying gibberellic acid up to 300 ppm. Therefore, the maximum mean value (25.06 and 24.31 ton/fed.) were found at 300 ppm level of gibberellic acid, while the minimum ones (24.28 and 23.03 ton/fed.) were found by spraying the distilled water only in the first and second growing seasons, respectively. The increase in root yield was as a result of the increase in single root weight/plant (Table 2). These results are in accordance with those performed by Enan (2015); Azab et al. (2018) and Leilah and Khan (2021).

Furthermore, the data in Table 4 revealed that the root yield trait was affected highly significantly by sugar beet varieties in both growing seasons. Bersea sugar beet variety produced the maximum root yield (25.33 and 24.33 ton/ fed.) followed by Helsinki variety (24.78 and 23.81 ton/ fed.) in the first and second growing seasons, respectively. The minimum mean values (24.14 and 23.17 ton/fed.) were produced by Belatos variety in the first and second growing seasons, respectively. This is to be logical since the same sugar beet varieties gave the highest or lowest mean values with regard to single root weight as aforementioned (Table 2). These results are in harmony with those pointed out by El- Shiekh et al. (2012); Aly and Khalil (2017); Gobarah et al. (2019); Mohamed et al. (2019) and El-Bakary et al. (2020).

Table 4. Main effects of varieties, gibberellic acid levels and their interaction on root yield (ton/fed.) of sugar beet in 2018/2019 and 2019/2020 growing seasons.

Growing season	2018/2019				
Treatments	Gibberellic acid concentrations (GA)				
Varieties (V)	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	23.43	23.94	24.09	25.10	24.14
Hercule	23.98	24.55	24.51	25.63	24.67
Helsinki	24.61	25.00	25.05	24.46	24.78
Bersea	25.16	25.59	25.49	25.06	25.33
Mean	24.28	24.77	24.78	25.06	--
Growing season	2019/2020				
	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	22.18	22.94	23.19	24.35	23.17
Hercule	22.73	23.55	23.61	24.88	23.69
Helsinki	23.36	24.00	24.15	23.71	23.81
Bersea	23.84	24.58	25.59	24.31	24.33
Mean	23.02	23.76	23.88	24.31	--

Statistical tests

Treatments	2018/2019		2019/2020	
	F-test	$LSD_{0.05}$	F-test	$LSD_{0.05}$
GA	**	0.19	**	0.17
V	**	0.32	**	0.30
VxGA	**	0.64	**	0.60

** Indicated highly significant at 1% level of probability

As for, the interaction between gibberellic acid levels with sugar beet varieties had a highly significantly influence on the root yield in the two growing seasons (Table 4). The maximum mean values (25.63 and 24.88 ton/fed.) were recorded by Hercule variety with 300 ppm gibberellic acid, while the minimum ones (23.43 and 22.18 ton/fed.) were recorded by Belatos variety under spraying with the control treatment in the first and second growing seasons, respectively.

Sugar yield (ton/fed.)

Data in Table 5 revealed that sugar yield was affected highly significantly by spraying gibberellic acid. The sugar yield was increased gradually by increasing gibberellic acid concentrations in the two growing seasons. Therefore, the maximum sugar yield values (4.392 and 3.806 ton/fed.) followed by (4.279 and 3.760 ton/fed) were confirmed by 300 ppm followed by 200 ppm gibberellic acid in the first and second growing seasons, respectively, without significant differences between them in the second growing season only. This is to be expected since the same gibberellic acid levels gave the highest mean values with regard to root yield/fed. and consequently produced the highest mean values of sugar yield (ton/fed.) in both growing seasons. These results are in coincidence with those recorded by Enan (2015); Azab et al. (2018); El-Kady and El-Mansoub (2020) and Leilah and Khan 2021).

Table 5. Main effects of varieties, gibberellic acid levels and their interaction on sugar yield (ton/fed.) of sugar beet in 2018/2019 and 2019/2020 growing seasons.

Growing season	2018/2019				
Treatments	Gibberellic acid concentrations (GA)				
Varieties (V)	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	3.790	3.956	4.059	4.309	4.029
Hercule	3.967	4.159	4.206	4.482	4.204
Helsinki	4.276	4.334	4.362	4.312	4.321
Bersea	4.347	4.460	4.492	4.466	4.448
Mean	4.095	4.227	4.279	4.392	
Growing season	2019/2020				
	Control	100 ppm	200 ppm	300 ppm	Mean
Belatos	3.46	3.70	3.75	3.979	3.728
Hercule	3.57	3.90	3.89	4.180	3.888
Helsinki	3.28	3.43	3.86	3.608	3.548
Bersea	3.12	3.27	3.52	3.495	3.354
Mean	3.36	3.58	3.76	3.806	--

Statistical tests

Treatments	2018/2019		2019/2020	
	F-test	$LSD_{0.05}$	F-test	$LSD_{0.05}$
GA	**	0.044	**	0.095
V	**	0.064	**	0.082
VxGA	**	0.128	**	0.164

** Indicated highly significant at 1% level of probability.

Concerning sugar beet varieties effect in this respect, the data in Table 5 showed that the sugar beet varieties had a highly significant influence on sugar yield in both growing seasons. Thus, the maximum mean values (4.448 and 3.888 ton/fed.) were found by Bersea and Helsinki varieties, while the minimum mean values (4.029 and 3.354) were found by Belatos and Bersea varieties in the first and second growing seasons, respectively. These results mean that the variance among sugar beet varieties may be due to the genotype make up. These results are confirmed with those cleared by Enan et al. (2016); Aly and Khalil (2017); Gobarah et al. (2019); Mohamed et al. (2019) and El-Bakary (2020).

As for the interaction between varieties and gibberellic acid levels, the data in Table 5 pointed out that sugar yield was affected highly significantly by this interaction in both growing seasons. The maximum mean values (4.492 and 4.180 ton/fed.) followed by (4.482 and 3.979 ton/fed.) were shown by Bersea and Hercule followed by Hercule and Belatos varieties, without significant difference in the first growing season, while the minimum mean values (3.79 and 3.12 ton/fed.) were showed by Belatos and Bersea varieties under control (without spraying) in the first and second growing seasons, respectively. Hence, the results may be due to the genetic variation among varieties under various gibberellic acid levels reflecting weather climatic condition.

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