Middle East Journal of Agriculture Research
Volume: 13 | Issue: 04| Oct. – Dec.| 2024

EISSN: 2706-7955 ISSN: 2077-4605
DOI: 10.36632/mejar/2024.13.4.54
Journal homepage: www.curresweb.com
Pages: 929-944

Influence of Bio and Inorganic Fertilizers on Productivity and Quality of some Sugar Beet Varieties

Makhlouf B.S.I.[1], K.A. Sadek[1], I.A. Abd Elateef[1] and Faten M. Mohamed[2]

[1]Sugar Crops Research Institute, Agricultural Research Center, Giza 12619, Egypt.
[2]Soil, Water and Environment Research Institute, Agricultural Research Center, Giza 12619, Egypt.

Received: 15 August 2024 **Accepted:** 05 Oct. 2024 **Published:** 20 Oct. 2024

ABSTRACT

Two field experiments were conducted at Sinnuris district, Fayoum Governorate, Egypt, during 2020/2021 and 2021/2022 seasons to study the possibility of using bio-fertilizers as a partial alternative to inorganic NPK fertilizers and their effects on yield, quality and economic returns of some mono-germ sugar beet varieties (Preziosa KWS, BTS smart 9830, and Jampol). Fertilization treatments included; T_1: 100% of the recommended rates of inorganic NPK fertilizers (80, 30 and 24 kg of N, P_2O_5, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds before sowing in specialized liquid media of bio-fertilizers "LBF_{sooked}" containing (*Azospirillum lipoferm*, *Azotobacter choococcum*, *Bacillus polymyxa,* and *klebsiella pneumonia*) at 2 L/fed + foliar spraying with a combination of liquid bio-fertilizers "LBF_{foliar}" [(*A. lipoferm*, *A. choococcum*, *B. polymyxa* and *K. pneumonia*) + liquid vinasse as a carrier] at the rate of 10 L/fed + 75% of NPK/fed, T_3: LBF_{sooked} at 2 L/fed + soil inoculation with a combination of liquid bio-fertilizers "LBF_{soil}" at the rate of 15 L/fed divided into [(5 L of *Sporolactobacillus lavolacticus*) and 10 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 75% of NPK/fed, T_4: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 5 L/fed + LBF_{soil} at 10 L/fed divided into (5 L of *S. lavolacticus*) and 5 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 75% of NPK/fed, T_5: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed divided into [(5 L of *S. lavolacticus*) and 15 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 50% of NPK/fed, and T_7: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 l/fed + LBF_{soil} at 15 L/fed divided into [(5 L of *S. lavolacticus*) and 10 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *K. pneumonia*, at 10 L/fed)] + 50% of NPK/fed. A strip plot design was used. The results showed that T_4 treatment resulted in the most favorable values of sucrose and extractable sugar percentages in the 1st season, quality index% in the 2nd one, root fresh weight/plant (RFW) and root and sugar yields/fed, in both seasons. Variety BTS Smart 9830 had the maximum values of RFW in the 1st season, sugar yield/fed in the 2nd one, and root yield/fed in both seasons. Significant interaction effects between fertilization treatments and varieties on the studied traits were discussed. Based upon the obtained results, sowing BTS Smart 9830 sugar beet variety fertilized with T_4 treatment can be recommended to attain the best root and sugar yields and economic return per feddan.

Keywords: Bio-fertilizers, economic evaluation, inorganic NPK fertilizers, sugar beet varieties

1. Introduction

In Egypt, the total cultivated area of sugar beet (*Beta vulgaris* var. saccharifera L.) in 2023 reached 658597 feddan, with a production of 14025098 tons of roots, and an average of 21.29 tons/fed. Sugar beet crop contributed to 1790787 tons of sugar, representing 63.8% of the total sugar production in Egypt (SCCAR, 2023). Improving agricultural practices, such as the use of bio-fertilizers in combination with the optimum levels of inorganic NPK fertilizers, are essential to enhance yield and quality of sugar beet varieties, as well as to reduce costs and keep the soil in high gene, *i.e.* decreasing the environmental pollution. Therefore, the rational use of chemical fertilizers is a cornerstone in achieving sustainable agricultural development. Application of nitrogen-fixing bio-fertilizers, which

Corresponding Author: Makhlouf B.S.I., Sugar Crops Research Institute, Agricultural Research Center, Giza 12619, Egypt.

are environmentally safe products, and increasing phosphorus and potassium availability in the soil, led to a decrease in the use of chemical fertilizers and the provision of high-quality (Mahfouz and Sharaf El-Din, 2007). Inoculation with multi-characteristics bacteria stimulated overall plant growth, sugar content, root yield and nutrients uptake. Bacterial formulations increased dry weights of storage root and leaves (Çakmakçı and Karagöz, 2020). *Azotobacter chroococcum* and *Azospirillum lipoferum* are not only associated with nitrogen fixation, but also with the production of growth hormones (Cassan and Diaz-Zorita 2016). *Azospirillum* has been shown to positively affect plant growth, crop yield, and plant nitrogen content. This plant stimulatory effect, exerted by *Azospirillum*, has been attributed to several mechanisms, including biological nitrogen fixation (Cassan *et al.,* 2020). The bacterial genus *Azotobacter* has been reported to synthesize auxins, cytokinins, and gibberellic acid-like substances that have been found to be directly related to improve plant growth (Wani *et al.,* 2013). *Azotobacter* sp. significance in agriculture could be attributed to other traits like phosphate dissolution (Nosrati *et al.,* 2014). *Klebsiella pneumoniae* strain promotes plant growth by fixing nitrogen (Iniguez *et al.,* 2004), indole-3-acetic acid (Sachdev *et al.,* 2009), gibberellic acid (Singh *et al.,* 2015) and solubilizing phosphate (Ji *et al.,* 2014). *Sporolactobacillus lavolacticus* is an essential microorganism for nitrogen fixing, secreting growth-promoting substances such as phenols and carbohydrate, as well as amino and organic acids (Mohamed *et al.,* 2023).

The effects of plant growth-promoting rhizobacteria under foliar application have been largely attributed to changes in hormonal homeostasis caused by phytohormones released by these bacteria (González *et al.,* 1991). On the other hand, the interaction between plant leaf surface and microorganisms is unknown, which needs further research (Preininger *et al.,* 2018). Rashed *et al.,* (2016) showed that seeds inoculation and foliar spraying with *Azospirillum* and *bacillus* bacteria with 90 kg N, 30 kg P_2O_5 per feddan significantly improved root dimensions and fresh weight/plant, sucrose%, as well as top, root and sugar yields/fed, compared to that left without bio-fertilizers. In addition, Sayed *et al.,* (2016) concluded that the highest and marked increments in root productivity and sugar/fed were found by using a mixture of microbeen + rhizobacterin + phosphorien as bio-fertilizers + 120 kg N/fed as a mineral fertilizer. Also, Zaki *et al.,* (2018) found that using urea fertilizer at 100 kg N/fed inclusion with sugar beet seeds inoculation by Nitrobin resulted in highest leaf area index (LAI), and crop growth rate (CGR). On the same line, Sarhan and El-Zeny (2020) demonstrated that fertilizing beets with 110 kg N/fed + seeds inoculation with a mix of bio-fertilizers (cerialin + rhizobacterin, 225 g/fed of each) produced the highest root yield/fed. Meantime, the same mixture of bio-fertilizers along with 90 kg N/fed attained the maximum sugar yield/fed. Makhlouf *et al.,* (2021) showed that adding 60 kg N/fed + soil drench with a mixture of *Azospirillum brasilense* and *Bacillus polymyxa* were dequate to produce economical values of root dimensions and fresh weight/plant, sucrose%, extractable sugar%, quality index, and root and sugar yields/fed. Nayel *et al.,* (2022) showed that fertilizing beets with 30, 48, and 75 kg P_2O_5, K_2O, and N per feddan, respectively, and seeds inoculating with Biogen containing *Azotobacter chroccocum* substantially increased root dimensions, sugar yield, and sucrose and purity percentages. Meanwhile, potassium content declined. Sadek *et al.,* (2022) showed that inoculation of cauliflower plants with *Azospirillum lipoferm*, *Azotobacter choococcum*, *Bacillus polymyxa,* and *Klebsiella pneumonia* markedly increased plant height, stem diameter, number of leaves/plant, fresh and dry leaves weights/plant, and nitrogen and potassium percentages. Likewise, inoculation with the same bacterial strains resulted in significant increases in nitrogen and potassium percentages, head weight and diameter, and total yield of cabbage plants.

Since all sugar beet varieties grown in Egypt are imported, it is necessary to evaluate them under the local conditions, as the varieties are considered the cornerstone of sugar production. Also, it is important to identify suitable varieties for the regions in order to produce high yield and quality parameters of sugar beet per unit area, in addition to the recommended set of agronomical practices. Hemayati *et al.,* (2012) evaluated some sugar beet varieties namely Rasoul, Monatuna, SBSI002, and SBSI003. They obtained the highest and significant value of white sugar yield/ha from SBSI002 variety. Meanwhile, impurities%, root yield/ha, sugar content%, and molasses sugar% were insignificantly affected. Mohamed and Yasin (2013) showed that Panther, Des 9003, LP15 and Sibel beet varieties statistically differed in root length and diameter, sucrose%, sugar extraction%, impurities%, sugar loss to molasses% (SLM), purity%, and root and sugar yields/fed. Sibel variety produced the highest values of sugar extraction, purity and extractability percentages, as well as the lowest records of α-amino N and SLM. Masri and Hamza (2015) revealed that Halawa variety registered the highest and significant values of root weight/plant, root and sugar yields/fed, and extractable sugar%. Sadek *et al.,* (2019) indicated that Carnuta variety overpassed Alauda and Nefirtitis in root dimensions and fresh weight/plant, root and sugar yields/fed, while insignificant differences were found among varieties in K, Na, alpha-amino N contents, sucrose% and purity%. Thalooth *et al.* (2019) reported that the highest means of root length, diameter, and fresh weight/plant as well as root, top and sugar yields/fed were reported with Heba variety. Makhlouf *et al.* (2021) mentioned that Sirona and Maximus varieties of sugar beet had the highest values of root dimensions and fresh weight/plant, and root and sugar yields/fed. Ahmed *et al.,* (2022) evaluated Gazelle, Lilly, Nancy, and Poseidon sugar beet cultivars. They reported that Poseidon variety showed a marked superiority in root dimensions, sucrose%, recoverable sugar%, and root and recoverable sugar yields/fed. However, Lilly variety gave the lowest values of the previously mentioned traits, except for quality traits, in the 1st season. Nayel *et al.* (2022) indicated that sugar beet varieties called Halawa, Melodia, and Raspoly differed markedly in sucrose and purity percentages, root length, and sugar yield/fed. Meanwhile, root diameter, and sodium and potassium contents varied slightly. Abd El-Monem *et al.* (2023) cleared that beet cultivars (Gazelle, Kawemira and Hossam) appreciably varied in root length and diameter, plant and leaves weights/plant, sugar recovery%, and root yield/fed. Hossam variety registered the highest values of the aforementioned traits, followed by Kawemira and Gazella varieties, successively. Yağmur and Yaşar (2023) found significant differences among 20 varieties of sugar beets in yield and quality parameters. Varieties MA4071, Garrot, and Chevalier registered the highest values of sucrose%, root yield/ha, and sugar yield/ha, respectively.

Thus, the objective of this investigation was to evaluate the possibility of using bio-fertilizers as a partial alternative to NPK chemical fertilizers to attain maximum productivity and best quality, in addition to reducing costs and increasing the economic return of some sugar beet varieties grown under the environmental conditions at Fayoum Governorate, Egypt.

2. Materials and methods

2.1. Study Area Attributes

Two field experiments were carried out at Sinnuris district (latitude of 30.87° N and longitude of 29.41° E), Fayoum Governorate, Egypt, in 2020/2021 and 2021/2022 seasons to study the possibility of using bio-fertilizers as a partial substitute to traditional inorganic NPK fertilizers and their impacts on yield, quality, and economic returns of some sugar beet varieties. Soil samples were collected from the experimental site before sowing to determine physical and chemical properties according to ICARDA (2013), as manifested in Table 1.

Table 1: Soil physical and chemical properties of the experimental sites (at 30-cm depth)

2020/2021 season

Particle size percentage			Soil texture	EC (dS/m)	pH	Available nutrients (mg kg^{-1} soil)		
Sand%	Silt%	Clay%				N	P	K
25.1	37.1	37.8	Clay loam	3.42	8.17	42.6	5.7	157.5

Soluble cations and anions (meq l^{-1})								OM %
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}	$CaCO_3$ %	
9.61	4.83	19.1	0.67	2.50	28.3	3.41	4.10	1.10

2021/2022 season

Particle size percentage			Soil texture	EC (dS/m)	pH	Available nutrients (mg kg^{-1} soil)		
Sand%	Silt%	Clay%				N	P	K
23.9	36.8	39.3	Clay loam	3.38	8.13	45.2	6.1	162.3

Soluble cations and anions (meq l^{-1})								OM %
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}	$CaCO_3$ %	
11.1	4.51	17.3	0.88	2.71	26.9	4.18	3.90	1.01

2.2 Experimental Design and Treatments

A strip plot design with three replicates was used. Three mono-germ sugar beet varieties (Preziosa KWS, BTS Smart 9830, and Jampol) occupied the horizontal plots, whereas fertilization treatments were applied in the vertical plots. The studied fertilization treatments were as follows:

- **T_1:** 100% of the recommended levels of inorganic NPK fertilizers; 80, 30, and 24 kg of N, P_2O_5, and K_2O per feddan, respectively.
- **T_2:** Soaking sugar beet seeds before sowing, for 2 hours in specialized liquid media of bio-fertilizers "LBF_{sooked}" containing "*Azospirillum lipoferm*, *Azotobacter choococcum*, *Bacillus polymyxa,* and *klebsiella pneumonia*" at the rate of 2 L/fed + foliar spraying with a combination of the liquid bio-fertilizers "LBF_{foliar}" comprising [(*A. lipoferm*, *A. choococcum*, *B. polymyxa,* and *k. pneumonia*) + liquid vinasse as a carrier] at the rate of 10 L/fed + 75% of the recommended NPK levels/fed.
- **T_3:** Soaking seeds for 2 hrs before sowing, in "LBF_{sooked}" at 2 L/fed + soil inoculation with a combination of the liquid bio-fertilizers "LBF_{soil}" at the rate of 15 L/fed, divided into [(5 L of *Sporolactobacillus lavolacticus*) and 10 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 75% of the recommended NPK levels/fed.
- **T_4:** Soaking seeds for 2 hrs before sowing, in "LBF_{sooked}" at 2 L/fed + LBF_{foliar} at 5 L/fed + LBF_{soil} at 10 L/fed, divided into [(5 L of *S. lavolacticus*) and 5 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *K. pneumonia*)] + 75% of the recommended NPK levels/fed.
- **T_5:** Soaking seeds for 2 hrs before sowing, in LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of the recommended NPK levels/fed.
- **T_6:** Soaking seeds for 2 hrs before sowing, in LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed divided into [(5 L of *S. lavolacticus*), and 15 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 50% of the recommended NPK levels/fed.
- **T_7:** Soaking seeds for 2 hrs before sowing, in LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 L/fed + LBF_{soil} at 15 L/fed divided into [(5 L of *S.lavolacticus*), and 10 L of (*A. lipoferm* + *A. choococcum* + *B. polymyxa* + *k. pneumonia*)] + 50% of the recommended NPK levels/fed.

Foliar application with LBF_{foliar} on beet canopy was done thrice: after thinning process and every 15 days interval later on. The volume of each solution was 250 L of water/fed, using the back-portable sprayer. Soil was inoculated with liquid bio-fertilizers "LBF_{soil}" three times with frequent irrigations beginning with that given after thinning process under flooding irrigation system. The liquid bio-fertilizers contained ~ $10^{6\sim9}$ CFU (Colony-forming unit)/ml. Bio-fertilizer's liquid media were obtained from Microbiology Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt. Some characteristics of the studied bacterial strains in their specific media are shown in Table 2. Phytohormons and N_2-ase activity were estimated according to the method described by Zimmer *et al.,* (1988), and Somasegarn and Hoben (1994), respectively.

Table 2: Some characteristics of the studied bacterial strains in their specific media

Strain	N_2-ase activity (n mole C_2H_4 ml^{-1} hr^{-1})	Phytohormons (ppm culture)		
		Indole acetic acid	Gibberellins	Cytokinine
Azotobacter choococcum	474.3	7.1	11.8	14.7
Azospirillum lipoferm	159.6	3.9	7.2	30.1
Bacillus polymyxa	254.1	3.3	9.9	19.5
klebsiella pneumonia	249.5	3.2	8.4	20.8
Sporolactobacillus lavolacticus	94.1	14.0	42.0	31.0

2.3. Crop Husbandry

During seedbed preparation, phosphorus fertilizer was added as calcium superphosphate (15% P_2O_5). Inorganic nitrogen fertilizer was applied as urea (46.5% N) in two equal doses; after thinning process (4-6 true-leaf stage) and one month later. Potassium fertilizer was added once as potassium sulfate (48% K_2O), with the 2^{nd} nitrogen dose. The experimental unit's area was 21 m^2, including 6 ridges of 0.50 m width and 7 m long, with 20 cm between hills. The preceding summer crop was

EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2024.13.4.54*

sorghum, in both seasons. Sugar beet varieties were sown in the 2nd week of September, while harvesting was done 7-month later, in both seasons. The other agricultural practices for growing sugar beet crop were followed as recommended by Sugar Crops Research Institute, Agricultural Research Center, Egypt.

2.4. The recorded data

After 110 days from sowing, a representative sample of five plants was randomly collected from the middle ridges of each plot to determine leaf area index (LAI), as described by Watson (1958). At harvest, a random sample of ten guarded plants was taken from the guarded ridges of each plot to determine root diameter (cm), and root and foliage fresh weights/plant (g). Top to root ratio was calculated on fresh weight basis. Root yield/fed was determined on plot weight (kg) and converted to tons/fed. Impurities; potassium (K), sodium (Na) and alpha-amino nitrogen in roots were estimated as meq/100 g beet according to Cooke and Scott (1993). Sucrose% was determined in fresh macerated root according to the method described by Le-Docte (1927). Impurities and sucrose% were estimated at the Quality Laboratory of Fayoum Sugar Company, Egypt. Sugar lost to molasses% (SLM), extractable sugar% (ES), and quality index (QI%) were computed using the equations of Deviller (1988), Dexter *et al.,* (1967), and Cooke and Scott (1993), respectively. Sugar yield/fed (ton) was calculated by multiplying root yield/fed (ton) by extractable sugar%.

Equations used:

LAI = leaf area per plant (cm^2) / plant ground area (cm^2)

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

SLM = 0.14 (Na + K) + 0.25 (α–amino N) + 0.5

ES = sucrose% - SLM - 0.6

QI = (extractable sugar% x 100) / sucrose%

2.5. Economic evaluation

The economic evaluations of root yield/fed (average of the two growing seasons) was calculated according to the following equations:

Total revenue/fed (L.E.) = root yield/fed (ton) x ton's price

Where:

Ton's initial price of roots at 16% sucrose = L.E. 575.0

Sucrose bonus above 16% sucrose = L.E. 25 per unit of sucrose/ton of roots

Net return/fed (L.E.) = total revenue/fed (L.E.) - total costs/fed (L.E.)

Based upon the total costs/fed (without land rent) = L.E. 10562, when 100% of the recommended doses of NPK fertilizers were added (T_1 Treatment).

Where: L.E. one = 0.055 USD, according to the exchange rate of the Egyptian currency against the US dollar, in April, 2022.

2.6. Statistical analysis

The obtained data were statistically analyzed according to the technique (MSTAT-C) computer software package, using analysis of variance (ANOVA) for the strip-plot design as published by Gomez and Gomez (1984). The least significant difference (LSD) was used to test the differences between treatment means at the 5% level of probability as described by Snedecor and Cochran (1980).

3. Results and Discussion

3.1. Main effects

3.1.1. Growth characteristics and root yield

Data in Table 3 showed that feeding sugar beet plants with different levels of inorganic NPK fertilizers combined with foliar and/or soil application of liquid bio-fertilizers (LBF_{foliar} and/or LBF_{soil}) had a significant effect on leaf area index (LAI), root diameter, root and top fresh weights/plant and root yield/fed, in both seasons, as well as top to root ratio in the 2nd one. Fertilizing beets with the recommended rates of inorganic NPK fertilizers (T_1) produced the highest values of root fresh weight/plant (RFW) and root yield/fed, in both seasons, and LAI in the 2nd one. Moreover, the studied combinations of organic and bio-fertilizers had insignificant influence on top/root ratio, in the 1st season.

The application of T_4 caused a substantial increment of 154 and 177 g/plant in RFW, corresponding to 7% (1.48 ton) and 15% (3.31 ton) in root yield/fed, in the 1st and 2nd season, successively, as compared to that gained from adding the same microbial inoculants with T_7. Thereby, adding T_4 treatment was adequate to produce the best values of the aforementioned traits, as RFW/plant achieved 832 and 939 g, and 22.63 and 25.33 ton for root yield/fed, in the 1st and 2nd season, respectively, as well as 2.55 for LAI, in the 2nd one.

Table 3: Main effect of bio and inorganic fertilizers on growth characteristics and root yield of the examined sugar beet varieties in 2020/2021 and 2021/2022 seasons

Treatments	Leaf area index		Root diameter (cm)		Root fresh weight/plant (g)		Top fresh weight/plant (g)		Top/root ratio		Root yield/fed (ton)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Bio and inorganic fertilizers												
T_1	3.31	2.59	12.26	12.93	860	958	275	321	0.320	0.335	22.98	24.62
T_2	2.96	2.35	9.56	12.22	730	860	228	278	0.312	0.324	22.22	23.18
T_3	2.99	2.44	9.67	12.35	813	899	258	304	0.318	0.341	22.58	23.79
T_4	3.08	2.55	11.11	12.22	832	939	241	296	0.291	0.316	22.63	25.26
T_5	1.75	2.20	8.44	10.33	583	689	178	213	0.304	0.312	18.01	20.52
T_6	1.97	2.32	9.11	10.90	589	725	180	233	0.306	0.324	18.72	20.67
T_7	2.53	2.33	9.39	12.15	678	762	208	241	0.307	0.320	21.15	21.95
$LSD_{0.05}$	0.18	0.14	0.28	0.37	37	59	23	19	NS	0.018	0.64	1.03
Varieties												
Preziosa KWS	2.48	2.31	8.94	11.29	674	789	216	255	0.319	0.325	20.40	21.60
BTS Smart 9830	2.70	2.35	11.07	12.70	768	886	224	266	0.292	0.299	22.27	24.06
Jampol	2.78	2.52	9.79	11.63	739	824	232	287	0.314	0.350	20.88	22.95
$LSD_{0.05}$	0.21	0.05	NS	0.37	26	70	10	NS	0.013	NS	0.44	0.67

1st: first season, 2nd: second season, T_1: 100% of NPK/fed (80, 30, and 24 kg of N, P_2O_5, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds in liquid bio-fertilizers "LBF_{sooked}" at 2 L/fed + foliar application with liquid bio-fertilizers "LBF_{foliar}" at 10 L/fed + 75% of NPK/fed, T_3: LBF_{sooked} at 2 L/fed + soil application with liquid bio-fertilizers "LBF_{soil}" at 15 L/fed + 75% of NPK/fed, T_4: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 5 l/fed + LBF_{soil} at 10 L/fed + 75% of NPK/fed, T_5: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed+ 50% of NPK/fed, T_7: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 L/fed + LBF_{soil} at 15 L/fed + 50% of NPK/fed, and NS: insignificant difference.

The increases in root yield/fed as a result of increasing N-level combined with bio-fertilizer may be attributed to nitrogen's role in enhancing growth, chlorophyll formation and photosynthesis process (Ismail and Badr, 2019). In addition, the effects of plant growth promoting *rhizobacteria* with foliar application may be due to changes in hormonal homeostasis caused by phytohormones released by these bacteria (González López *et al.,* 1991). Also, phosphorus plays a key role in energy storage and transfer, as well as cell division and enlargement. Adequate phosphorus improves the efficiency of other nutrients; such as nitrogen fixation (Kabir *et al.,* 2013). The effective role of potassium comes through its influence in storing materials of metabolic process, which may be used partially in plant growth in terms of root length and thickness, increasing cell volume and hence increasing leaf area/plant (Mehran and Samad, 2013).

The addition of 75% of the recommended inorganic NPK fertilizer/fed + soil inoculation with 15 L/fed of LBF_{soil} (T_3) gave higher values in all of the previously-mentioned traits than those gained by foliar application with 10 L/fed of LBF_{foliar} (T_2). There were statistical differences between soil and foliar inoculations with liquid bio-fertilizers in top fresh weight/plant (TFW) in both seasons, and RFW in the 1st one, while the variances failed to reach the significance level in the other traits. These results are in harmony with those achieved by Rashed *et al.,* (2016), Zaki *et al.,* (2018), Makhlouf *et al.,* (2021) and Nayel *et al.,* (2022).

The stimulatory effect of plant growth-promoting bacterial bio-stimulants may be referred to the production of phyto-hormones resulted from microbial activity in root zone (Table 2), as explained by Hernandez *et al.,* (2001). Also, soil microorganisms play a vital role in decomposing organic matter and producing organic acids, which lower the soil pH, thereby releasing in nutrients in available form such as solubilizing phosphate (Ji *et al.,* 2014 and Mohamed *et al.,* 2023). Additionally, bio-fertilizers stimulate plant growth regulators that have a major role in some vital processes in plant for the purpose of increasing the availability of nutrients in the soil, which positively reflects on plant growth (Harman, 2000).

Concerning the performance of sugar beet varieties (Table 3), the results pointed-out that the examined varieties significantly differed in TFW and top: root ratio, in the 1st season, and root diameter in the 2nd one, in addition to LAI, RFW and root yield, in both seasons. The tested varieties substantially varied in RFW, in the 1st season. Meanwhile, the variance among Jampol and each of Preziosa KWS and/or BTS Smart 9830 varieties did not reach the level of significance, in the 2nd one. Significant variances were detected among the varieties in root yield/fed, in both seasons, as well as in root diameter with the exception of difference between Preziosa KWS and Jampol in the 2nd one.

Jampol variety was the most distinguished in leaf-related traits, as it scored the highest values of leaf area index and weight of TFW/plant, in the 1st and 2nd season, respectively, whereas Preziosa KWS variety was the highest in top/root ratio, in the 1st one. Sugar beet BTS Smart 9830 variety outperformed the other tested ones in recording the thickest and heaviest roots and the greatest root yield/fed, followed by Jampol and Preziosa KWS varieties, successively, in both seasons. Sugar beet BTS Smart 9830 variety exhibited the superiority in root yield/fed, recording an increase of 9.17% (1.87 ton) and 6.66% (1.39 ton), in the 1st season, corresponding to 11.39% (2.46 ton) and 4.84% (1.11 ton), in the 2nd one, higher than those produced by Preziosa KWS and Jampol varieties, respectively. The advantage of BTS Smart 9830 variety in achieving higher root productivity/fed may be due to its higher values of root diameter and RFW/plant, especially there was a positive and highly correlated relationship with the final root yield. The differences among sugar beet varieties may be attributed to the variation in the gene make-up that plays vital roles in morphology and structure of plant, and their response to the environmental conditions. Such varietal differences among sugar beet varieties were reported by Sadek *et al.,* (2019), Thalooth *et al.,* (2019) and Abd El-Monem *et al.,* (2023).

3.1.2. Quality parameters and sugar yield

Soil application of NPK fertilizers and its combinations with bio-fertilizer bacteria to the soil and/or foliar inoculation appreciably affected sucrose%, potassium and α-amino N contents in beet roots, sugar lost to molasses% (SLM), extractable sugar%, quality index, and sugar yield/fed, in both seasons, in addition to sodium content in the 1st one, which corresponds with the presented results in Table 4.

Concerning the impurities, which play a principal role in the values of quality index%, the combined application of bio-fertilizers, *i.e.*, LBF_{foliar} + LBF_{soil}, along with 75 or 50 % of inorganic NPK/fed reduced SLM, compared to that gained from the recommended dose of NPK individually, in both seasons, except for treatment of 75% of NPK/fed + soil inoculation with 15 L/fed of LBF_{soil} (T_3), in the 2nd one. The lowest contents of alpha-amino nitrogen (in both seasons) and potassium (in the 1st one) were achieved by feeding beets with 50% of NPK/fed + 15 L/fed of LBF_{foliar} (T_5), while the lowest ones of sodium (in the 1st one) were found with treatment of 75% NPK/fed + 10 L/fed of LBF_{foliar} (T_2).

There were insignificant differences in sucrose% and extractable sugar%, in the 1st season, and quality index values, in the 2nd one, as well as sugar yield in both seasons, as a result of feeding beet plants with 100% of NPK/fed individually, compared to that gained with 75% of NPK/fed in combination with 5 L/fed of LBF_{foliar} + 10 L/fed of LBF_{soil} (T_4). On the other hand, a significant decrease was detected in the aforementioned traits when the inorganic fertilizers rates of NPK/fed were reduced from 75% to 50%, combined with LBF_{foliar} + LBF_{soil}. Fertilizing beets with 75% of NPK/fed combined with 5 L/fed of LBF_{foliar} + 10 L/fed of LBF_{soil} (T_4) gave the favorable values of sucrose, reaching 18.41 and 16.70 %, corresponding to 16.16 and 14.35 % for extractable sugar, in the 1st and 2nd season, consecutively, in addition to quality index%, which amounted to 87.73% in the 1st one. Addition of 75% NPK/fed to beet plants along with 5 L/fed of LBF_{foliar} + 10 L/fed of LBF_{soil} (T_4) resulted in a substantial increment in sugar yield/fed of 0.51 and 0.67 tons, in the 1st and 2nd season, successively, as compared to that obtained from 50% of NPK/fed with 10 L/fed of LBF_{foliar} + 15 L/fed of LBF_{soil} (T_7). These results are in line with those reviewed by Sayed-Ahmed *et al.,* (2016) and Sarhan and El-Zeny (2020), and Yağmur and Yaşar (2023). The distinct effect of inoculation with bio-fertilizer may be due to the fact that it plays a fundamental role in converting NPK form to be ready soluble for plant nutrition and making the uptake of nutrients by plants more easily (Dawa *et al.,* 2014). In addition to the production of bacterial photohormones resulted from microbial activity in root zone which may enhance growth of

Middle East J. Agric. Res., 13(4): 929-944, 2024
EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2024.13.4.54*

Table 4: Main effect of bio and inorganic fertilizers on quality parameters and sugar yield of the examined sugar beet varieties in 2020/2021 and 2021/2022 seasons

Treatments	Sucrose %		Impurities (meq/100 g beet)						Sugar lost to molasses%		Extractable sugar %		Quality index %		Sugar yield/fed (ton)	
			Potassium		Sodium		α-amino N									
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Bio and inorganic fertilizers																
T_1	18.08	17.25	3.45	3.42	2.36	2.56	1.91	1.68	1.79	1.76	15.69	14.89	86.70	86.25	3.60	3.64
T_2	17.12	15.11	3.09	2.96	1.96	2.19	1.51	1.37	1.58	1.56	14.93	12.95	87.12	85.65	3.31	2.97
T_3	17.52	15.33	3.15	3.33	2.40	2.58	1.58	1.82	1.67	1.78	15.25	12.95	86.97	84.22	3.44	3.09
T_4	18.41	16.70	3.19	3.36	2.14	2.22	1.62	1.87	1.65	1.75	16.16	14.35	87.73	85.83	3.66	3.61
T_5	15.21	14.74	2.74	3.07	2.58	2.33	1.27	1.34	1.56	1.59	13.05	12.55	85.72	85.10	2.35	2.58
T_6	16.37	14.66	2.82	3.27	2.44	2.30	1.43	1.74	1.59	1.72	14.18	12.35	86.50	84.09	2.65	2.56
T_7	17.14	15.69	3.02	3.32	2.28	2.31	1.46	1.76	1.61	1.73	14.93	13.37	87.01	84.90	3.15	2.94
$LSD_{0.05}$	1.32	0.44	0.39	0.17	0.18	NS	0.23	0.25	0.06	0.07	1.31	0.46	1.02	0.73	0.34	0.18
Varieties																
Preziosa KWS	17.97	15.70	2.81	2.91	2.44	2.64	1.45	1.50	1.60	1.65	15.77	13.44	87.73	85.37	3.23	2.91
BTS Smart 9830	16.26	15.47	3.21	3.63	2.23	2.07	1.63	1.74	1.67	1.73	13.99	13.14	85.97	84.78	3.13	3.17
Jampol	17.14	15.75	3.18	3.20	2.25	2.35	1.55	1.72	1.65	1.71	14.89	13.45	86.76	85.29	3.13	3.09
$LSD_{0.05}$	NS	0.14	0.31	0.47	0.10	0.14	NS	0.17	NS	NS	NS	0.14	NS	NS	NS	0.10

1st: first season, 2nd: second season, T_1: 100% of NPK/fed (80, 30, and 24 kg of N, P_2O_5, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds in liquid bio-fertilizers "LBF_{sooked}" at 2 L/fed + foliar application with liquid bio-fertilizers "LBF_{foliar}" at 10 L/fed + 75% of NPK/fed, T_3: LBF_{sooked} at 2 L/fed + soil application with liquid bio-fertilizers "LBF_{soil}" at 15 L/fed + 75% of NPK/fed, T_4: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 5 l/fed + LBF_{soil} at 10 L/fed + 75% of NPK/fed, T_5: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed+ 50% of NPK/fed, T_7: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 L/fed + LBF_{soil} at 15 L/fed + 50% of NPK/fed, and NS: insignificant difference.

beet plants and consequently more metabolites translocation from leaves to roots (Mahmoud *et al.,* 2014).

In the same table, significant distinctions were detected among the studied sugar beet varieties in their impact on K and Na contents, in both seasons, as same as sucrose%, α-amino N content, extractable sugar%, and sugar yield/fed, in the 2nd one. However, SLM% and quality index% did not reach the significance level, in the two growing seasons. The highest values of sucrose and extractable sugar percentages were obtained from Preziosa KWS and/or Jampol varieties, followed by BTS Smart 9830 variety. Preziosa KWS and Jampol varieties achieved superiority with a marked increment in sucrose% by 0.23 and 0.28, as compared to BTS Smart 9830 variety, respectively, in the 2nd season. Vice versa, the same variety, *i.e.* Preziosa KWS, gave the lowest values of K and α-amino N contents, SLM%, and sugar yield/fed. The results obtained revealed that sugar beet varieties obviously varied with respect to their content of sucrose% and extractable sugar% which may be due to their different in maturity states which attributed by gene-make up influence.

In the 2nd season, sugar beet varieties BTS Smart 9830 and Jampol were the most distinguished in terms of sugar yield with an insignificant difference between them, while both appreciably outperformed Preziosa KWS variety. BTS Smart 9830 and Jampol varieties registered a statistical increment in sugar yield/fed amounted to 8.93 and 6.19 %, higher than that produced from Preziosa KWS variety, successively, in the 2nd season. In this respect, it could be noticed that the actual increase in the values of root yield/fed (Table 3) compensated the decrease in sucrose% (Table 4) in turn let to a marked increment among varieties with regard to sugar yield/fed. This observation may be referred to the gene make-up among varieties. The differences among sugar beet varieties were found by Masri and Hamza (2015), Makhlouf *et al.,* (2021), and Ahmed *et al.,* (2022).

3.2. Significant interaction effects

3.2.1. Significant interaction effect between fertilization treatments and varieties on growth characteristics and root yield

Data in Table 5 showed that, the interaction between fertilization treatments and sugar beet varieties markedly affected leaf area index (LAI), root diameter, root fresh weight/plant, and top/root ratio, in the 2nd season, as well as root yield/fed in both seasons.

Significant variances were detected between BTS Smart 9830 and Jampol varieties, as well as between Jampol and Preziosa KWS in LAI and root diameter, when beet plants were fed with T_1, T_2 and/or T_3 treatments. However, the differences between Preziosa KWS and Jampol varieties in root fresh weight/plant failed to reach the level of significance under the above fertilization treatments. Under fertilization conditions with T_4, the tested varieties drastically differed in leaf area index, corresponding to a slight variance in root fresh weight/plant. There were statistical differences between Preziosa KWS and BTS Smart 9830 varieties in root diameter, as well as between BTS Smart 9830 and Jampol varieties in top to root ratio, under the same fertilization treatment (T_4). Feeding beet plants with T_7 resulted in significant distinctions among the examined varieties in root fresh weight/plant (except for the differences between Preziosa KWS and Jampol varieties), and top to root ratio.

A negligible difference was detected between T_1 and T_4 in their effect on LAI, top to root ratio, and root fresh weight/plant with each of the tested varieties, except for Preziosa KWS in LAI and BTS Smart 9830 in top to root ratio, which showed sharp distinctions. There were statistical variances between T_4 and T_7 in root fresh weight/plant with the tested varieties, as well as leaf area index with BTS Smart 9830 and Jampol varieties, and top to root ratio with Jampol variety, while there were no statistical differences between varieties in root diameter under the same fertilization conditions. The tested varieties, *i.e.*, Preziosa KWS, BTS Smart 9830, and Jampol, severely increased in root fresh weight/plant by 201, 120, and 211 g, consecutively, when NPK inorganic fertilizer levels/fed were raised from 50% to 75% along with LBF_{foliar} + LBF_{soil} with both of them. Whilst, increasing fertilizer levels from 75% of NPK/fed along with foliar and soil inoculations of liquid bio-stimulants to 100% of NPK/fed individually, failed to reach the significance level among varieties with respect to root fresh weight/plant.

Table 5: Significant interaction effect between fertilization treatments and varieties on growth characteristics and root yield in 2020/2021 and 2021/2022 seasons

Fertilization treatments	Varieties	Leaf area index	Root diameter (cm)	Root fresh weight/plant (g)	Top/root ratio	Root yield/fed (ton)	
		2nd season	2nd season	2nd season	2nd season	1st season	2nd season
T_1	**Preziosa KWS**	2.46	13.00	981	0.312	22.23	21.97
	BTS Smart 9830	2.55	14.44	945	0.341	23.63	**27.35**
	Jampol	2.77	11.33	947	0.354	23.07	**24.55**
T_2	**Preziosa KWS**	2.26	11.67	802	0.323	21.22	21.13
	BTS Smart 9830	2.31	11.89	929	0.288	**23.52**	24.29
	Jampol	2.49	13.10	848	0.361	**21.91**	24.11
T_3	**Preziosa KWS**	2.28	12.22	837	0.349	21.46	23.13
	BTS Smart 9830	2.41	14.33	972	0.302	**24.01**	24.27
	Jampol	2.63	10.49	889	0.372	**22.28**	23.97
T_4	**Preziosa KWS**	2.32	11.67	914	0.315	21.38	23.45
	BTS Smart 9830	2.51	12.78	972	0.299	**24.20**	**27.85**
	Jampol	2.83	12.23	931	0.335	**22.31**	**24.49**
T_5	**Preziosa KWS**	2.03	9.78	606	0.326	17.89	20.14
	BTS Smart 9830	2.13	11.22	744	0.291	**18.67**	21.11
	Jampol	2.43	10.00	717	0.319	**17.47**	20.32
T_6	**Preziosa KWS**	2.50	9.78	672	0.337	18.13	20.40
	BTS Smart 9830	2.27	11.80	791	0.297	**19.73**	20.93
	Jampol	2.19	11.11	713	0.338	**18.31**	20.67
T_7	**Preziosa KWS**	2.36	10.89	713	0.313	20.50	21.01
	BTS Smart 9830	2.29	12.44	852	0.275	**22.13**	22.62
	Jampol	2.33	13.13	720	0.371	**20.82**	22.51
$LSD_{0.05}$		0.12	0.97	71	0.031	0.66	0.78

T_1: 100% of NPK/fed (80, 30, and 24 kg of N, P_2O_5, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds in liquid bio-fertilizers "LBF_{sooked}" at 2 L/fed + foliar application with liquid bio-fertilizers "LBF_{foliar}" at 10 L/fed + 75% of NPK/fed, T_3: LBF_{sooked} at 2 L/fed + soil application with liquid bio-fertilizers "LBF_{soil}" at 15 L/fed + 75% of NPK/fed, T_4: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 5 l/fed + LBF_{soil} at 10 L/fed + 75% of NPK/fed, T_5: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed+ 50% of NPK/fed, and T_7: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 L/fed + LBF_{soil} at 15 L/fed + 50% of NPK/fed.

Regarding root yield/fed in the same table, a negligible difference was detected between BTS Smart 9830 and Jampol varieties in root yield/fed, when they were fed with T_1. However, BTS Smart 9830 out-yielded Jampol substantially in this trait, in case of supplying these two varieties with the other studied combinations of bio and inorganic fertilizers (T_2 to T_7), in the 1st season. In the 2nd one, the variance between BTS Smart 9830 and Jampol varieties in root yield/fed was insignificant, as they treated with T_2, T_3, T_6 and/or T_7, while BTS Smart 9830 appreciably surpassed Jampol, when they were fertilized with T_1, T_4, in the 2nd season. Preziosa KWS and BTS Smart 9830 varieties severely differed in root yield, when the plants were grown under conditions of the studied fertilization treatments, in the two growing seasons, except for T_6, in the 2nd season. There were sharp differences among all the examined varieties when the plants were fed with T_4, in both seasons. BTS Smart 9830 variety achieved the highest values and statistical increases when grown under T_4, compared to Preziosa KWS and Jampol varieties amounted to 2.82 ton (13.19%) and 1.89 ton (8.47%), in the 1st season, and 4.40 ton (18.76%) and 3.36 ton (13.72%), in the 2nd one, respectively. On the other hand, decreasing NPK levels from T_1 to T_4 slightly incremented root yield for BTS Smart 9830 variety, in the 1st season, and for all the tested ones, in the 2nd season. Conversely, decreasing NPK levels/fed from T_4 to T_7 substantially increased root yield for all the tested varieties, in both seasons.

These results indicate that, the addition of T_4 treatment was sufficient to produce economic values of root yield in most of the studied varieties compared to the other studied fertilization treatments, which means that the addition of bio-fertilizers partially compensated for the deficiency in the level of inorganic fertilizers required for the studied varieties. These findings are in harmony with those achieved by Makhlouf *et al.,* (2021). In addition, Nayel *et al.,* (2022) reported that the interaction between sugar beet varieties and bacterial inoculation had a substantial impact on some growth traits.

3.2.2. Significant interaction effect between fertilization treatments and varieties on quality parameters and sugar yield

The interaction between fertilization treatments and sugar beet varieties significantly affected potassium and extractable sugar% in the 1st season, and alpha-amino nitrogen, sugar lost to molasses%, and quality index%, in the 2nd one, as well as sucrose% and sugar yield/fed, in both seasons, which corresponds with the presented results in Table 6.

Significant differences were found among the examined varieties in their impact on sucrose% in both seasons, and extractable sugar% in the 1st one, when beets were treated with T_1 and/or T_7, meanwhile the variances among potassium means did not reach the level of significance with T_1 treatment. Application of T_4 treatment led to a statistical variance among all the tested varieties in sucrose and quality index percentages, in the 2nd season, corresponding to a marginal distinction in sucrose and extractable percentages in the 1st season, as well as alpha-amino N and sugar lost to molasses%, in the 2nd one.

There were noticeable differences between Preziosa KWS and each of BTS Smart 9830 and Jampol varieties in their effect on sucrose and extractable percentages in the 1st season, as a result of fertilizing beet plants with T_6, while a marginal variance was found between BTS Smart 9830 and Jampol varieties. A statistical difference was detected between T_1 and T_4 treatments in their influence on sucrose and extractable percentages in both seasons, as well as alpha-amino N and quality index% in the 2nd one, with BTS Smart 9830 variety, while the variances did not reach the level of significance with Preziosa KWS and/or Jampol varieties. With all the examined varieties, slight variances were found between T_1 and T_4 treatments in potassium content and sugar lost to molasses%, in the 1st and 2nd season, respectively, while the significant difference was showed between T_2 and T_3, with respect to sugar lost to molasses%.

In the same table, the differences among all the studied varieties were significant in their impact on sugar yield/fed when grown under the studied fertilization treatments, except for those grown under T_1 and T_4 treatments in the 2nd season. BTS Smart 9830 variety achieved highest sugar yield/fed with T_4 treatment, recording significant increases of 0.44 ton (12.72%) and 0.28 ton (7.73%), compared to Preziosa KWS and Jampol varieties, respectively, in the 1st season. On the other hand, BTS Smart 9830 variety gave the highest values with T_1 fertilization treatment, but without significance with T_4 treatments, in the 2nd season. Decreasing NPK doses from 100% individually to 75% NPK/fed combined with 5 L/fed of LBF_{foliar} + 10 L/fed of LBF_{soil} resulted in a slight decrement in sugar yield for all the examined varieties, in both seasons. Conversely, reducing NPK levels from 75 to 50 % per feddan combined with LBF_{foliar} + LBF_{soil} with each of them appreciably increased sugar yield in all the studied varieties, in both seasons, with the exception of Preziosa KWS variety in the 1st season.

Compared to the other studied fertilization treatments, adding 75% of NPK/fed along with LBF_{foliar} + LBF_{soil} was more appropriate to achieve economic values of sugar yield in the majority of the studied varieties. This means that adding bio-fertilizers partially compensated for the shortage of inorganic fertilizers needed for the examined varieties. Similar tendency was observed by Nayel *et al.,* (2022), who stated that sugar yield, sucrose%, and purity% were substantially affected by the interaction between sugar beet varieties and bacterial inoculation as seed treated and foliar spraying with *Azospirillum* and *Bacillus* bacteria.

3.3. Economic evaluation and general discussion

As shown in Fig. 1, the presented values pointed out that the total costs of the examined varieties, *i.e.*, Preziosa KWS, BTS Smart 9830, and Jampol, differed according to rates and methods of bio-fertilizer applications that promote plant growth, in addition to the amounts of inorganic fertilizers added; thus, the total revenue of the evaluated varieties had been varied. Based on the net return data, it could be observed that application of plant-growth promoting bacteria as foliar spraying on beet canopies and soil inoculations along with reducing rates of inorganic fertilizers added to 75% of NPK/fed tended to an increment in total revenue as a result of the continuous increase in root yield/fed

Middle East J. Agric. Res., 13(4): 929-944, 2024
EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2024.13.4.54*

Table 6: Significant interaction effect between fertilization treatments and varieties on quality parameters and sugar yield in 2020/2021 and 2021/2022 seasons

Fertilization treatments	Varieties	Sucrose %		Potassium (meq/100 g beet)	α-amino nitrogen (meq/100 g beet)	Sugar lost to molasses %	Extractable sugar %	Quality index %	Sugar yield/fed. (ton)	
		1st season	2nd season	1st season	2nd season	2nd season	1st season	2nd season	1st season	2nd season
T_1	Preziosa KWS	19.18	18.66	3.45	1.79	1.78	16.81	87.22	3.74	3.58
	BTS Smart 9830	16.92	15.83	3.42	1.41	1.69	14.50	85.50	3.43	3.71
	Jampol	18.14	17.26	3.48	1.85	1.81	15.76	86.03	3.64	3.65
T_2	Preziosa KWS	18.19	15.56	2.77	1.27	1.60	16.07	85.85	3.41	2.82
	BTS Smart 9830	16.19	14.67	3.39	1.63	1.66	13.93	84.53	3.28	3.02
	Jampol	16.97	15.11	3.12	1.22	1.43	14.79	86.56	3.24	3.16
T_3	Preziosa KWS	18.25	13.09	3.06	1.71	1.74	15.99	82.12	3.43	2.49
	BTS Smart 9830	16.20	17.54	3.21	1.87	1.83	13.91	86.05	3.34	3.67
	Jampol	18.11	15.36	3.16	1.87	1.77	15.85	84.50	3.53	3.12
T_4	Preziosa KWS	18.38	17.99	3.25	1.75	1.72	16.16	87.07	3.46	3.68
	BTS Smart 9830	18.40	15.17	3.17	1.94	1.72	16.12	84.65	3.90	3.58
	Jampol	18.44	16.95	3.16	1.91	1.80	16.19	85.77	3.62	3.56
T_5	Preziosa KWS	15.68	13.54	2.27	0.80	1.42	13.56	85.04	2.43	2.32
	BTS Smart 9830	14.65	15.77	2.87	1.67	1.69	12.48	85.41	2.33	2.84
	Jampol	15.30	14.92	3.08	1.54	1.65	13.10	84.85	2.29	2.57
T_6	Preziosa KWS	17.68	13.45	2.40	1.61	1.65	15.53	83.22	2.81	2.28
	BTS Smart 9830	15.60	15.89	3.06	1.82	1.75	13.39	85.18	2.65	2.84
	Jampol	15.84	14.65	2.99	1.80	1.75	13.62	83.88	2.49	2.54
T_7	Preziosa KWS	18.42	17.59	2.47	1.60	1.67	16.28	87.06	3.34	3.21
	BTS Smart 9830	15.84	13.45	3.33	1.87	1.79	13.59	82.16	3.01	2.51
	Jampol	17.16	16.04	3.24	1.82	1.72	14.92	85.48	3.11	3.09
$LSD_{0.05}$		0.96	0.53	0.35	0.37	0.10	0.98	0.73	0.22	0.14

T_1: 100% of NPK/fed (80, 30, and 24 kg of N, P_2O_5, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds in liquid bio-fertilizers “LBF_{sooked}” at 2 L/fed + foliar application with liquid bio-fertilizers "LBF_{foliar}" at 10 L/fed + 75% of NPK/fed, T_3: LBF_{sooked} at 2 L/fed + soil application with liquid bio-fertilizers "LBF_{soil}" at 15 L/fed + 75% of NPK/fed, T_4: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 5 l/fed + LBF_{soil} at 10 L/fed + 75% of NPK/fed, T_5: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 15 L/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 L/fed + LBF_{soil} at 20 L/fed+ 50% of NPK/fed, and T_7: LBF_{sooked} at 2 L/fed + LBF_{foliar} at 10 L/fed + LBF_{soil} at 15 L/fed + 50% of NPK/fed.

compared to that was gained from adding 100% of NPK/fed, individually. When feeding beet varieties with T_4 treatment (foliar spraying with liquid bio-fertilizers "LBF_{foliar}" at 5 L/fed + soil inoculation with "LBF_{soil}" at 10 L/fed + 75% of NPK/fed), BTS Smart 9830 variety achieved maximum net return/fed (L.E. 7293), as it registered distinctions reached L.E. 1651 and 1239 compared to Preziosa KWS and Jampol varieties, respectively. With the same variety, *i.e.*, BTS Smart 9830, application of T_4 treatment produced increases in net return/fed amounted to L.E. 920 and 2350, comparing to T_1 treatment (recommended rates of NPK/fed), and T_7 (50% of NPK/fed + foliar spraying with LBF_{foliar} at 10 L/fed + soil inoculation with 15 L/fed of LBF_{soil}), successively.

These findings may be attributed to the increased efficiency of BTS Smart 9830 variety in using inorganic fertilizers at 75% of the recommended NPK levels/fed along with bio-fertilizers, which had a positive impact on net return/fed. Therefore, it became necessary to conduct extensive studies on bio-fertilizers and new varieties of sugar beet in order to face any expected degradation, climate change, or shortage in inorganic fertilizers production.

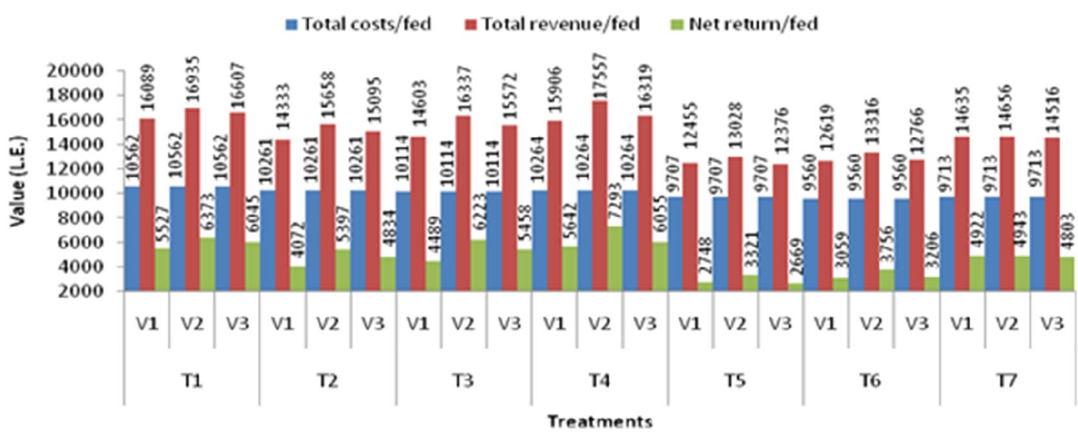

Fig. 1: Economic evaluation of root yield/fed of sugar beet varieties as affected by bio and inorganic fertilizers (average of 2020/2021 and 2021/2022 seasons).

T_1: 100% of NPK/fed (80, 30, and 24 kg of N, P_{25}, and K_2O/fed, respectively), T_2: Soaking sugar beet seeds in liquid bio-fertilizers "LBF_{sooked}" at 2 l/fed (L.E. 50/l) + foliar application with liquid bio-fertilizers "LBF_{foliar}" at 10 l/fed (L.E. 0.2/l) + 75% of NPK/fed, T_3: LBF_{sooked} at 2 l/fed + soil application with liquid bio-fertilizers "LBF_{soil}" at 15 l/fed (L.E. 0.2/l) + 75% of NPK/fed, T_4: LBF_{sooked} at 2 l/fed + LBF_{foliar} at 5 l/fed + LBF_{soil} at 10 l/fed + 75% of NPK, T_5: LBF_{sooked} at 2 l/fed + LBF_{foliar} at 15 l/fed + 50% of NPK/fed, T_6: LBF_{sooked} at 2 l/fed + LBF_{soil} at 20 l/fed+ 50% of NPK/fed, T_7: LBF_{sooked} at 2 l/fed + LBF_{foliar} at 10 l/fed + LBF_{soil} at 15 l/fed + 50% of NPK/fed, and V1, V2 and V3: Preziosa KWS, BTS Smart 9830, and Jampol varieties, respectively. Average price for the two seasons of urea "46.5% N", calcium superphosphate "15% P_2O_5", and potassium sulphate "48% K_2O" were L.E. 248, 100 and 500 per 50 kg, respectively.

4. Conclusion

Under conditions of the current study, sugar beet variety BTS Smart 9830 was more distinguished than the other tested varieties in achieving favorable values of root and sugar yields and the highest economic return per feddan, when beet plants were fertilized with T_4 treatment [soaking seeds in specialized liquid media of bio-fertilizers (*Azospirillum lipoferm*, *Azotobacter choococcum*, *Bacillus polymyxa,* and *klebsiella pneumonia*) at a rate of 2 l/fed + foliar spraying with 5 L/fed of liquid bio-fertilizers combination (*A. lipoferm*, *A. choococcum*, *B. polymyxa* and *K. pneumonia* + liquid vinasse as a carrier) + soil inoculation with 10 L/fed of liquid bio-fertilizers combination of divided into (5 L of *Sporolactobacillus lavolacticus*, and 5 L of "*A. lipoferm + A. choococcum + B. polymyxa + K. pneumonia*") + 75% of the recommended inorganic fertilizer levels/fed]. There were slight differences in most of the studied traits between beets fertilized with T_1 (100% of the recommended inorganic fertilizer rates, *i.e.*, 80, 30, and 24 kg of N, P_2O_5, and K_2O/fed, respectively) and T_4 treatment.

References

Abd El-Monem, A.M., K.M. Ibrahim, T.A.A. Ahmed, and E.A. Teama, 2023. Effect of various boron forms and rates on growth, yield and quality traits of sugar beet (*Beta vulgaris* L.). New Valley J. Agric. Sci., 3(7):669-678. DOI: 10.21608/nvjas.2023.186862.1157

Ahmed, Sara Y., M.A. Bekheet, M.A. Eissa, H.A. Hussien, and S.F. Abou-Elwafa, 2022. Effect of water deficit irrigation and bio-fertilizers on growth, yield and quality of sugar beet. Egyptian Sugar J., 19:71-81. DOI: 10.21608/esugj.2023.181138.1028.

Çakmakçı, R. and H. Karagöz, 2020. Effect of plant growth promoting rhizobacteria on growth, nutrient uptake and physiological parameters in sugar beet under different irrigation levels. COMU J. Agric. Fac., 8(2): 301-317. DOI: 10.33202/comuagri.804228.

Cassan, F. and M. Diaz-Zorita, 2016. *Azospirillum* sp. in current agriculture from the laboratory to the field. Soil Biol. Biochem., 103:117-130. DOI: 10.1016/j.soilbio.2016.08.020.

Cassán, F., A. Coniglio, and G. López, *et al.,* 2020. Everything you must know about *Azospirillum* and its impact on agriculture and beyond. Biol. Fertil. Soils, 56:461-479. DOI:10.1007/s00374-020-01463-y.

Cooke, D.A. and R.K. Scott, 1993. The Sugar Beet Crop. Science Practice. Published by Chapman and Hall, London. P., 595-605.

Dawa. K.K., S.M. Farid, and A.E. El-Bauomy, 2014. Effect of biofertilizers inoculation methods and some foliar application treatments on yield and quality of pea plants. J. Plant Prod., Mansoura Univ., 5(11):1759-1775. DOI: 10.21608/JPP.2014.64714.

Deviller, P., 1988. Prevision du sucre melasse sucrerie feanases.129:190-200. [C.F. Cooke, D.A. and R.K. Scott (1993): The Sugar Beet Crop Book, Published by Chapman and Hall, London].

Dexter, S.T., M.G. Frankes, and F.W. Snyder, 1967. A rapid and practical method of determining extracted white sugar as may be applied to the evaluation of agronomic practices and grower deliveries in the sugar beet industry. J. Am. Soc. Sugar Beet Technol., 14:433-454.

Estefan, G., R. Sommer, and J. Ryan, 2013. Methods of Soil, Plant, and Water Analysis: A Manual for the West Asia and North Africa Region. 3rd Edn., ICARDA, Lebanon.

Gomez, K.N. and A.A. Gomez, 1984. Statistical procedures for agricultural research. 2nd Ed., John Wiley and Sons, Inc., New York, pp:95-109.

González López, J., M.V. Martínez Toledo, S. Reina, and V. Salmeron, 1991. Root exudates of maize on production of auxins, gibberellins, cytokinins, amino acids and vitamins by *Azotobacter chroococcum* chemically defined media and dialysed soil media. Toxicol. Environ. Chem., 33:69-78.

Harman, G.E., 2000. Myths and dogmas of biocontrol changes in perceptions derived from research on Trichoderma harzinum T-22. Plant disease, 84(4):377-393.

Hemayati, S.S., M.H. Shirzadi, M. Aghaeezadeh, D.F. Taleghani, M.A. Javaheri, and A. Aliasghari, 2012. Evaluation of sowing and harvesting date effects on yield and quality of five sugar beet cultivars in Jiroft region (autumn planting). J. Sugar Beet, 28(1):13-21. DOI: 10.22092/JSB.2012.659

Hernandez, Y., O.A. Garcia, and M. Ramon, 2001. The use of soil microorganisms in crops of interest for livestock production. Cuban J. Agric. Sci., 35(2): 81-92.

Iniguez, A.L., Y.M. Dong, and E.W. Triplett, 2004. Nitrogen fixation in wheat provided by *Klebsiella pneumoniae* 342. Mol. Plant Microbe Interact., 17:1078-1085.
DOI: 10.1094/MPMI.2004.17.10.1078

Ismail, Fatma S.H. and Azza M.M. Badr, 2019. Effect of nitrogen and bio-fertilization with different planting distances on improving the growth and quality of beet yield and its effect on digestion by in-vitro gas production technique. Egypt. J. Nutr. and Feeds, 22(3):505-520. DOI: 10.21608/EJNF.2019.79443

Ji, S.H., M.A. Gururani, and S. Chun, 2014. Isolation and characterization of plant growth promoting endophytic diazotrophic bacteria from Korean rice cultivars. Microbiol. Res., 169:83-98. DOI: 10.1016/j.micres.2013.06.003

Kabir, R., S. Yeasmin, A.K.M.M. Islam and M.D.A.R. Sarkar, 2013. Effect of phosphorus, calcium and boron on the growth and yield of groundnut (*Arachis hypogea* L.). Int. J. BioSci. and Bio-Technol., 5(3):51-59.

Le Docte, A., 1927. Commercial determination of sugar in the beet root using the Sacks-Le Docte process. Int. Sugar J., 29, 488-492.

Mahfouz, S.A. and M.A. Sharaf Eldin, 2007. Effect of mineral vs. bio-fertilizer on growth, yield, and essential oil content of fennel (*Foeniculum vulgare* Mill). Int. Agrophysics, 21(4):361-366. DOI: 10.1055/s-2007-987419

Mahmoud, E.A., B.S.H. Ramadan, I.H. El-Geddawy, and Samah F. Korany, 2014. Effect of mineral and bio-fertilization on productivity of sugar beet. J. Plant Prod., Mansoura Univ., 5(4):699-710. DOI: 10.21608/JPP.2014.53887

Makhlouf, B.S.I., E.H.S. El-Laboudy, and F.F.B. Abu-Ellail, 2021. Effect of n-fixing bacteria on nitrogen fertilizer requirements for some sugar beet varieties. J. of Plant Prod., Mansoura Univ., 12(1):87-96. DOI: 10.21608/JPP.2021.152023

Masri, M.I. and M. Hamza, 2015. Influence of foliar application with micronutrients on productivity of three sugar beet cultivars under drip irrigation in sandy soils. World J. Agric. Sci., 11(2):55-61. DOI: 10.5829/idosi.wjas.2015.11.2.1846

Mehran, S. and S. Samad, 2013. Study of potassium and nitrogen fertilizer levels on the yield of sugar beet in jolge cultivar. J. Novel Appl. Sci., 2-4/94-100.

Mohamed, Faten M., Gehan H. Abd El Aziz, A.E.A. Sherif, I.I. Sadek, and Shreen S. Ahmed, 2023. Biotransformation of low-quality wastewater into the production of water of economic value. European J. Biol. and Biotechnol., 4(3):10-16. DOI: 10.24018/ejbio.2023.4.3.469

Mohamed, Y.H. and M.A.T. Yasin, 2013. Response of some sugar beet varieties to harvesting dates and foliar application of some boron and zinc in sandy soils. Egypt. J. Agron., 35(2):227-252. DOI: 10.21608/AGRO.2013.89

Nayel, Mayada S.A., H.R.A. EL-Deeba, M.I.M. Salwau, and S.A.S. Mehasen, 2022. Productivity and quality of some sugar beet varieties as affected by bacterial inoculation and inducing materials in saline soil. Ann. Agric. Sci., Moshtohor, 60(4):1045-1050.

Nosrati, R., P. Owlia, H. Saderi, I. Rasooli, and M.A. Malboobi, 2014. Phosphate solubilization characteristics of efficient nitrogen fixing soil *Azotobacter* strains. Iran J Microbiol., 6(4):285-295.

Preininger, C., U. Sauer, A. Bejarano, and T. Berninger, 2018. Concepts and applications of foliar spray for microbial inoculants. Appl. Microbiol. Biotechnol., 102:7265-7282. DOI: 10.1007/s00253-018-9173-4

Rashed, Sahar H., Ranya M. Abdel Aziz, Sahar M.I. Moustafa, and Shahrzad M.M. Neana, 2016. Raising productivity and quality of sugar beet using of seed inoculation and foliar application with *Azospirillum brasiliense* and *Bacillus megatherium*. J. Soil Sci. and Agric. Eng., Mansoura Univ., 7(1):89-96. DOI: 10.21608/JSSAE.2016.39329

Sachdev, D.P., H.G. Chaudhari, V.M. Kasture, D.D. Dhavale, and B.A. Chopade, 2009. Isolation and characterization of indole acetic acid (IAA) producing *Klebsiella pneumoniae* strains from rhizosphere of wheat (Triticum aestivum) and their effect on plant growth. Indian J. Exp. Biol., 47:993-1000.

Sadek, I.I., T.M. Younis, M.M. Heggi, and F.M. Mohamed, 2022. Using bio-fertilizer as alternative of mineral fertilizer at cauliflower and cabbage crops. European J. Appl. Sci., 10(6):132-155. DOI:10.14738/aivp.106.13426

Sadek, K.A., B.S.I. Makhlouf, A.M.E. Fadel, and Amira E. El-Sherief, 2019. Response of some sugar beet varieties grown under different saline soils and plant populations. Alex. J. Agric. Sci., 64(6):399-407. DOI: 10.21608/alexja.2019.80851

Sarhan, H.M. and Maha M. El-Zeny, 2020. Impact of sowing models, nitrogen levels and biofertilization on yields and quality of sugar beet under sandy soil conditions. Zagazig J. Agric. Res., 47(2):403-417. DOI: 10.21608/ZJAR.2020.94484

Sayed-Ahmed, I.F., Ranya M. Abdel Aziz, and Sahar H. Rashed, 2016. Effect of bio and mineral fertilization on yield and quality of sugar beet in newly reclaimed lands in Egypt Int. J. Curr. Microbiol. App. Sci., 5(10): 980-991. DOI: 10.20546/ijcmas.2016.510.104

SCCAR, 2023. Sugar Crops Council Annual Report, MALR (Ministry of Agriculture and Land Reclamation), Dokki, Giza, Egypt.

Singh, R.P., P. Jha, and P.N. Jha, 2015. The plant-growth-promoting bacterium *Klebsiella* sp. SBP-8 confers induced systemic tolerance in wheat (Triticum aestivum) under salt stress. J. Plant Physiol. 184:57-67. DOI: 10.1016/j.jplph.2015.07.002

Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7th Ed. Iowa State Univ. Press, Iowa, USA.

Somasegarn, P. and H.J. Hoben, 1994. In: Hand Book for *Rhizobia* “Springer Veriag. New York. USA.

Thalooth, A.T., M.M. Tawfik, Elham A. Badreand, and Magda H. Mohamed, 2019. Yield and quality response of some sugar beet (*Beta vulgaris* L.) varieties to humic acid and yeast application in newly reclaimed soil. Middle East J. Agric. Res., 8(1): 56-65.

Wani S.A., S. Chand, and T. Ali, 2013. Potential use of *Azotobacter chroococcum* in crop production: an overview. Curr. Agric. Res. J., 1(1):35-38. DOI: 10.12944/CARJ.1.1.04

Watson, D.J., 1958. The dependence of net assimilation rate on leaf area index. Ann. Bot. Lond. N.S., 22:37-54.

Yagmur, H. and M. Yasar, 2023. Investigation of yield and quality parameters of some sugar beet varieties in Muş ecological conditions. Int. J. Agri., Environ. and Food Sci., 7(2):436-447. DOI: 10.31015/jaefs.2023.2.22

Zaki, M.S., Eman I. El-Sarag, Howaida A. Maamoun, and M.H. Mubarak, 2018. Using different types of fertilization for increasing sugar beet growth under sandy soil conditions. J. Plant genetics and crop Res. **1**(1):19-39. DOI: 10.14302/issn.2641-9467.jgrc-18-1936

Zimmer, W., K. Roben, and H. Bothe, 1988. An alternative explanation for the plant growth promotion by bacteria of genus *Azospirillum*. Planta, 176:333-342.