J. of Plant Production, Mansoura Univ., Vol. 16 (7):407 - 412, 2025

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Towards the Optimal Use of Organic Additives to Improve Growth Characteristics and Enhance the Productivity of Sugar Beet Crop

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Cross Mark

Article Information
Received 1 / 7 /2025
Accpted 23 / 7 /2025

ABSTRACT

Organic amendments are increasingly recognized for sustainably enhancing crop productivity, particulary in arid soils, by improving soil health and reducing environmental impact. This study was undertaken over two seasons (2021/2022 and 2022/2023) at El-Nobaria Farm, El-Beheira Governorate, National Research Centre's Research and Production Station,. to assess the impact of three organic additives chicken manure, farmyard manure, and compost applied at 2.50, 2.86, and 4.32 t fed^{-1}, respectively, in comparison with recommended mineral NPK fertilization. A randomized complete block design (RCBD) with three replications was utilized. Results indicated that chicken manure significantly improved sugar beet growth parameters, mineral composition, and quality traits, leading to the highest root yield 17.9% greater than the NPK control and superior economic returns. The treatments can be ordered from highest to lowest as follows: chicken manure, followed by farmyard manure, then recommended NPK, and finally compost. Consequently, applying chicken manure at 2.50 t fed^{-1} is recommended to enhance productivity and profitability under sandy soil conditions in Egypt.

Keywords: Farmyard manure; Chicken manure; Compost; Organic additives; Sugar beet; Sandy soils; Sugar yield; Economic evaluation

INTRODUCTION

Soil organic matter (OM) consists of a complex mixture of of plant and animal remains decomposed to varying extents (Kögel-Knabner, 2017) and plant and animal secretions (Ondrasek et al., 2019). Soil OM is a key factor of soil quality and enhancing plant productivity in the arid and semiarid regions (Jordán *et al*., 2010), especially sandy soils of Egypt.

Due to the low levels of OM in these soils, the application of organic manures is of great importance (Hussein et al., 2022). Organic manures not only enrich the soil's OM content but also support plant growth in a manner comparable to mineral fertilizers, enhancing their desirability (Menšík et al., 2018). The growing interest in organic farming has highlighted the preference for organic fertilizers over synthetic ones, particularly given the rapid decomposition of soil OM under natural conditions, which leads to decreased soil fertility. Soil OM is composed of 90–95% organic carbon (Park et al., 2024). There is an improved interest in carbon-based materials recycling to recover soil fertility and its efficiency (Mohamed et al., 2024). Furthermore, the use of the natural organic trash to soil had excessed drive in the recent past years and called organic agric. or bio-agric. (Chatterjee *et al.,* 2017).

The beneficial effects of organic additives on production of crops and its components have been widely documented by researchers, such as Hossain et al., (2017) found that the useful effect when treating soil using organic trash was directly related to the developed plants. The favorable impact depended on their carbon-to-nitrogen ratio, which plays a vital function in the degree of decomposition (Scavo *et al.*, 2022). As well, crop productivity and its components reacted evidently to various organic manures applied, either separately or composed (Adekiya *et al.,* 2022). These useful effects are clarified through enhancing the chelating agent by organic acids for micronutrients and their absorption by plants easily (Yao *et al.,* 2023). Thus, adding various sources of organic manures besides mineral fertilizers became necessary to these soils (Alexander, 1990; Penuelas *et al.,* 2023). Nanwai *et al.,* (1998) found that the application of organic additives in sandy soil enhanced microbial activity, improving nutrient conservation and thereby promoting plant growth and use water more effectively (Ding *et al.*, 2024). Bassouny and Jiazhou, (2016) showed that organic fertilizer can enhance soil-water-plant relations by amending total porosity, bulk density, soil-water relations and then increase in plant growth. Furthermore, several soil properties influence fertilizer availability, including high pH levels, nutrient losses due to leaching or volatilization under conditions of poor soil structure or flooding (Ma *et al.,* 2024). Ghaly *et al.,* (2020) stated that several studies have demonstrated that adding organic fertilizers to sandy soils was associated with diminishing the conditions negatively affecting the efficiency of chemical fertilizers and therefore enhancing the productivity of soil.

Sugar beet is one of Egypt's substantial crops; its roots include a high sucrose concentration and are utilized commercially for the sugar production process. Sugar beet cultivation has expanded throughout the governorates of Upper and Lower Egypt. Sugar beet's roots contain, on average, 20% total soluble solids, 75% water content, 16% sucrose (of fresh weight), about 4% impurities, such as mineral salts and nitrogenous substances, their overabundance prevents sugar from crystallizing, resulting in a reduction in the crop quality, especially potassium and sodium salts (El-Zayat, 2022). Egypt has adopted sugar beet to enhance sugar production and reduce the disparity between production and consumption. Increasing sugar yield is most likely to be achieved through increasing sugar beet cultivation in newly reclaimed soils and improving

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DOI: 10.21608/jpp.2025.398192.1478

its agronomic practices (Gobarah *et al.,* 2019). Sucrose derived from sugar beet is chemically indistinguishable from sugarcane sucrose. Sugar content should be at an acceptable level (15:20%) in sugar beet. Soils in Egypt are poor in organic matter, exceeding 2%, to conserve their level of organic matter; the soils of Egypt showed receiving millions of tons annually (El-Seedy, 2019). Recently, as mineral fertilizer costs rise and questions about their future attainability, there is renewed interest in organic recycling to enhance soil fertility and agricultural productivity. As a result, organic compost wastes may be used in the soil to provide nutrients for crop production (Hussein *et al.,* 2022). The newly reclaimed sandy soils productivity in Egypt is significantly lower than the yield potential of most cultivated varieties. These sandy soils have poor fertility and fertilizer utilization efficiencies; for these reasons, the present study was conducted to assess the impacts of organic additives on growth characteristics, productivity and nutritious status of sugar beet cultivated in newly reclaimed soils.

MATERIALS AND METHODS

Site description:

The current study was conducted at the National Research Centre's Research and Production Station in El-Nubaria, l-Beheira Governorate, Egypt (latitude 30° 30' 1.4"N, and longitude 30° 19' 10.9"E). The site falls within the arid and semi-arid climate zones. It is characterized by a cool winter a long hot summer, high relative humidity and short rainy season.

Samples of soil were collected from (0 - 0.3 m). According to the USDA classification, the soil texture is sandy loam, comprising 76.20% sand, 20.70% silt, and 3.10% clay (Klute, 1986). The main chemical properties of the soil include: organic matter content of 1.90 g/kg; electrical conductivity (EC) of 1.10 dS/m (soil paste extract); pH of 8.20 (1:2.5 soil:water suspension); calcium carbonate content of 31.70 g/kg; total nitrogen (N) of 150.34 mg/kg; total phosphorus (P) of 131.65 mg/kg; available potassium (K) of 42.78 mg/kg; available iron (Fe) of 4.78 mg/kg; available manganese (Mn) of 2.91 mg/kg; available copper (Cu) of 5.22 mg/kg; and available zinc (Zn) of 3.73 mg/kg (Black et al., 1982).

The organic additives:

Three types of the organic additives were used in the study: chicken manure, farmyard manure and compost derived from recycled agricultural residues. The main chemical properties of these additives are presented in Table 1.

Table 1. Properties of the investigated additives used in the experiment

Properties	Chicken manure	Farmyard manure	Compost
pH (1:10 ratio)	7.95	7.71	7.49
EC (1:10 ratio), dS m^{-1}	2.92	2.59	2.87
Organic matter, %	37.2	31.0	24.4
Total N, %	3.20	2.79	1.88
C/N ratio	13.4	11.9	10.2
Available P, %	0.826	0.862	0.934
Available K, %	0.919	0.863	0.842
Fe, Mg/L^{-1}	5.53	5.22	4.01
Mn, Mg/L^{-1}	33.80	29.50	20.60
Zn, Mg/L^{-1}	29.70	26.30	22.80
Cu, Mg/L^{-1}	25.90	21.80	18.60

The field investigation:

Two field trails were implemented at National Research Centre's experimental farm Station, El-Nobaria Site, using drip irrigation system throughout the two consecutive growing seasons of 2021/2022 and 2022/2023 to define and evaluate the growth traits, roots yield parameters and qualitative characteristics of sugar beet (*Beta vulgaris L., oscar poly*) as influenced by various organic additives. This work included four treatments (T_1: NPK fertilizer (control), T_2: chicken manure (2.50 t fed^{-1}), T_3: farmyard manure (2.86 t fed^{-1}) and T_4: compost (4.32 t fed^{-1}). Organic additives applyed at the rate of 80 kg N fed^{-1} before soil prepration. Moreover, mineral NPK fertilizers (T_1) applied with rates calculated to cover 100% of the crop's requirements according to Egyptian Ministry of Agriculture. Rate of 200 kg fed^{-1}calcium superphosphate (15.5% P_2O_5) was applied during soil preparation, 390.2 kg fed^{-1} ammonium sulphate (20.5% N) was added in three doses: the initial dose of fertilizer before planting, then the second dose after thinning, while the remaining was applied 30 days later, as well 50 kg fed^{-1} potassium sulphate (48% K_2O) was applied after 21 days from growing. Randomized complete block design was used. Each treatment was represented by 3 plots. Each plot area was $15m^2$ (5 m in length and 3 m in width) consisted of five ridges. Each ridge consists of 10 plants. Seeds of sugar beet (*Beta vulgaris L., oscar poly*) were sown on 15 and 17 October 2021 and 2022 and planted under a drip irrigation system with all standard agricultural practices and inputs applied as recommended for optimal production.

Plant Sampling and Measurements

After 50 days post-planting, plant height, leaves number plant-^{1}, leaf area as well as leaves and stem fresh and dry weights were determined. Also, top and root fresh weight plant-^{1} were measured according to FAO (1980). After 200 days from planting, root length and root diameter. Top and root yield (ton fed^{-1}) were calculated based on experimental plot's weight and then converted to feddan. Yield quality parameters (sucrose %, total soluble solids% and purity%) as well as sugar yield were assessed at Nile Sugar Company's certified laboratories at El Nobaria district, sugar refining factories, Beheira Governorate. In sugar beet roots, macronutrients (N, P and K) and micronutrients (Mn, Zn, Cu and Fe) were assessed according to Cottenic *et al.* (1982). Furthermore, total carbohydrates % in roots was determined according to Dubois et al. (1956), as well as proteins and vitamin C (L-Ascorbic acid) were quantified following the standardized protocols outlined in A.O.A.C (1995).

Economic evaluation

The economic evaluation was carried out based on the relationship between inputs and outputs of sugar beet crop. This was calculated from the production costs and market prices published by Department of Agric. Econ., Ministry of Agric., Egypt. Total cost :the sum of fixed and variable costs. Gross income calculated by multiplying yield (root and top yield ton fed^{-1}) by average farmgate prices. Net profit is calculated by subtracting total costs from gross income.

Statistical Analysis and Data Processing

Statistical analyses were implemented using SAS software (SAS, 1996). Combined analysis was proceeded on the data of both seasons after confirming consistency using statistical tests for homogeneity using Bartlett's test and means were compared using Duncan's Multiple Range (DMR) test as described by Waller and Duncan (1969)

RESULTS AND DISCUSSIONS

Effect of organic additives on vegetative growth:

Data in Table (2) showed the effected of organic additives on sugar beet plant *i.e* Plant height, Number of leaves per plant, leaf area/plant, root length and diameter as well as fresh weight per plant.

Data in (Table 2) illustrated that it is clear to notice the promotive effect of organic additives on sugar beet plants. The highest sugar beet growth parameters were observed by plants that were treated with chicken manure, while compost gave the lowest ones. Data in (Table 2) also indicated that no significant difference ($p<0.05$) in leaves No., top fresh weight per plant and root length between chicken manure and farmyard manure. These findings are consistent with previous reports obtained by Curvelo *et al.* (2018) who found that poultry manure outperformed mineral fertilizers in enhancing root diameter and root fresh weights per plant. Fatma *et al.* (2020) added that poultry manure application induced gradual increase in sugar beet performance, yield and its component as well as the quality traits as compared with other treatments.

Table 2. Growth parameter of sugar beet plant as affected by organic additives (combined analysis)

Treatments	Plant height Cm	Leaf no. Per plant	Leaf area/plant cm^3	Fresh weight per plant (g) Top	Fresh weight per plant (g) Root	Root length cm	Root diameter cm
Control NP and K	28.8 c	17 b	227 c	269 b	683 c	9.76 b	18.6 b
Chicken manure	36.2 a	20 a	263 a	344 a	848 a	11.80 a	20.8 a
Farmyard manure	32.6 b	19 a	251 b	318 a	789 b	10.60 ab	19.2 b
Compost	24.8 d	15 c	211 d	237 b	491 d	8.32 c	17.0 c

Means with the same letter(s) within column indicate not significantly different among treatments.($p < 0.05$) by DMR test.

In regard to the effect of organic additives on fresh and dry weights, the results in Figure (1) indicated that all treatments had significant effects on stem and leaves fresh and dry weights. The chicken manure resulted in the greatest values followed by farmyard manure followed by the recommended NP K as chemical fertilizer while compost gave the lowest ones. Chicken manure constitutes a predominant organic fertilizer because of its comprehensive range of essential plant nutrients required for optimal crop growth and development.

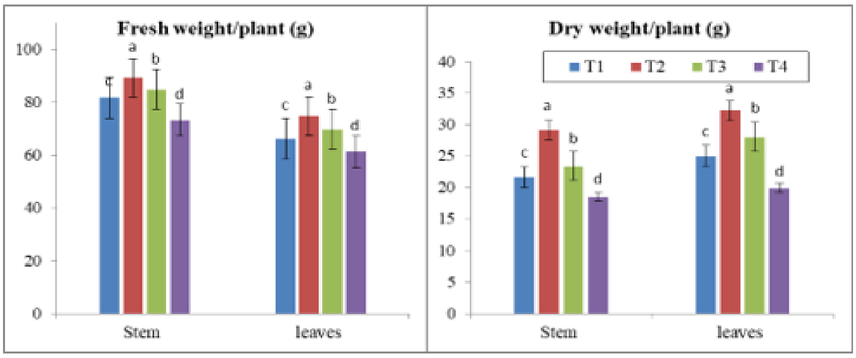

Fig. 1 Effect of various organic additives on fresh and dry weight of stem and leaves per plant (combined analysis). T1: Control NP and K, T2: Chicken manure, T3: Farmyard manure and T4: compost. Similar letters indicate not significantly different among treatments.

Effect of organic additives on yield characteristics:

Data in Fig. (2) clearly indicated that chicken manure produced the highest productivity of sugar beet roots (ton/fed) which reached to 17.9%, while Farmyard manure research to 9.05%, whereas compost gave the lowest yield, compared to the recommended N, P and K.

Figure 2 indicated that there was no significant difference ($p<0.05$) in top yield and sugar yield between mineral fertilizer and farmyard manure. The highest root yield was recorded by plants that were supplied with chicken manure.

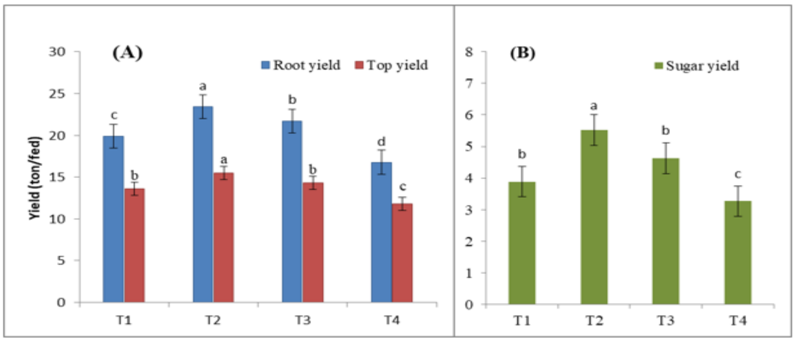

Fig. 2. Effect of various organic additives on top, root and sugar yield of sugar beet (combined analysis). T1: Control NP and K, T2: Chicken manure, T3: Farmyard manure and T4: compost. Similar letters indicate not significantly different among treatments.

These findings are consistent with those obtained by Marinhovic *et al.* (2004) who observed that the use of organic additives induced increment in root yield and its component. Hassan (2005) demonstrated that the application of organic additives significantly enhanced root yield, sugar yield and sucrose content. Confirm these results, Saidia and Mrema (2017) found that application of farmyard manure as an organic fertilizer to improve soils can substantially improve crop production, particularly in areas with infertile soils and limited water availability.

Effect of organic additives on nutritional status:

To investigate the effects of different organic additives on the nutrient absorption of sugar beet, the contents of N, P, K, Fe, Mn, Zn and Cu were detected in root tissues.

Results presented in Figure (3) revealed that organic additives on sugar beet significantly increased N, P and K in sugar beet roots. Chicken manure (T2) resulted in the greatest values, while compost (T4) gave the lowest ones (Figure 3A). No significant differences were observed in sugar beet roots content of N between chemical fertilizer (T1) and compost. There were no significant differences between Fe content in sugar beet Tissue due to various fertilizers (Figure 3B).

The addition of organic manure to sandy soils enhances microbial activity and improves moisture retention capacity, thereby increasing soil fertility and promoting more efficient fertilizer use (Nanwai et al., 1998). On the other hand, the organic manure released acidic compounds that lowered soil pH, which in turn increased the bioavailability of essential macronutrients (N, P, K). Awad et al. (2002) added that organic manure conditions resulted in higher levels of readily available nutrients, which are essential for plant growth. Furthermore, it plays a substantial role for enhancing the soil's physical characteristics.

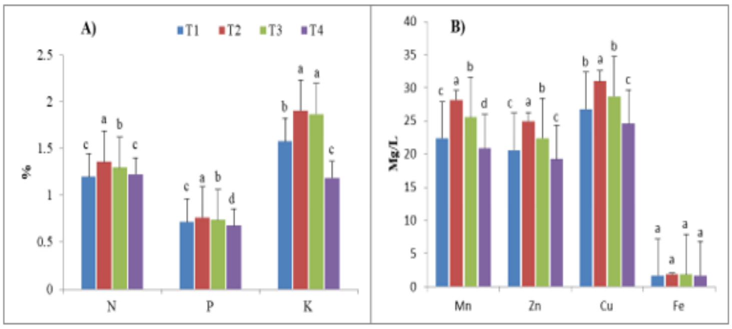

Fig. 3. Nutritional status of sugar beet roots as influenced by various organic additives (combined analysis). T1: Control NP and K, T2: Chicken manure, T3: Farmyard manure and T4: compost. Similar letters indicate not significantly different among treatments.

Confirm our results Dikinya and Mufwanzala (2010) who detected that application of chicken manure increased significantly soil productivity and increased N, P %.

Presented data in (Figure 3B) showed similar trend of Fe, Mn, Zn and Cu. Organic additives significantly increased the content of Mn, Zn and Cu in sugar beet roots compared with the control treatment. Chicken manure recorded the highest micronutrients (Fe, Mn, Zn and Cu). These findings are consistent with those reported by Belay *et al.* (2001) who stated that organic additives provide a steady release of essential macro- and micronutrients while simultaneously enhancing the physical, chemical and biological characteristics of soil, thereby supporting plant growth and productivity.

Effect of organic additives on chemical constituents:

Presented data in Figure (4,5) clearly indicated the percentage of proteins, carbohydrates, sucrose content, total soluble solids, purity and vitamin "C" (L-Ascorbic acid) levels.

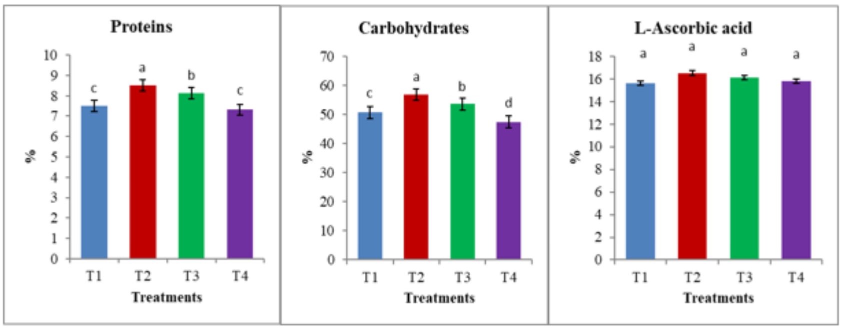

Fig.4. Proteins, carbohydrates and vitamin "C" as L-Ascorbic acid contents on sugar beet roots as influenced by various organic additives (combined analysis). T1: Control NP and K, T2: Chicken manure, T3: Farmyard manure and T4: compost Similar letters indicate not significantly different among treatments.

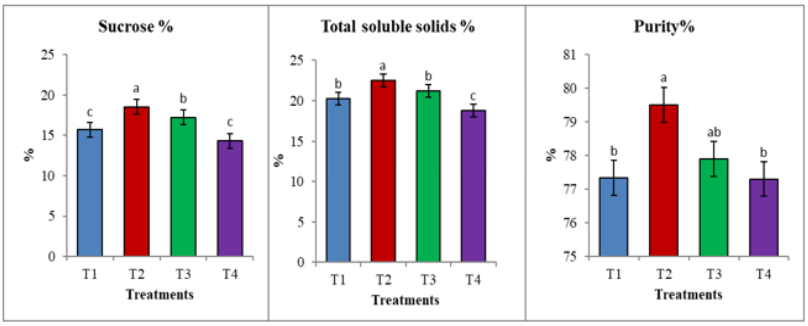

Fig. 5. Sucrose, total soluble solids and purity on sugar beet roots as affected by various organic additives (combined analysis). T1: Control NP and K, T2: Chicken manure, T3: Farmyard manure and T4: compost. Similar letters indicate not significantly different among treatments.

Fig. 4 and 5 detected similar responses of sugar beet roots chemical constituents to organic additives. Chicken manure had a favorable effect, followed by farmyard manure, followed by control (NPK fertilizers). While compost showed the lowest values. These findings are in harmony with those obtained by Hassan (2005), who demonstrated that organic manure application enhanced sugar beet root yield, sucrose content, purity percentage and NPK concentration.

On the other hand, data in Fig. 4 revealed that organic additives had insignificant increase in vitamin "C" as L-ascorbic acid content. Chicken manure (T2) recorded the greatest values of vitamin C compared to other organic manures. These findings agree with Ali et al., (2019). Vitamin "C" is the major antioxidant in plant cells. Griffiths and Lunce (2001) stated that L-ascorbic acid acts in many biochemical processes as mentioned before. In this concern, reported that high vitamin "C" dietary is associated with reduced gastric cancer risk in humans.

Economical evaluation:

Data regarding the economical evaluation are shown in Table (3) demonstrated that the application of chicken manure achieved the highest gross income (20726.5 LE) followed by farmyard manure (19165.7 LE) while the lowest gross income obtained by using compost.

Table 3. Effect of various organic additives on economical evaluation

Treatments	Gross income (LE)	Total cost (LE)	Net income (LE)
Control NP and K	17644.3	13030	4614.3
Chicken manure	20726.5	16250	4476.5
Farmyard manure	19165.7	15000	4165.7
Compost	14937.8	13824	1089.8

Mineral fertilizer recorded the highest net income (4,614.3 LE), followed closely by chicken manure (4,476.5 LE). This result is closely aligns with Ahmad, et al. (2017), who declared that mineral fertilizer can achieve higher economic return The results also indicated that the use of organic additives increased production costs, which led to a reduction in net income—particularly in the case of compost, as shown in Table (3). On the other hand, organic additives (*i.e.,* chicken manure, farmyard manure, compost) sustain long-term fertility via gradual nutrient release. They also enhance soil organic matter content, which improves soil structure, increases water retention capacity and raises nutrient availability. Furthermore, they significantly reduce environmental pollution compared to synthetic mineral fertilizers.

CONCLUSION

The present study sheds light on the impact of organic additives on the growth, yield and quality of sugar beet plants. The organic additives improved nutrients availability, especially micronutrients, consequently, support the maximum plant growth, yield and its components and chemical constituents as well as root quality within the growing seasons. Chicken manure outperformed the other treatments, producing the highest sugar beet yield, optimal growth characteristics, improved quality parameters and achieved higher gross income. Accordingly, chicken manure is guaranteed to increase sugar beet productivity.

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نحو الأستخدام الأمثل للإضافات العضوية لتحسين خصائص النمو وتعزيز إنتاجية محصول بنجر السكر

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الملخص

في مزرعة النوبارية، محافظة البحيرة، بمحطة البحوث والإنتاج التابعة للمركز القومي للبحوث، أُجريت تجربتان حقليتان خلال موسمي ٢٠٢٢/٢٠٢١ و٢٠٢٣/٢٠٢٢ لتحديد تأثير الإضافات العضوية على إنتاج بنجر السكر. واشتملت علي ثلاث إضافات عضوية (سماد الدجاج - سماد المزرعة - كمبوست) ومعدلاتها (٢,٥٠ و ٢,٨٦ و ٤,٣٢ طن للفدان على التوالي) ومعاملة الكنترول (سماد NPK المعدني) بالجرعة الموصى بها. تم استخدام تصميم القطاعات الكاملة العشوائية بثلاثة مكرارات . أشارت النتائج التي تم الحصول عليها الي تفوق مؤشرات نمو بنجرالسكر والانتاجية والتركيب المعدني وكذلك المكونات الكيميائية مع معاملة سماد الدجاج. ويمكن ترتيب جميع المعاملات بترتيب تنازلي على النحو التالي: سماد الدجاج> سماد المزرعة> NPK الموصي به > الكمبوست. كان سماد الدجاج متفوقا في تحسين الحالة الغذائية للنباتات المزروعة وبالتالي سجل زيادة أعلى في صفات النمو والإنتاجية. وقد نتج عن سماد الدجاج أعلى إنتاجية لجذور بنجر السكر والتي بلغت ١٧,٩٪ مقارنة بالكميات الموصى بها من NPK بينما أعطى الكمبوست أقل إنتاجية. كما حققت معاملة سماد الدواجن أعلى دخل إجمالى مقارنة بباقى المعاملات. وبالتالي، تقترح الدراسة الي أن تسميد بنجر السكر بسماد الدجاج بمعدل ٢,٥٠ طن للفدان سيحسن إنتاج بنجر السكر إلى أقصى حد ممكن في ظل الظروف البيئية للتربة الرملية في مصر.

الكلمات المفتاحية: بنجر السكر، سماد المزرعة، سماد الدجاج، الكمبوست، الإضافات العضوية، التربة الرملية، التقييم الاقتصادى