Response of table beet plants *Beta Vulgaris* L. to organic fertilization and nano-calcium spraying in terms of vegetative and root growth indicators.

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Abstract

The experiment was laid out in a randomized complete block design with three replications in a factorial arrangement. The treatments were three levels of organic fertilizer (0, 1800, and 3600 g ha^{-1}) and three concentrations of nano-calcium (0, 20, and 40 mg L^{-1})..Results revealed that both organic fertilizer and nano-calcium boosted the nutritional status of the plants significantly over the control. The highest values of number of leavesat 14.46 leaves.$Plant^{-1}$ and dry matter of the vegetative partsat 28.77 g were recorded with the combined application of 3600 g ha^{-1} organic fertilizer and 40 mg L^{-1} nano-calcium. Root content of ascorbic acid, total sugars content in roots, T.S.S, and root shape guide treatment to reach 2.341 mg. 100 ml ,2.412 % ,11.478 ,14.06 In succession . reducing sugars and sucrose content decreased with increasing levels of fertilizer and nano-calcium, which indicates a shift in carbohydrate allocation toward structural growth and biomass formation. A very strong synergistic effect emerged between the two factors to give the highest marketable yield. According to the variance analysis, the treatments were highly significant at the 5% probability level ($LSD_{0.05}$ = 372.7). Organic fertilization with nano calcium foliar application enhances nutrient uptake efficiency and increases both yield and quality parameters of beetroot under field conditions. Keywords: Beta vulgaris L.; organic fertilizer; nano-calcium; nutrient uptake; reducing sugars; carbohydrate composition; marketable yield; sustainable fertilization.

Keywords: *Beta Vulgaris*, organic fertilizer, spraying, nano-calcium.

Introduction

Beetroot *Beta vulgaris* L. is a root vegetable known for its dark redcolor and sweet taste. is a root crop of economic and nutritional importance importance that belongs to the family Amaranthaceae (earlier classified under Chenopodiaceae). This crop has a fleshy root that swells, commonly used for human consumption and industrial purposes, mainly in red beet cultivars[21].Historical data has it that beetroot was first cultivated in regions bordering the coasts of Europe and the southern Mediterranean. It then spread to other parts of the world because of its easy adaptability to different soil and climatic conditions. Besides its value as a vegetable crop, sugar beet is one of the major sources of sugar globally. This is very important in the food industry[22]. Beetroot has been associated with a high content of biologically active compounds, most notably betalains, organic pigments that give the typical red-purple coloration to the roots. These compounds are potent

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antioxidants and have, therefore, drawn much scientific interest in their possible contribution to human health by reducing the risk of chronic diseases. Thus, beetroot is currently gaining more and more significance as a functional food that has not only nutritive value but also therapeutic value [8]. According to global agricultural statistics, thereby ranking it as one of the most important industrial crops cultivated across the globe. 1 Major regions of production are Europe, Central Asia, and North America. Russia leads the production, followed by the European Union and the United States [14]. Over 50 countries cultivate sugar beet. The principal producers are Russia, France, the United States, Germany, and Turkey. Crop yield increase and quality can be realized by applying organic fertilization practices[1]. Organic fertilizers are safe for the environment compared to mineral fertilizers, and they can be derived from either plant or animal sources. According to Colorado State University Extension,organic fertilizers are those natural products containing one or more of the essential nutrients for plants[9]." They are mostly applied to improve soil fertility and enhance the performance of crops. The organic fertilizers referred to here include farmyard manure, compost, and liquid organic formulations, which also contribute to sustainable farming systems by improving soil fertility for sustained long-term productivity [20]. The advantages of organic fertilizers do not just stop at nutrients. They also include boosting soil organic matter, stimulating microbial activity, improving the physical structure of the soil, and enhancing its water-holding capacity. All these organic fertilizers also release their nutrients slowly, so leaching losses are lower, and nutrient use efficiency is better compared to many conventional fertilizers [10]. Recent advancements in nanotechnology have helped develop nano-fertilizers to improve ways of delivering nutrients for better crop performance. Generally, the particles of calcium are defined to be less than 100 nm, making them more reactive and easier for absorption in plant tissues. Some studies have proved that applying nano-calcium can make the uptake of nutrients more significant and accumulate calcium in the plants. For instance, nano-CaO treatments increased the content of calcium as well as the uptake of nitrogen in mango seedlings compared with common sources of calcium [14]. Studies on tomato plants have also indicated that nano-calcium contributes to increased vegetative growth, nutrient status, and several quality-related traits when used singly or in combination with regular calcium fertilizers. More recent versions, such as nano-calcium phosphate[11] have been formulated as effective carriers of nutrients that enhance the availability and uptake of nutrients in plants. Calcium is vital in the formation of the cell wall, membrane stability, and regulation of stomata, as well as in the general tolerance of environmental stress in the plant in all forms. Its nano form is anticipated to improve nutrient use efficiency and lower losses. No data is available regarding their combined effects on nutrient accumulation and reducing sugar content in beetroot plants under Iraqi conditions. Hence, it is suggested that a further study be conducted to assess their impacts on the nutritional composition and carbohydrate status of beetroot in Najaf Governorate. Research Objectives 1. To determine the effects of organic fertilizer and nano-calcium application on nutrient content and concentration of reducing sugar in beetroot plants.

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Material and Methods

The field experiment was conducted at the Agricultural Research Station, Faculty of Agriculture, University of Kufa. It continued for one successive growing to observe the response of table beet plants to organic fertilization and nano-calcium foliar application concerning some vegetative growth parameters and root yield. Soil samples were collected before sowing from different locations within the experimental field at a depth of 0-30 cm. The samples were then mixed thoroughly to prepare a composite sample representing the whole and air-dried for 72 hours. After crushing them, once air-dried, the soils were sieved with a 6 mm sieve and then used for laboratory analysis. The physical and chemical properties of the experimental soil were determined later; they are presented [16] in Table 1.

Table 1. Some of the physical and chemical properties of the soil used in the study.

unit of measurement	Analysis result	Type of analysis	
	Physical properties		
gm. kg^{-1}	87	Clay	
	201	Silkenage	
	705	Sand	
	Sandy mixture		tissue
	Chemical and fertility properties		
	7.21		Degree of reactivity
Decimins. M^{-1}	2.4		Electrical conductivity
%	1.9		Organic matter
mg. kg^{-1} soil	0.668		Nitrogen
mg. kg^{-1} soil	0.670		Phosphorus
mg. kg^{-1} soil	5.2		Potassium
millimol charge $^{-1}$ liter	24.1	Calcium	Dissolved ions Positive ions
	9.6	Magnesium	
	1.2	Sodium	
millimol charge $^{-1}$ liter	5.1	Sulfates	ions melted
	2	bicarbonate	
	17.6	chloride	

*Soil analyses were conducted in the laboratory of the Soil and Water Resources Department, College of Agriculture, University of Kufa.

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unit of measurement	Analysis result		Type of analysis
	Chemical properties		
	8.40		Degree of reactivity
Decimens.L^{-1}	**1.29**		Electrical conductivity
%	**1.3**		Organic substance
mg. L^{-1}	**12.2**	Potassium	Ions
Millimol charge. Liter	**7.3**		Positive
	8.1	Sodium	Soluble
	9.3	Calcium	Ions
Millimol charge. Liter^{-1}	**3.2**	Magnesium	Negative
	Nil	Bicarbonate	
	3.4	Carbonate	
	3.3	Chloride	
	4.51	Phosphorus	
	1.13	Iron	

Soil Preparation and Experimental Layout

the field was plowed and leveled to create a good seedbed for the crop. The experimental field was laid out in accordance with the design of the experiment, divided into three replications, each replicate comprising nine experimental plots. The size of each individual plot was 3 m long and 1 m wide, thus making an area of 3 m² for each experimental unit. Each plot was subdivided into 8 rows, with 5 plants in each row. The spacing between plants in the row was 20 cm, while that between the adjacent rows was 30 cm. Thus, each experimental unit had 40 plants. A 50-cm buffer zone was left between the neighboring plots to help in the management of the field and to avoid any interference among the treatments. The distance between replicates was kept at 1 m for easy movement for irrigation, cultivation, and weeding, besides all other routine operations during the whole period of growth [6].

Experimental Treatments

The experiment was laid out as a 3x3 factorial Randomized Complete Block Design (RCBD) with three replicates. This study considered two factors. The first factor was the organic fertilizer at three levels (0, 1800, and 3600 g/ h^{-1}), applied at a rate of 40 g plant^{-1} based on the manufacturer's recommendation. The second factor was foliar nano-calcium at three levels (0, 20, and 40 mg L^{-1}). Nano-calcium was sprayed in the growing season at two timings; the first spray was applied after 4–5 true leaves had developed and before storage root formation, and the second spray was applied 20 days after the first spray. These two factors create nine

treatment combinations; the nine treatments were assigned randomly to the experimental plots.

studied characteristics:

1- number of leaves
2- dry matter of the vegetative parts,
3- Root content of ascorbic acid,
4- Total sugars content in roots[15].
5- T.S.S
6- Root shape guide

Statistical Analysis

The experimental design was 3 x 9, making a total of 27 experimental units. Each unit was 3m² and had 40 plants. Data obtained for the traits under study were analyzed as per the factorial RCBD model. The means of treatments were compared using the LSD test at 5% probability ($P \leq 0.05$) to confirm the significance of treatment effects.

3. Results and Discussions

1- number of leaves (leaves. Plant^{-1})

Table (3) shows that organic fertilizerat a concentration of 3600 g ha^{-1}. increased number of leaves to 13.07 leaves. Plant^{-1}Compared to the measurement treatment that reached of 11.46 leaves.Plant^{-1}

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L^{-1} increased number of leaves by 13.77 leaves.Plant^{-1} over the distilled water spray treatment, which was 10.92 leaves.Plant^{-1}.

Table (3) shows that organic fertilizer at a concentration of 3600 g ha^{-1}, along with nano-calcium at a concentration of 40 mg L^{-1} with increased number of leaves to 14.06 leaves.Plant^{-1} Compared to the measurement treatment that reached of 10.20 leaves.Plant^{-1}

Table 3. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on number of leaves Content (leaves.Plant^{-1}) of Table Beetroot.

Treatment		Nano-calcium mg L^{-1}			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h^{-1}	0	11.20	10.40	10.80	11.46
	1600	12.12	12.63	13.06	12.68
	3600	11.43	12.03	14.46	13.07
Average effect of nano-calcium		10.92	12.68	15.77	
(0.05) L.S.D		Organic fertilizer		0.521	
		Nano-calcium		0.521	
		Interference		0.912	

2- dry matter of the vegetative parts (g)

Table (4) shows that organic fertilizerat a concentration of 3600 g ha^{-1}. increased dry matter of the vegetative parts to 24.72 g Compared to the measurement treatment that reached of 21.11 g.

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L^{-1} increased dry matter of the vegetative parts by 13.77 g over the distilled water spray treatment, which was 1.411 g.

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Table (4) shows that organic fertilizer at a concentration of 3600 g ha^{-1}, along with nano-calcium at a concentration of 40 mg L^{-1} with increased dry matter of the vegetative parts to 28.77 g Compared to the measurement treatment that reached of 11.92 g.

Table 4. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on dry matter of the vegetative parts Content (g) of Table Beetroot.

Treatment		Nano-calcium mg L^{-1}			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h^{-1}	0	11.95	20.94	30.45	21.11
	1600	12.89	15.33	25.41	17.88
	3600	22.02	23.36	28.77	24.72
Average effect of nano-calcium		15.62	19.88	28.21	
(0.05) L.S.D		Organic fertilizer		2.262	
		Nano-calcium		2.262	
		Interference		4.524	

3-Root content of ascorbic acid (mg. 100 ml)

Table (5) shows that organic fertilizerat a concentration of 3600 g ha^{-1}. increased root content of ascorbic acid to 1.366 mg. 100 ml Compared to the measurement treatment that reached of 1.259 mg. 100 ml.

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L^{-1} increased root content of ascorbic acid by 2.241 mg. 100 ml over the. distilled water spray treatment, which was 0.374 mg. 100 ml.

Table (5) shows that organic fertilizer at a concentration of 3600 g ha^{-1}, along with nano-calcium at a concentration of 40 mg L^{-1} with increased root content of ascorbic acid to 2.426 mg. 100 ml Compared to the measurement treatment that reached of 0.365 mg. 100 ml

Table 5. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on root content of ascorbic acid Content (mg. 100 ml) of Table Beetroot.

Treatment		Nano-calcium mg L^{-1}			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h^{-1}	0	0.365	1.228	2.184	1.259
	1600	0.411	1.273	2.412	1.370
	3600	0.346	1.250	2.426	1.336
Average effect of nano-calcium		0.374	1.250	2.341	
(0.05) L.S.D		Organic fertilizer		0.2065	
		Nano-calcium		0.2065	
		Interference		0.3577	

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4- Total sugars content in roots

Table (6) shows that organic fertilizerat a concentration of 3600 g ha⁻ ¹. increased Total sugars content in roots to 1.366 Compared to the measurement treatment that reached of 1.248 .

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L⁻ ¹ increased Total sugars content in roots by 2.214 over the distilled water spray treatment, which was 0.346.

Table (6) shows that organic fertilizer at a concentration of 3600 g ha⁻ ¹, along with nano-calcium at a concentration of 40 mg L⁻ ¹ with increased Total sugars content in roots to 2.423 Compared to the measurement treatment that reached of 0.356 .

Table 6. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on Total sugars content in roots Content of Table Beetroot.

Treatment		Nano-calcium mg L^{-1}			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h^{-1}	0	0.356	1.228	2.151	1.248
	1600	0.411	0.940	2.400	1.259
	3600	0.346	1.250	2.426	1.336
Average effect of nano-calcium		0.346	1.250	2.412	
(0.05) L.S.D		Organic fertilizer		0.2495	
		Nano-calcium		0.2495	
		Interference		0.4258	

5- T.S.S

Table (7) shows that organic fertilizerat a concentration of 3600 g ha⁻ ¹. increased T.S.S to 10.442 Compared to the measurement treatment that reached of 10.332

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L⁻ ¹ increased T.S.S by 11.478 over the distilled water spray treatment, which was 9.113.

Table (7) shows that organic fertilizer at a concentration of 3600 g ha⁻ ¹, along with nano-calcium at a concentration of 40 mg L⁻ ¹ with increased T.S.S to 11.500 Compared to the measurement treatment that reached of 9113 .

Table 7. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on T.S.S **Content of Table Beetroot.**

Treatment		Nano-calcium mg L-1			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h-1	0	9.113	10.267	11.333	10.332
	1600	9.400	10.267	11.600	10.422
	3600	9.297	13.03	11.500	10.442
Average effect of nano-calcium		9.267	10.200	11.478	
(0.05) L.S.D		Organic fertilizer		0.1775	
		Nano-calcium		0.1775	
		Interference		0.3074	

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6-Root shape guide H/D

Table (8) shows that organic fertilizerat a concentration of 3600 g ha^{-1}. increased root shape guide to 13.77 Compared to the measurement treatment that reached of 10.92 .

The same table also shows that spraying with nano-calcium at a concentration of 40 mg L^{-1} increased root shape guide by 12.68 over the distilled water spray treatment, which was 11.46.

Table (8) shows that organic fertilizer at a concentration of 3600 g ha^{-1}, along with nano-calcium at a concentration of 40 mg L^{-1} with increased root shape guide to 14.06 Compared to the measurement treatment that reached of 10.20 .

Table 8. Effect of Organic Fertilizer, Spraying with Nano-Calcium, and Their Interaction on root shape guide Content of Table Beetroot.

Treatment		Nano-calcium mg L-1			Average effect of organic fertilizer
		0	20	40	
Organic fertilizer gm h-1	0	10.20	11.40	12.80	10.92
	1600	11.13	13.63	14.46	12.68
	3600	11.43	13.03	14.06	13.77
Average effect of nano-calcium		11.46	13.07	12.68	
(0.05) L.S.D		Organic fertilizer		0.469	
		Nano-calcium		0.469	
		Interference		0.812	

He addition of organic fertilizers significantly affected the vegetative and root ,chemical growth characteristics of table beet plants. as shown in Tables 3, 4, 5, 6, 7 and 7. The increase Increase the number of leavesdry matter of the vegetative parts,root content of ascorbic acid,total sugars content in roots,T.S.S, and root shape guide is ascribed to the organic fertilization. organic fertilization was explained as a factor through which food production is increased because it raises nutrient efficiency in photosynthesis and other important processes of the plant[23]. this causes more nutrients to be produced by the plant, especially carbohydrates and proteinsThis leads to an increase in the number of leaves and dry matter in the plant [4].and their accumulation in the roots. It should be noted that roots develop into the principal storage site for carbohydrates and proteins as they grow. This would form sufficient ascorbic acid,total sugars content in roots [5] and has a positive effect on dry matter content. This effect may also be due to the role of humic acid in organic fertilizer, which enhances the plant's absorption of nutrients in a balanced manner. This, in turn, enhances vegetative growth, especially that of leaf area and chlorophyll content. It is followed by an increase in photosynthesis efficiency and the production of complex compounds such as carbohydrates and soluble amino acids. These are then transported to the roots. The nitrogen content of the organic fertilizer extract further influenced increased vegetative growth[19], which was reflected in the products of carbon metabolism and the amount of nitrogen absorbed[3]. This led to increased protein content in the roots, as increased nitrogen increases the amino acids that comprise them and thus increases TSS [2]. This finding is in agreement with those of Sami et al. [18].

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The increase in total sugar content, reducing sugar content, and sucrose content in the roots is due to organic fertilizers. Organic fertilization positively affects the root system by improving its cellular structure[13]. It increases the efficiency of sugar transport and storage within the root tuber; hence, sugar content (sucrose) and quality of the crop are improved. This finding is similar to that of [11] for beetroot. Nano-calcium spraying on table beetroot had a highly significant effect on its affected the vegetative and root chemical properties, namely total chlorophyll content in the leaves and total soluble carbohydrate content, The increase Increase the number of leaves dry matter of the vegetative parts,root content of ascorbic acid,total sugars content in roots,T.S.S, and root shape guide is ascribed for the formation . this could bring about enhanced efficiency of photosynthesis and increased production of organic matter within the plant, hence an appreciable improvement. the reason may also be due to the role of calcium in maintaining the integrity of cell membranes and controlling their permeability which enhances the movement of nutrients and chemicals within the plant increases carbohydrate accumulation in the roots, these results corroborate those of [12]. In another study bycalcium was found to accumulate to higher levels in plants supplied with the nutrient. This could be the reason 8 why calcium has been associated with protecting the pigments of the plant and also keeping the integrity of cellular structures in chloroplasts[17].

Conclusion

The interaction of organic fertilization and nano-calcium had a highly significant effect on improving the nutritional efficiency of the plant. It increased the concentration of Parameters det number of leaves dry matter of the vegetative parts,root content of ascorbic acid,Total sugars content in roots, T.S.S, and root shape guide The integrated treatment resulted in the highest marketable yield per unit area, particularly at the maximum organic fertilizer rate (3600 g ha^{-1}) with foliar application of nano-calcium at 40 mg L^{-1}, which confirms the role of nanotechnology in improving nutrient uptake efficiency. This serves as a validation of the earlier hypothesis. Low levels of reducing sugars and free sucrose in roots were observed at high fertilization, which indicates a physiological change in carbohydrate partitioning toward structural biomass and better root quality.

Recommendations

The integrated fertilization strategy comprising 3600 g ha^{-1} organic fertilizer with 40 mg L^{-1} nano calcium foliar application is recommended as the optimal nutrient management package for beetroot cultivation to maximize marketable yield. Other quality parameters of beetroot roots include betalain pigments (betanin) and antioxidant compounds. Economic evaluations should assess the feasibility of reducing reliance on conventional chemical fertilizers and replacing them with sustainable organic and nano-fertilizer systems under local soil and environmental conditions. Other studies would be required to assess the impact of such nano-organic combinations on other quality parameters of beetroot roots, particularly betalain pigments (betanin) and antioxidant compounds.

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