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Response of coriander plants to spray with vermicompost tea and biofertilization under organic farming system

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Abstract The results showed that spraying vermicompost tea at various dilutions significantly gave better growth, yield, and essential oil parameters than the untreated plants. Biofertilization also resulted in considerably more significant vegetative growth, yield, and oil measures than the control. According to treatments, linalool was the main component of fruit essential oil, with a range of 72.91 to 77.54%. This study advised organic growers to spray coriander with prepared vermicompost tea at a 1:4 v/v dilution and apply biofertilization as a soil drench throughout the vegetative development stage to enhance all attributes.

Keywords: Biofertilizer, *Coriandrum sativum*, Vermicompost extract, Yield

Introduction

The main uses of medicinal and aromatic plants as raw materials are therapeutic purposes, flavoring substances, and cosmetics. These plants are necessary for many products, including medicines, spice preparation, dietary supplements, fragrances, and other natural wellness items (Badr *et al*., 2013 and 2014; Sachan *et al*., 2018).

Coriander (scientific name: *Coriandrum sativum* L.) is an essential plant with medicinal and aromatic characteristics, classified under the family Apiaceae. It is an annual herb cultivated both in the Arab Republic of Egypt and in many regions across the world. The plant is endemic to the Mediterranean Basin area, although it is also cultivated in many parts of Europe, Asia, and other worldwide locations. Although all parts of the plant are edible, the dried fruits are the most valuable. Coriander fruits are frequently used in food preparation as a condiment due to the presence of essential oils in fruits, which enhance the flavor and scent of dishes. The essential oil contains many terpenes, including linalool, a significant constituent for aroma and taste (Peter, 2004; Singh and Davidson, 2013).

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It has been used in traditional medicine since ancient times to treat various ailments, and ongoing scientific research has substantiated these therapeutic properties. Consumption of coriander fruits has been found to substantially impact the reduction of cholesterol and dangerous triglyceride levels and work to burn fat and lose weight. It has anti-cancer activity, as the antioxidants in fruits have been linked to slowing the growth of cancer cells. Coriander is very good at promoting digestive health and enhancing liver function. It helps lower blood sugar levels. Calcium and other essential minerals found in it help maintain healthy, strong, and durable bones and protect against osteoporosis. It also contains anti-inflammatory substances, which help prevent arthritis and protect the heart by lowering blood pressure (Semwal, 2019; Devi *et al*., 2020; Huang *et al*., 2020).

Organic yields are priced higher than conventional ones and command a premium worldwide. Organic agriculture of medicinal and aromatic plants is a farming system that uses biological materials instead of chemicals. It also does not allow the use of genetically modified strains and organisms. Organic agriculture is based on the following practices: using natural sources such as organic fertilizers to fertilize plants; maintaining soil fertility by adding materials of organic origin while maintaining natural cycles of nutrients; protecting crops from insects and diseases by following integrated agricultural management; and keeping the ecosystem without the need for harmful chemicals, protecting natural enemies of pests, and using raw materials in control operations; leadership based on the exploitation of plant and animal waste; limiting the use of non-renewable sources; and preserving the environment. Establishing a sustainable agricultural system means reusing and recycling field waste. Because of the importance of this topic, Egypt passed Organic Agriculture Law No. 12 of 2020.Vermicompost tea and biofertilization are widely recognized as effective natural growth stimulators in organic farming (Mishra *et al*., 2013; Verma *et al*., 2019; Somasundaram *et al*., 2021).

Vermicompost, the meaning of this word, is worm fertilizer. Vermicompost is considered one of the finest types of organic fertilizer known to date. It consists of waste from worms eating organic materials. Compost is the decomposition of organic materials, whether animal or plant waste and is poor in terms of macro and microelements. Vermicompost is the result of a digestion process after the complete decomposition of the organic matter, in addition to the ability of worms to overcome and digest the harmful residues present in organic matter. Vermicompost contains higher percentages of macro and microelements, amino acids, humic substances, vitamins, and hormones. It is also richer in its content of microorganisms with multiple essential plant functions than regular compost. Vermicompost tea is the water extract of vermicompost. Studies have shown that when used as a spray on plants, it gives positive results, which helps in organic agriculture (Singh and Singh, 2014; Nourafcan *et al*., 2016; Alizadeh *et al*., 2018; Abdel Salam and Roshdy, 2022).

Biofertilizers are considered cheap sources of nutrients and growth promoters for medicinal crops in organic farming. Biofertilization depends on using isolated strains from the soil that are highly efficient in their enzymatic and hormonal behavior towards the plant and the soil, which leads to improving the properties of the soil and increasing its fertility, thus boosting growth and yield. Phosphorus-dissolving bacteria in the soil convert phosphorus compounds from insoluble to soluble forms using the organic acids they secrete, such as fumaric, lactic, and formic. They also increase plants' resistance to diseases. Non-symbiotic nitrogen-fixing bacteria are a group of bacteria that fix atmospheric nitrogen for plants and contribute to providing quantities of nitrogen fertilizer and improving plant growth. Its most essential genera are Azotobacter and Azospirillum (Menesy *et al*., 2002; Board, 2012; Hamed *et al*., 2017; Toaima *et al*., 2023).

The top ten countries with the highest production volumes of coriander are India, Turkey, Mexico, Russia, Iran, China, Syria, Egypt, Morocco, and Vietnam. The top exporting countries are Bulgaria, Canada, Poland, the Netherlands, Turkey, the United States, Ukraine, Germany, Switzerland, and the United Kingdom. However, organic production is still limited and insufficient in many countries (Tridge, 2024).

Egypt has strategically shifted its focus towards organically farming medicinal and aromatic plants on newly reclaimed lands to boost production capacity and quality while supporting its export market development. This study investigated the effects of different doses of vermicompost tea as a foliar spray, biofertilization, and their combination on organically cultivated plant growth, fruit production, and essential oil characteristics.

Materials and methods

This study was conducted at a field in the Oraby Association, Al-Eubour, which is situated at 30° 14′ 8.3″ North and 31° 31′ 34.1″ East, during the seasons of 2021/2022 and 2022/2023. The field of the experiment was certified to use organic farming methods (Agricert Organic Standard, 2019).

The mechanical and chemical characteristics of the soil are shown in Table 1. Table 2 offers the chemical measurements of the irrigation water. Before cultivation, the soil was improved with 48 m^3/hectare of compost. The chemical properties of the compost are mentioned in Table 3. The water, soil, and organic manure samples underwent analysis in compliance with AOAC (2022). The study area's average minimum temperature in autumn was 16 ºC, and the maximum was 28 ºC. The average minimum temperature in winter was 8 ºC, and the maximum was 20 ºC. The average minimum temperature in spring was 13 ºC, and the maximum was 27 ºC (Egyptian Meteorological Authority, 2025).

Coriander seeds (local variety) were obtained from the Egyptian Ministry of Agriculture and Land Reclamation and planted in the first week of November 2021 and 2022 for the first and second seasons. A drip irrigation system with drippers (4 l/h) was in use. The space between hills was 30 cm, while the space between rows was 75 cm. The plants were thinned, with four plantlets remaining on each hill (177778 plants per hectare).

A split-plot trial was conducted and had three replications and eight treatments. Spraying with vermicompost tea at four concentrations was used in the main plots. Vermicompost was made of animal and plant waste as raw materials. The finest red wiggler, tiger, and African worms produced this manure. Table 4 displays the chemical components of vermicompost. Water was added to the vermicompost to make a liquid source. Before usage, the final solutions were allowed to stand for twenty-four hours. During vegetative development, vermicompost tea was sprayed monthly. The tea was made at the following dilutions, control plants were only sprayed with distilled water, soaking vermicompost in water at 1:4 v/v and spraying with the extract, soaking vermicompost in water at 1:8 v/v and spraying with the extract, and soaking vermicompost in water at 1:12 v/v and spraying with the extract.

Biofertilization treatments (without and with) were used in the subplots. As a soil drench, a biofertilizer produced from bacteria that fix atmospheric nitrogen and promote phosphorus in the soil was applied to plants monthly throughout the vegetative growth period. *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Bacillus megaterium* were used for inoculation. The Egyptian Ministry of Agriculture and Land Reclamation supplied the biofertilizer. Drip irrigation was used immediately after biofertilization.

Organic agriculture methods were implemented (Chandran *et al*., 2023). The plants were manually harvested in the first week of April, when the fruits matured. Plant height (cm), fresh weight per plant (g), dry weight per plant (g), number of umbels per plant, dry fruit weight per plant (g), and dry fruit yield per hectare (ton) were among the growth and yield parameters detected. Fruits were separated from the plants, cleaned, and any foreign matter was eliminated. The dry matter weight was estimated by drying the sample at 70 ˚C until it attained a constant weight. All the data were assessed using an ANOVA, and the differences were investigated at the 5% probability level using L.S.D. (Snedecor and Cochran, 1982).

The chemical measurements involved the subsequent parameters. The essential oil percentage in the air-dried fruits was estimated via hydrodistillation (British Pharmacopoeia, 2002). Determine the essential oil yield per plant (ml) by multiplying the essential oil percentage by the weight of dry fruits per plant. Essential oil yield per hectare (l) was calculated by multiplying essential oil yield per plant by the number of plants per hectare. The essential oil samples of the second season were tested using a gas chromatography-mass spectrometer (GC/MS) in Egypt's National Research Center's Laboratory of Medicinal and Aromatic Plants. TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA) were used with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). A TR-5MS column (30 m x 0.32 mm i.d., 0.25 m film thickness) was used in the GC-MS system. The analyses were carried out with helium as the carrier gas at a flow rate of 1.3 ml/min, a split ratio of 1:10, and the following temperature program: 80°C for 1 minute, rising at 4°C/min to 300°C, and holding for 1 minute. The injector and detector were kept at 220 and 200°C, respectively. Diluted (1:10 hexane, v/v) samples of µl mixtures were continuously injected. Electron ionization (EI) at 70 eV gave mass spectra ranging from m/z 40–450. Retention time comparisons with established standards, the mass spectral library, and commercial spectra were used to identify compounds in agreement with Massada (1976) and Jennings and Shibamoto (1980).

Table 1. Mechanical and chemical aspects of the soil

Sand (%)			Silt (%)		Clay (%)		Soil texture			
65.50			31.00		3.50		Sandy loam			
pH	**O.M. (%)**	**E.C. (ppm)**	**Soluble anions (meq/l)**				**Soluble cations (meq/l)**			
			CO_3^{--}	**HCO_3^-**	**Cl^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**
8.61	0.40	588.80	-	0.50	5.50	3.17	2.50	1.50	4.85	0.32

Table 2. Irrigation water's chemical traits

pH	E.C. (ppm)	Soluble anions (meq/l)				Soluble cations (meq/l)			
		CO_3^{--}	**HCO_3^-**	**Cl^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**
7.20	316.00	-	1.46	1.19	2.68	3.10	1.32	0.82	0.09

Table 3. Compost chemical parameters

pH	EC (ppm)	O.M. (%)	C/N ratio (%)	N (%)	P (%)	K (%)	Ash (%)	Humidity (%)	Weight m^3 (kg)
6.38	3571.00	41.58	1 : 20.97	1.15	1.20	0.48	58.42	27.00	655.00

Table 4. Chemical characteristics of vermicompost used to prepare tea

pH	EC (ppm)	O.M. (%)	C/N ratio (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Organic carbon (%)
7.00	2240	33.00	1:15	3.00	0.75	0.85	2.50	2.00	20.00

Results

Effects of vermicompost tea concentrations

Results indicated how varying vermicompost tea concentrations affected growth, including plant height and fresh and dry weights (Tables 5, 6, and 7). They also showed their impact on yield attributes such as the number of umbels per plant, fruit weight per plant, and fruit output per hectare (Tables 8, 9, and 10).

In both seasons, all treatments sprayed with vermicompost liquid at different concentrations performed significantly better than the control for varied attributes. The rate of vermicompost in water at 1:4 v/v resulted in the most significant top parameters, followed by 1:8 v/v and 1:12 v/v in terms of fresh and dry weight per plant, fruit weight per plant, and fruit yield per hectare. In the first season, these values were 101.53, 82.23, and 70.48 g; 40.69, 32.86, and 28.18 g; 13.99, 12.50, and 9.70 g; 2.49, 2.23, and 1.73 tons for the first, second, and third concentrates, respectively. In the second season, these measurements were 109.58, 92.04, and 79.08 g; 42.63, 35.42, and 30.91 g; 12.90, 10.98, and 9.44 g; 2.29, 1.95, and 1.68 tons regarding the first, second, and third levels of vermicompost tea, in that order. The number of umbels in the first season had the same trend; however, the second season did not significantly change between the vermicompost and water at 1:8 v/v and 1:12 v/v treatments.

Results showed the effects of vermicompost tea on essential oil percentage, oil production per plant, and oil per hectare. The data revealed that sprayed vermicompost dilutions significantly impacted most previous parameters (Tables 11, 12, and 13). The highest essential oil percent was between vermicompost and water at 1:4 v/v. The oil percentage in the first season was 0.24%; in the second, it was 0.19%. Vermicompost in water at 1:4 v/v, followed by 1:8 v/v, produced the maximum essential oil yield per plant and hectare. These data were 0.04 and 0.03 ml, 6.22 and 4.45 l in the first season, and 0.03 and 0.02 ml, 4.45 and 2.67 l in the second season.

Effects of biofertilization

Results demonstrated the effects of biofertilizer strains on growth traits such as plant height and fresh and dry mass per plant (Tables 5, 6, and 7). They displayed the impact of biofertilizer on the number of umbels per plant, fruit weight per plant, and fruit production per hectare (Tables 8, 9, and 10). All inoculated plants significantly performed better than the control (untreated plants) over the two conducted seasons regarding plant height, fresh and dry weight per plant, number of umbels per plant, fruit weight per plant, and fruit yield per area. The biofertilized plants gave 72.57 cm, 82.83 g, 33.11 g, 14.84 umbels, 11.62 g, and 2.07 tons in the first season. The second season's data were 74.28 cm, 92.65 g, 35.70 g, 16.29 umbels, 11.37 g, and 2.02 tons.

Biofertilization's effects on fruits' flavor attributes, including essential oil percentage, oil quantity per plant, and oil production per hectare, are displayed in Tables 11, 12, and 13. The results showed that biofertilization significantly influenced the previously listed criteria and produced the maximum values. In the first season, treatments with biofertilizer achieved 0.24%, 0.03 ml, and 4.89 l. These data were 0.19%, 0.02, and 3.56 l in the second season. On the other hand, uninoculated plants detected lower values.

Effects of the interaction between vermicompost tea concentrations and biofertilizer

Concerning the interaction between the factors mentioned above on growth characteristics, the significantly highest values of plant height, fresh weight per plant, and dry weight per plant were observed by a combination of biofertilization with vermicompost tea at a dilution of 1:4 v/v followed by 1:8 v/v (Tables 5, 6, and 7). In the first season, these averages were 83.89 and 75.31 cm; 113.78 and 91.42 g; 45.54 and 36.46 g, while in the second season, they were 80.83 and 77.17 cm; 123.33 and 103.50 g; 48.55 and 39.43 g.

Also, results gave a similar direction regarding yield metrics: biofertilization with vermicompost in water at 1:4 v/v produced the most umbels per plant, followed by 1:8 v/v (Table 8). The first season's values showed 17.39 and 16.04 umbels, whereas the second season exhibited 19.17 and 17.00 umbels. The best fruit weight per plant and fruit yield per hectare results were obtained by biofertilizing and spraying with vermicompost liquid extract at a ratio of 1:4 v/v followed by 1:8 v/v (Tables 9, 10, and Figure 1). The first season's data were 15.50 and 13.60 g; 2.76 and 2.42 tons, whereas the second season's records were 14.87 and 12.45 g; 2.64 and 2.21 tons.

Related to the essential oil percentage in fruits, it went in the same direction; the highest essential oil percentage was extracted in both seasons from biofertilized plants conjugated with spray by vermicompost tea at a dosage of 1:4 v/v, followed by 1:8 v/v treatments. In the first season, the percentages were 0.26 and 0.25%; in the second season, they were 0.21 and 0.19%. The highest essential oil per plant and hectare was identified by inoculating plants with biofertilizer and supplying them with vermicompost tea at 1:4 v/v (Tables 12, 13, and Figure 2). The first season offered 0.04 ml and 7.11 l, respectively. They reached 0.03 ml and 5.33 l in the second season, respectively.

Different treatments impacted the chemical composition of the resulting essential oils, considerably influencing their quality (Table 14). The essential oils were generally high in oxygenated compounds, ranging from 86.23 to 89.03%. Linalool was the primary ingredient in the oil, ranging from 72.91 to 77.54%. GC/MS analysis revealed that combining biofertilization and vermicompost tea at various dilutions increased the linalool in oils between 73.25 and 77.54%. In contrast, the control had the lowest linalool level (72.91%). Total hydrocarbon compounds recorded the minimum values in essential oil composition, ranging between 10.32 and 13.76%.

Table 5. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on plant height (cm) of *Coriandrum sativum* L.

Treatments	**1st season**			**2nd season**		
	Biofertilization		Mean	**Biofertilization**		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	56.43 g	61.76 h	59.10 a	63.00 f	66.33 g	64.67 a
Vermicompost:water at a 1:4 v/v	74.00 jk	83.89 l	78.95 d	73.67 h	80.83 j	77.25 c
Vermicompost:water at a 1:8 v/v	72.17 ijk	75.31 k	73.74 c	73.00 h	77.17 i	75.09 c
Vermicompost:water at a 1:12 v/v	71.33 ij	69.33 i	70.33 b	70.67 h	72.77 h	71.72 b
Mean	68.48 e	72.57 f		70.09 d	74.28 e	
LSD at 0.05 Vermicompost tea		2.685			2.255	
Biofertilization		1.895			1.595	
Interaction		3.795			3.190	

Means with the same letter are not significantly different at 5% level of probability

Table 6. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on fresh weight per plant (g) of *Coriandrum sativum* L.

Treatments	1st season			2nd season		
	Biofertilization		Mean	Biofertilization		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	36.75 g	49.50 h	43.13 a	43.75 g	54.17 g	48.96 a
Vermicompost:water at a 1:4 v/v	89.28 k	113.78 l	101.53 d	95.83 jk	123.33 l	109.58 d
Vermicompost:water at a 1:8 v/v	73.04 ij	91.42 k	82.23 c	80.58 i	103.50 k	92.04 c
Vermicompost:water at a 1:12 v/v	64.33 i	76.63 j	70.48 b	68.58 h	89.58 ij	79.08 b
Mean	65.85 e	82.83 f		72.19 e	92.65 f	
LSD at 0.05 Vermicompost tea	7.925			8.120		
Biofertilization	5.601			5.740		
Interaction	11.200			11.475		

Means with the same letter are not significantly different at 5% level of probability

Table 7. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on dry weight per plant (g) of *Coriandrum sativum* L.

Treatments	1st season			2nd season		
	Biofertilization		Mean	Biofertilization		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	14.82 g	19.75 h	17.29 a	17.21 g	20.50 g	18.86 a
Vermicompost:water at a 1:4 v/v	35.83 k	45.54 l	40.69 d	36.71 jk	48.55 l	42.63 d
Vermicompost:water at a 1:8 v/v	29.25 ij	36.46 k	32.86 c	31.41 hi	39.43 k	35.42 c
Vermicompost:water at a 1:12 v/v	25.68 i	30.67 j	28.18 b	27.50 h	34.32 ij	30.91 b
Mean	26.40 e	33.11 f		28.21 e	35.70 f	
LSD at 0.05 Vermicompost tea	3.305			2.785		
Biofertilization	2.335			1.971		
Interaction	4.670			3.942		

Means with the same letter are not significantly different at 5% level of probability

Table 8. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on number of umbels per plant of *Coriandrum sativum* L.

Treatments	**1^{st} season**			**2^{nd} season**		
	Biofertilization		Mean	**Biofertilization**		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	9.17 ^{g}	10.77 ^{h}	9.97 ^{a}	10.92 ^{f}	12.67 ^{g}	11.80 ^{a}
Vermicompost:water at a 1:4 v/v	14.88 ^{jk}	17.39 ^{l}	16.14 ^{d}	15.75 ^{ij}	19.17 ^{k}	17.46 ^{c}
Vermicompost:water at a 1:8 v/v	13.75 ^{j}	16.04 ^{k}	14.90 ^{c}	14.42 ^{hi}	17.00 ^{j}	15.71 ^{b}
Vermicompost:water at a 1:12 v/v	12.33 ^{i}	15.17 ^{k}	13.75 ^{b}	13.74 ^{gh}	16.33 ^{j}	15.04 ^{b}
Mean	12.53 ^{e}	14.84 ^{f}		13.71 ^{d}	16.29 ^{e}	
LSD at 0.05 Vermicompost		0.865			1.070	
Biofertilization		0.610			0.756	
Interaction		1.225			1.515	

Means with the same letter are not significantly different at 5% level of probability

Table 9. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on fruit weight per plant (g) of *Coriandrum sativum* L.

Treatments	**1^{st} season**			**2^{nd} season**		
	Biofertilization		Mean	**Biofertilization**		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	5.53 ^{g}	6.45 ^{h}	5.99 ^{a}	6.16 ^{g}	7.95 ^{h}	7.06 ^{a}
Vermicompost:water at a 1:4 v/v	12.48 ^{k}	15.50 ^{m}	13.99 ^{d}	10.93 ^{k}	14.87 ^{m}	12.90 ^{d}
Vermicompost:water at a 1:8 v/v	11.39 ^{j}	13.60 ^{l}	12.50 ^{c}	9.50 ^{ij}	12.45 ^{l}	10.98 ^{c}
Vermicompost:water at a 1:12 v/v	8.48 ^{i}	10.91 ^{j}	9.70 ^{b}	8.67 ^{hi}	10.20 ^{jk}	9.44 ^{b}
Mean	9.47 ^{e}	11.62 ^{f}		8.82 ^{e}	11.37 ^{f}	
LSD at 0.05 Vermicompost		0.400			0.725	
Biofertilization		0.285			0.513	
Interaction		0.570			1.026	

Means with the same letter are not significantly different at 5% level of probability

Table 10. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on fruit yield per hectare (ton) of *Coriandrum sativum* L.

Treatments	**1^{st} season**			**2^{nd} season**		
	Biofertilization		Mean	**Biofertilization**		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	0.98 ^{g}	1.15 ^{h}	1.07 ^{a}	1.10 ^{g}	1.41 ^{h}	1.26 ^{a}
Vermicompost:water at a 1:4 v/v	2.22 ^{k}	2.76 ^{m}	2.49 ^{d}	1.94 ^{k}	2.64 ^{m}	2.29 ^{d}
Vermicompost:water at a 1:8 v/v	2.03 ^{j}	2.42 ^{l}	2.23 ^{c}	1.69 ^{ij}	2.21 ^{l}	1.95 ^{c}
Vermicompost:water at a 1:12 v/v	1.51 ^{i}	1.94 ^{j}	1.73 ^{b}	1.54 ^{hi}	1.81 ^{jk}	1.68 ^{b}
Mean	1.69 ^{e}	2.07 ^{f}		1.57 ^{e}	2.02 ^{f}	
LSD at 0.05 Vermicompost		0.070			0.129	
Biofertilization		0.050			0.092	
Interaction		0.100			0.183	

Means with the same letter are not significantly different at 5% level of probability

Table 11. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on essential oil percentage of *Coriandrum sativum* L.

Treatments	1st season			2nd season		
	Biofertilization		Mean	Biofertilization		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	0.23 i	0.23 i	0.23 b	0.16 h	0.18 j	0.17 b
Vermicompost:water at a 1:4 v/v	0.22 h	0.26 k	0.24 c	0.17 i	0.21 l	0.19 c
Vermicompost:water at a 1:8 v/v	0.20 g	0.25 j	0.23 b	0.15 g	0.19 k	0.17 b
Vermicompost:water at a 1:12 v/v	0.18 f	0.20 g	0.19 a	0.13 f	0.16 h	0.15 a
Mean	0.21 d	0.24 e		0.15 d	0.19 e	
LSD at 0.05 Vermicompost	0.006			0.007		
Biofertilization	0.004			0.005		
Interaction	0.009			0.010		

Means with the same letter are not significantly different at 5% level of probability

Table 12. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on essential oil yield per plant (ml) of *Coriandrum sativum* L.

Treatments	1st season			2nd season		
	Biofertilization		Mean	Biofertilization		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	0.01 g	0.02 h	0.02 a	0.01 f	0.01 f	0.01 a
Vermicompost:water at a 1:4 v/v	0.03 i	0.04 j	0.04 d	0.02 g	0.03 h	0.03 c
Vermicompost:water at a 1:8 v/v	0.02 h	0.03 i	0.03 c	0.01 f	0.02 g	0.02 b
Vermicompost:water at a 1:12 v/v	0.02 h	0.02 h	0.02 b	0.01 f	0.02 g	0.02 b
Mean	0.02 e	0.03 f		0.01 d	0.02 e	
LSD at 0.05 Vermicompost	0.004			0.003		
Biofertilization	0.003			0.002		
Interaction	0.005			0.005		

Means with the same letter are not significantly different at 5% level of probability

Table 13. Effect of vermicompost tea dilutions, biofertilizer, and their interaction on essential oil yield per hectare (l) of *Coriandrum sativum* L.

Treatments	1st season			2nd season		
	Biofertilization		Mean	Biofertilization		Mean
Vermicompost tea dilutions	Without	With		Without	With	
Without	1.78 g	3.56 h	2.67 a	1.78 f	1.78 f	1.78 a
Vermicompost:water at a 1:4 v/v	5.33 i	7.11 j	6.22 d	3.56 g	5.33 h	4.45 c
Vermicompost:water at a 1:8 v/v	3.56 h	5.33 i	4.45 c	1.78 f	3.56 g	2.67 b
Vermicompost:water at a 1:12 v/v	3.56 h	3.56 h	3.56 b	1.78 f	3.56 g	2.67 b
Mean	3.56 e	4.89 f		2.23 d	3.56 e	
LSD at 0.05 Vermicompost	0.629			0.543		
Biofertilization	0.445			0.385		
Interaction	0.890			0.769		

Means with the same letter are not significantly different at 5% level of probability

Table 14. Chemical components (%) of essential oils for different treatments

No	Compounds	Treatments							
		Without v.t. + without bio.	**Without v.t. + with bio.**	**With v.t. 1:4 dilution + without bio.**	**With v.t. 1:4 dilution + with bio.**	**With v.t. 1:8 dilution + without bio.**	**With v.t. 1:8 dilution + with bio.**	**With v.t. 1:12 dilution + without bio.**	**With v.t. 1:12 dilution + with bio.**
1	Nonane	0.08	-	0.07	0.07	0.10	0.04	0.07	0.08
2	Heptanal	0.10	-	0.09	0.03	0.04	-	0.09	-
3	α-pinene	3.48	3.35	4.28	3.82	3.88	1.96	3.40	3.45
4	Camphene	0.26	0.24	0.28	0.33	0.31	0.20	0.25	0.26
5	α-phellandrene	0.20	-	0.24	-	-	-	-	-
6	4(10)-thujene	-	0.13	-	0.23	0.21	0.11	0.40	0.17
7	α-myrcene	0.38	-	0.39	0.47	0.42	0.23	0.35	0.38
8	Octanal	0.09	-	0.08	0.04	0.05	-	0.08	-
9	p-cymene	2.90	2.70	3.00	3.11	-	3.23	2.50	2.08
10	γ-terpinene	5.11	4.25	5.48	5.73	5.40	5.33	4.33	3.96
11	Linalool oxide	-	-	0.05	0.09	0.04	0.04	0.04	-
12	Hexyl octyl ether	-	0.13	-	-	-	-	0.15	-
13	2-carene	0.18	-	-	-	-	-	-	0.16
14	2,4-decadienal, (E,E)-	0.14	-	0.09	-	0.04	-	0.16	-
15	α-linalool	72.91	76.39	74.49	73.25	74.82	77.54	76.00	74.10
16	(+)-2-bornanone	4.96	4.85	4.54	5.36	4.66	3.69	4.57	5.02
17	endo-borneol	0.83	1.06	-	0.61	-	-	0.55	0.47
18	Decanal	0.73	0.24	0.64	0.33	0.44	-	0.68	0.29
19	Terpinen-4-ol	-	-	0.42	-	0.40	0.39	-	-
20	α-terpineol	0.37	0.25	0.30	0.42	0.31	0.29	0.33	0.30
21	Citronellol	0.11	0.09	0.10	0.10	0.08	0.09	0.08	0.07
22	Geraniol	3.15	1.87	2.27	3.00	2.60	2.97	2.82	3.17
23	α-citral	-	-	-	-	-	-	-	1.06
24	Nerol acetate	-	-	-	-	-	-	-	0.07
25	2-decenal	0.37	-	0.16	0.04	0.07	-	0.18	-
26	1-undecanol	-	-	0.13	0.08	-	-	0.18	-
27	n-tridecan-1-ol	0.16	-	-	-	-	-	-	-
28	2-n-octylfuran	0.08	-	-	-	-	-	-	-
29	Undecanal	0.19	0.11	0.19	0.12	0.16	0.11	0.21	0.12
30	Myrtenyl acetate	0.07	-	0.06	0.07	0.05	0.06	0.07	0.07
31	Geranyl acetate	2.41	2.06	2.29	2.46	2.19	2.75	2.23	4.15
32	Myristaldehyde	0.07	-	-	-	-	-	-	-
33	Nonadecane	-	-	-	-	-	-	-	0.04

Table 14. (Con.)

No	Compounds	Treatments							
		Without v.t. + without bio.	Without v.t. + with bio.	With v.t. 1:4 dilution + without bio.	With v.t. 1:4 dilution + with bio.	With v.t. 1:8 dilution + without bio.	With v.t. 1:8 dilution + with bio.	With v.t. 1:12 dilution + without bio.	With v.t. 1:12 dilution + with bio.
34	1-nonadecanol	-	-	-	-	-	0.10	-	-
35	1-octanol, 2-butyl-	-	0.10	-	-	0.08	-	-	-
36	Dodecane	-	0.11	-	-	-	0.05	-	-
37	Dodecanal	-	-	0.06	0.04	0.05	0.04	0.07	0.03
38	2-dodecenal	0.17	-	0.14	0.10	0.12	0.20	0.16	0.08
39	2,4-dodecadienal	-	-	0.04	0.03	0.04	-	-	-
40	9-n-hexylheptadecane	0.07	-	-	-	-	-	-	-
41	(n)-trans-nerolidol	-	-	-	-	0.41	0.10	-	-
42	Rhodopin								0.03
43	Ethyl iso-allocholate	-	-	0.04	-	-	-	-	-
44	Hexahydrofarnesyl acetone	-	-	0.07	0.06	0.05	0.05	0.05	-
45	Octatriacontyl pentafluoropropionate	0.19	-	-	-	-	-	-	-
	Total identified components	99.76	97.93	99.99	99.99	97.02	99.57	100.00	99.61
	Total hydrocarbon components	12.66	10.78	13.74	13.76	10.32	11.15	11.3	10.58
	Total oxygenated components	87.1	87.15	86.25	86.23	86.7	88.42	88.7	89.03

v.t. = vermicompost tea, bio. = biofertilizer

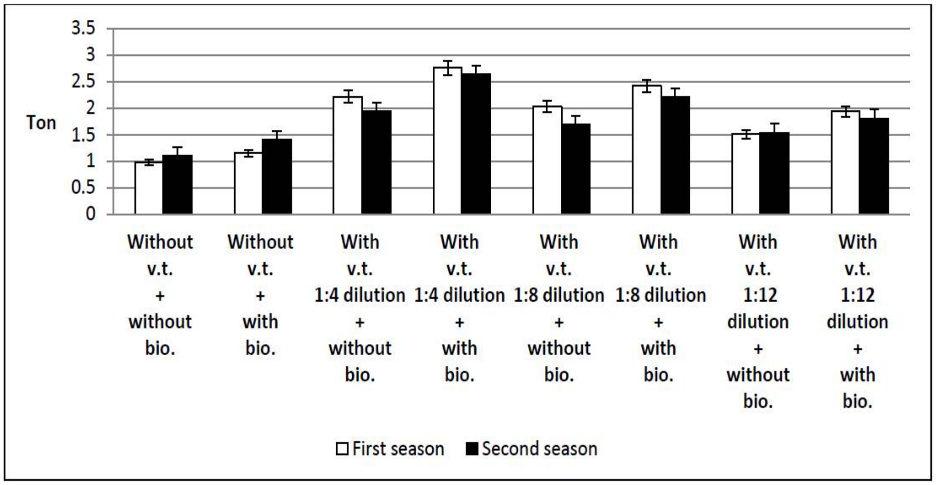

Figure 1. Effect of interaction between treatments on fruit yield per hectare (v.t. = vermicompost tea, bio. = biofertilizer)

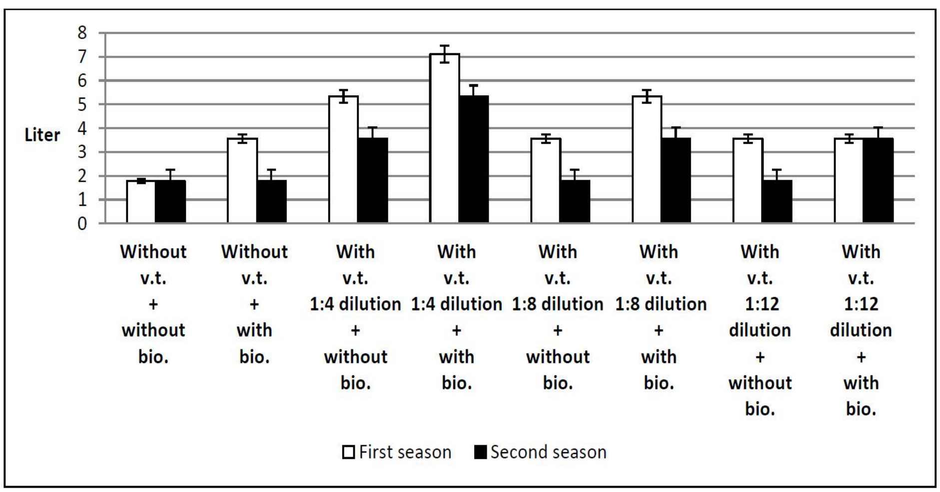

Figure 2. Effect of interaction between treatments on oil yield per hectare (v.t. = vermicompost tea, bio. = biofertilizer)

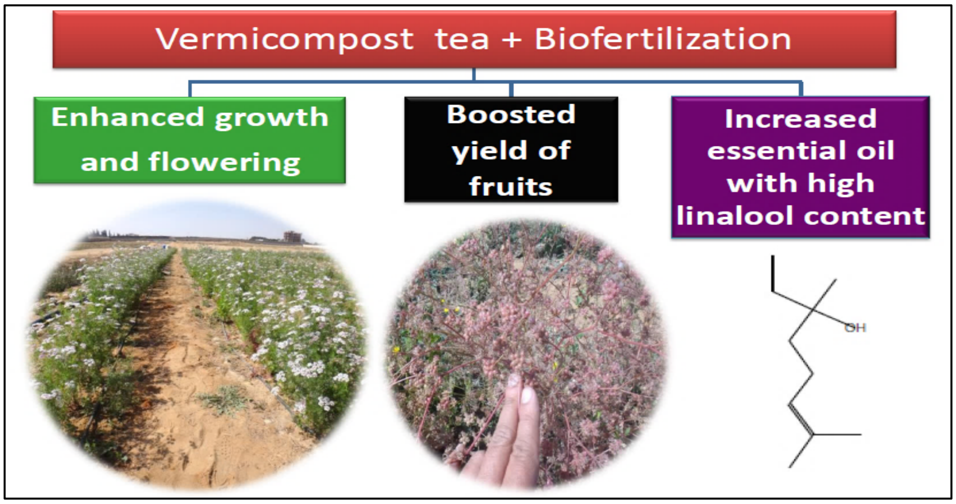

Figure 3. Graphical shows the merits of biostimulants on parameters

Discussion

Organic production is considered low on newly reclaimed desert lands because the soil is low in nutrients, irrigation water only lasts for a short time, and the difference between day and night temperatures is vast in these areas. As a result, growth stimulants were required to boost tolerance to adverse conditions and thus develop production (Abd El-Aleem *et al*., 2021; Toaima *et al*., 2023; Attia *et al*., 2024).

The outcome of this investigation showed that all characters were enhanced by foliar vermicompost tea spray regarding growth and yield parameters. These increments in growth and yield could be due to numerous factors.

Vermicompost tea contains water-soluble bioactive compounds such as phytohormones like indole acetic and gibberellic acids, fulvic and humic acids, minerals, amino acids, antioxidants, vitamins, and stimulant compounds secreted by microorganisms, which may be responsible for developmental promotion. These natural chemicals play critical roles in encouraging plant vegetative growth. They may also boost enzymes, leading to increased nutritional uptake and photosynthesis (Singh and Singh, 2014). Therefore, the effect of vermicompost tea substances on the plant varied depending on their concentration in the spray solution. The most efficient was the one with the highest concentration.

These results regarding the increase in quantitative and qualitative characteristics resulting from using vermicompost tea on plants were consistent with the findings of several scientists. Zaller (2006) on tomatoes, Nourafcan *et* *al*. (2016) on Jimsonweed, Chaichi *et al*. (2018) on faba bean, and Rekha *et al*. (2018) on bell pepper.

The advancement of all growth and yield indicators by biofertilization might be attributed to several causes. Azotobacter and Azospirillum are two classical free-living microorganisms capable of fixing atmospheric nitrogen. *Azotobacter chroococcum* and *Azospirillum lipoferum* inoculation cause mineral solubilization and manufacturing vitamins, amino acids, auxins, and gibberellins, all driving plant development. *Bacillus megaterium* can convert insoluble phosphorus in the soil to soluble forms by secreting organic acids such as formic, acetic, lactic, glycolic, fumaric, and succinic acids. These acids reduce the pH and cause the breakdown of bound types of phosphate. Some hydroxy acids may chelate with calcium and iron, resulting in the effective solubilization and use of phosphate. The secretion of hormones by this bacterial strain encourages plants' vegetative growth (Giri *et al*., 2019).

Many researchers agreed with the results regarding the positive effect of biofertilization on coriander (Choudhary *et al*., 2008; Abdalla, 2009; Rahimi *et al*., 2009; Mounika *et al*., 2017; Mounika *et al*., 2018; Swain *et al*., 2020; Ali *et al*., 2023).

The combination of spraying vermicompost tea and biofertilization was promising, and the best treatment was biofertilization and spraying the solution of vermicompost in water at 1:4 v/v. In that case, these significant increments could be explained by their promotive effects on plant physiological processes, as mentioned above, which contributed to the highest growth traits (plant height, fresh weight per plant, and dry weight per plant), the highest number of umbels per plant, and the highest yield of fruits that had rich secondary metabolites as essential oils (Figure 3).

Regarding the quality attributes, the essential oil produced from the treatment of biofertilization with vermicompost tea at a dilution of 1:4 v/v was between 0.21 and 0.26%. These percentages followed the International Standard Specifications (ISO 2255, 1996), which demonstrated that group B fruits should contain essential oil between 0.1 and 0.5% as minimum and maximum limits on a dry basis.

Also, its concentration of linalool was 73.25%, which matches the ISO 3516, 1997 specifications. Their report described that the concentration of linalool in the coriander essential oil should be between 65% and 78% as a maximum. Many countries around the world commonly accept ISO standards.

The detected composition of coriander essential oil was in harmony with the research by Orav *et al*. (2011), Davazdahemami (2015), Hani *et al*. (2015), Milica *et al*. (2016), and Nofal and Menesi (2019), who reported that linalool was the chief ingredient of fruit oil. The other distinguishing compounds were γ-terpinene, α-pinene, and p-cymene.

Based on the findings reported in the study, we recommend that organic coriander growers spray the plants with vermicompost tea at a dilution of 1:4 v/v (soaking vermicompost in water at 1:4 v/v and spraying with the extract) and add a biofertilizer as a soil drench composed of the following bacterial strains: *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Bacillus megaterium*, each a month during the vegetative growth stage, to produce the highest fruit and oil yield.

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