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Response of Coriander Plants to Some Organic and Bio-Fertilizer Treatments

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ABSTRACT

This investigation was conducted during two experimental seasons of 2020/2021 and 2021/2022 to explore the impact of fertilization (farmyard manure at rats 0, 10, 15 and 20 m³/fed., plus half-recommended dose of NPK fertilizer) and bio-fertilizers (seed inoculation with a mixture of bacteria; *Azospirillum chroococcum, Bacillus megatherium* var. *phosphaticum, Bacillus circulans* and/or arbuscular mycorrhizal fungi), as well as their interactions on growth, yield, and coriander volatile oil. Results showed a significant increase in plant growth traits, i.e., plant height, branches number, fresh and dry weight of plant, yield components, i.e., number of umbels per plant, seed yield per plant and per feddan, as well as volatile oil production. Treating plants with a high rate of farmyard manure registered the highest values of parameters under study. Also, adding a mixture of bacteria; *A. chroococcum, B. megatherium* var. *phosphaticum, B. circulans* with arbuscular mycorrhizal fungi proved to be more effective in increasing the previously studied traits. The tested characteristics were significantly affected by the interaction treatments. Also, most combined treatments significantly enhanced all examined traits. Moreover, farmyard manure at a high rate (20 m^3/fed.) plus inoculation coriander seeds with mixed bacteria and mycorrhizal fungi were the most effective treatments. The main constituents of volatile oil were also affected by farmyard manure and bio-fertilizers applications. In general, the combination of farmyard manure at a high rate (20 m^3/fed.) plus inoculation of seeds by mixed bacteria and mycorrhizal fungi increased percentages of main components of volatile oil compared to untreated plants.

Keywords: farmyard manure, *Azospirillum chroococcum*, *Bacillus megatherium* var. *phosphaticum*, *Bacillus circulans*, Arbuscular mycorrhizal fungi, coriander plant.

INTRODUCTION

Coriander (*Coriandrum sativum* L.) belongs to the Apiaceae (Umbelliferae) family besides, coriander contains various phytochemicals such as many phytosterols, vitamins and polyphenols that account for its properties including analgesic, antidiabetic, anti-inflammatory and anti-cancer effects (Mahleyuddin et al., 2021). South Asia is the world's greatest maker of coriander, moreover a looming exporter to nations like USA, the Middle East, the EU, also Southeast Asia (Ranjan and Bhadra, 2020). It grows best in climates; moreover, it can cultivate in any soil like light to heavy black soil and light, moist, well-drained, loamy soil (Verma et al., 2011).

Organic manure improves the physical and chemical properties of the soil, especially sandy soil fertility, reduce losses of nutrients, also it is considered a good source of nutrients. Therefore, organic manure is an important factor in the vegetative growth and chemical properties of several aromatic and medicinal plants.

Cow manure increases the content of organic carbon in the degraded soil; it may lead to improve the activity of microorganisms in the soil besides the fertility status by enhancing the nutrients availability for the plants. Farmyard manure is the most desirable animal manure because it has high organic matter content nutrient, so it significantly improved the plant growth and yield (Gudugi, 2013; Akande et al., 2006 and Mehedi et al., 2012). In addition, many research recorded a positive effect of organic manure on the vegetative growth and chemical compounds of aromatic and medicinal plants (Bishr et al., 2006; Gewefiel et al., 2009 and Abdou et al., 2011).

Microbial interactions in the plant rhizospheres improve biological activities (Tilak and Reddy, 2006). Associations of syntrophic are ecological importance in agriculture with implied. The plant growth-promoting rhizobacteria (PGPR) can directly influence growth of plant by producing phytohormones and indirectly by fixing nitrogen and producing bio-control agents against phytopathogens in soil (Glick, 2003).

Azospirillum species fixed nitrogen while *Bacillus megatherium* var. *phosphaticum* solubilize phosphate rock (Han and Lee, 2005). Bio-soluble potassium fertilizer (KSB) can solubilize the mineral powder of potassium rock, such as illite and micas, KSBs such as *Bacillus circulans* and *Bacillus mucilaginosus* improve availability of potassium in soil and increase plant mineral contents (Sheng and Huang, 2002).

Inoculation of *Ammi visnaga* seeds with N-fixing bacteria (*Azotobacter* and/or *Azospirillum*) results in increasing the yield of fruit (El-Shafie et al., 2010). In the same context, bio-fertilizer mixtures (*B. megatherium* var. *phosphaticum*, *B. circulans*, and *Azotobacter* sp.) application increased the growth characteristics, yield, crude oil and essential oil of *Foeniculum vulgare* L. (Azzaz et al., 2009). Likewise, Hassan et al. (2009) hypothesized that inoculation of *Nigella sativa* seeds with *B. megatherium* var. *phosphaticum* and vesicular arbuscular mycorrhizal fungi resulted in increasing the growth parameters, yield, and the percentage of volatile oil.

MATERIALS AND METHODS

This experiment was conducted at the experimental farm of the Faculty of Agriculture, New Valley University, El-Kharga, Egypt during two successive seasons 2020/2021 and 2021/2022 to investigate the effect of fertilization (farmyard manure at rats 0, 10, 15, and 20 m^3/fed. plus, half-recommended dose of NPK fertilizer) and bio-fertilizers (seed inoculation with a mixture of bacteria; *Azospirillum chroococcum*, *Bacillus megatherium* var. *phosphaticum*, *Bacillus circulans* and/or arbuscular mycorrhizal fungi), as well as their interactions on growth parameters, yield, volatile oil of coriander seeds. Coriander seeds were obtained from the Department of Medicinal and Aromatic Plants, Horticultural Research Institute, Giza, Egypt.

Bacterial mixture and arbuscular mycorrhizal fungi were obtained from Microbiology Department, National Research Center, Dokki, Egypt.

Five samples were randomly collected from the experimental soil (0-30 cm depth) before plantation to measure some soil physical and chemical properties by the methods of Black (1965) and Page et al. (1982). Data of soil analysis is shown in Table (1).

Table (1): Some soil physical and chemical analysis of the experimental soil during the 2020/2021 and 2021/2022 seasons

Soil properties		Season	
		2020/2021	2021/2022
	Particle size distribution (%)		
Physical analysis	Coarse sand	4.73	5.10
	Fine sand	76.05	75.38
	Clay	6.98	6.72
	Silt	12.24	12.80
	Texture class	Sandy	Sandy
Chemical analysis	EC. dsm^{-1} (1:1 ex.)	0.91	0.88
	pH (1:1 w/v)	7.82	7.92
	Organic matter (%)	0.75	0.84
	Saturation capacity (%)	27.49	27.85
	Available nutrients (mg/kg)		
	N	50.4	52.3
	P	6.22	6.85
	K	87.8	85.6

Farmyard manure (FM) was obtained from the cattle farm, Faculty of Agriculture, New Valley University, Egypt. They were analyzed to determine their content of nutrients, as shown in Table (2).

Table (2): Chemical analysis of farmyard manure during the 2020/2021 and 2021/2022 seasons

Ser.	Component	Farmyard manure	
		2020/2021	2021/2022
1	EC.dsm^{-1}(1:2 ex)	3.25	3.00
2	pH (1:2 w/v)	7.2	7.00
3	O.M (%)	37.4	37.0
4	O.C (%)	21.8	20.5
5	N (%)	3.13	3.11
6	C/N ratio	19:1	20:1
7	P (%)	0.94	0.91
8	K (%)	3.75	3.55
9	Fe (ppm)	6100	5950
10	Mn (ppm)	235	222
11	Zn (ppm)	274	262
12	Cu (ppm)	15.5	15.0

Experimental design and tested treatments

The experiment distributed in a split plot in a randomized complete block design (RCBD) with three replicates was followed in this experiment. The main plots were farmyard manure rates (FM0=0, FM1=10, FM2=15, FM3=20 m^3/fed. and NPK at a half-recommended dose as follows; ammonium nitrate (33.5%) at 150 kg/fed., calcium super phosphate (15.5% P_2O_5) at 200 kg/fed. and potassium sulfate (48% K_2O) at 37.5 kg/fed.). Bio-fertilizers treatments (control, *Azospirillum chroococcum*, *Bacillus megatherium* var. *phosphaticum*, *Bacillus circulans* and/or arbuscular mycorrhizal fungi were assigned as sub-plot. Coriander seeds were sown on 5th November of both seasons.

The experimental unit area (plot) was (12 m^2) and contained 5 rows, each row 4 m in length and 0.6 m in width. The planting distance between plants was 30 cm. After 35 days from sowing, the plants were thinned to two plants per hill. Before cultivation, coriander seeds were treated for one-hour by immersion in the solution of bacteria, while fungi of arbuscular mycorrhizal which contains three effective strains *Glomus intraradices*, *Glomus etunicatum* and *Glomus fasciculatum* used to inoculate the soil.

All other agricultural practices were achieved as described by recommendation of the Ministry of Agriculture in Egypt. Data recorded in the first week of May, i.e., height of plant (cm), number of branches, fresh and dry weight (g), number of umbels per plant, yield of seed per plant (g), and yield of seed per fed. (kg). In addition to volatile oil (%), yield of volatile oil per plant (ml), and yield of volatile oil per fed. (l) were calculated.

Mineral fertilizers were added four times at three-week intervals, stated 35 days after cultivation. Mature farmyard manure was added and mixed with the soil before sowing during preparing the soil for cultivation.

Essential oil (EO) extracting

Coriander seeds were taken from each treatment in both seasons and weighed for essential oil extraction; Then 100 g from each treatment of all transactions Hydro Distillation (HD) for 3 hours by a Clevenger-type apparatus according to Clevenger (1928). The content of EO was recorded as a relative percentage (v/w). The total EO where ml/100 plant was calculated using dry weight. The extracted EOs were collected from *Coriandrum sativum* during the two seasons of each treatment and dried by anhydrous sodium sulfate for chemical determination.

Essential oil (EO) percentage

Volatile oil or essential oil in seeds as extracted using the HD method according of Miller (1963) and British Pharmacopoeia using the following equation:

The percentage of volatile oil = (oil volume in the graduated tube/weight of sample) × 100.

Fifty grams of each sample was milled (before distillation) and placed immediately in unit of extraction. The percentage volatile oil was determined and yield of oil per plant and feddan was considered. Volatile oil was dried by anhydrous sodium sulfate then the oil was stored in dark and cool conditions until GC-MS analysis.

Gas chromatography-mass spectrometry (GC-MS) analysis

Analysis of some samples was carried out by gas chromatography (Agilent 8890 GC System), coupled to a mass spectrometer (Agilent 5977B GC/MSD) and equipped with an HP-5MS column of fused silica capillary (30 m, 0.25 mm i.e., 0.25 mm thickness of film). Oven temperatures was sustained initially at 50 °C, and programmed from 50 to 220°C at 5°C/min and from 220°C to 280°C at 20°C/min, and then held for 5 min at 280°C.

Helium was used as the carrier of gas, at a flow rate of 1.0 mL/min. Essential oils were dissolved in diethyl ether (30 µL of EO/mL of diethyl ether), then 1 µL of solution was injected into the GC with a split ratio 1:50. Injection temperature was 230 °C. Spectra of mass in the electron impact mode (EI) were obtained at 70 eV and scan m/z range from 39 to 500 am. The peaks of isolations were identified by matching them with data from the library of mass spectra (National Institute of Standards and Technology, NIST).

Statistical analysis

All obtained data were tabulated and analyzed according to Nissen (1983) and the means were compared using L.S.D. test at 5% according to Mead and Drasgow (1993).

RESULTS AND DISCUSSION

Growth parameters

The results in Table (3) illustrated that the height of plant, number of branches per plant, fresh and dry weight of shoot (g) were significantly influenced by farmyard manure treatments in both seasons. These results appear that the fertilization of plants with farmyard manure at all levels, plus the half-recommended dose of NPK recorded a significant increase in the height of plant, number of branches per plant, and fresh and dry weight of shoot compared to untreated coriander plants in the two growing seasons. Also, it is noticed that a high rate of farmyard manure (20 m^3/fed.) gave the highest values for all traits, whereas increased height of plant, number of branches per plant and fresh and dry weight of shoot per plant by 71.75 and 57.95, 119.60 and 203.96, 34.94 and 26.77 and 36.53 and 23.17 % over untreated plants in both seasons, respectively.

These results agree with the observations of Hassan et al. (2009) on black cumin, Hassan (2015) on dill, and Khalil et al. (2018) on caraway plants, which investigated the role of some natural fertilizers in enhancing growth. This might be due to the property of nitrogen to promoting the growth and the plant capacity to utilize more nitrogen amount. These results were confirmed Rao et al. (1983), Singh and Goswami (1996) and Bhaskar et al. (1996).

Furthermore, phosphorus might have resulted due to better moisture availability and nutrients which resulted in increasing growth due to better phosphorus availability. These results were confirmed by Das et al. (1991) on coriander. Likewise, NPK fertilizer plays important roles in many processes of physiology in the plant (Lambers et al., 2008). These effects were detected in yield components and production of volatile oil in the two seasons. Besides the effect of farmyard manure enhances the vegetative growth and yield of coriander (Lal et al., 2019).

Regarding the effect of bacteria and arbuscular mycorrhizal fungi mixture treatments, the presented data in Table (3) illustrated that height of plant, number of branches per plant, fresh and dry weight shoot of coriander (*Coriandrum sativum* L.) were significantly increased compared to untreated ones in both seasons under study. The inoculated coriander seeds with bacteria plus arbuscular mycorrhizal fungi recorded the highest values of plant height, branches number, fresh and dry weight of coriander ranging from 14.47 and 15.59, 93.00 and 47.31, 9.64 and 9.23 and 41.03 and 36.99 % over untreated plants in both seasons, respectively.

Effects of biofertilizers on promoting plant growth were noticed by Ghallab and El-Gahdban (2004) on marjoram (*Origanum majorana*), El-Hindi and El-Boraie (2005), Leithy et al. (2006) and Abdullah et al. (2012) on rosemary, Gharib et al. (2008) on marjoram (*Majorana hortensis*), Hendawy et al. (2010) on *Thymus vulgaris*, Mahdi et al. (2012) and Ali and Hassan (2014) on black cumin plants. Concerning the interaction between farmyard manure and mixed bacteria and arbuscular mycorrhizal fungi treatments, results showed a significant effect on dry weight of shoot in both growing seasons.

These results indicated that the most effective treatments were due to the high farmyard manure rate (20 m^3/fed.) plus a mixture of bacteria with arbuscular mycorrhizal fungi compared to control treatments. On the other hand, the interaction between two factors is significant for height of plant and branches number of plant during two seasons (Table 3). Karagiannidis et al. (2011) reported that inoculated plants with arbuscular mycorrhizal fungi (AMF) reflect an increase in nitrogen, phosphate and micronutrients in the plants and enhanced biomass. According to Rajan et al. (2000), the benefit of AMF attributed to increase the secondary metabolites of plants. Also, growth and active compounds were improved (Toussaint et al., 2007; Smith and Read, 2010; Zubek et al., 2009).

Table (3): Effect of farmyard manure (FM) and inoculation seeds with bacteria mix (BM) and mycorrhizal fungi (MF) on the growth of coriander plants during the 2020/2021 and 2021/2022 growing seasons

FM (A)	Bio-fertilizers (B)									
	Plant height (cm)									
	Control	BM	MF	BM+MF	Mean (A)	Control	BM	MF	BM+MF	Mean (A)
	First season					Second season				
Control	42.12	45.15	44.18	46.27	44.43	44.12	47.15	50.18	53.27	48.68
NPK $_{HRD}$	65.15	69.41	68.44	72.48	68.87	67.15	70.41	73.44	76.48	71.87
FM (1)	51.63	54.55	57.52	61.84	56.39	52.63	55.55	58.52	61.84	57.14
FM (2)	56.41	59.30	62.51	66.30	61.13	56.41	59.30	59.51	62.30	59.38
FM (3)	71.49	74.70	77.66	81.40	76.31	71.49	74.70	77.99	83.40	76.89
Mean (B)	57.36	60.62	62.06	65.66		58.36	61.42	63.93	67.46	
L.S.D $_{0.05}$	A:0.25 B:0.25 AB:0.55					A:0.24 B:0.26 AB:0.57				
	Number of branches/plant									
Control	5.083	8.155	8.693	12.33	8.57	6.081	9.157	9.69	12.33	9.317
NPK $_{HRD}$	10.08	13.16	16.69	19.33	14.82	21.08	24.15	24.69	27.33	24.32
FM (1)	7.085	10.16	10.69	14.33	10.57	9.085	12.16	12.69	15.33	12.32
FM (2)	9.086	12.16	15.69	18.33	13.82	11.08	14.16	17.69	20.33	15.82
FM (3)	14.09	17.16	20.69	23.33	18.82	25.08	28.16	28.69	31.33	28.32
Mean (B)	9.083	12.16	14.49	17.53		14.48	17.56	18.69	21.33	
L.S.D $_{0.05}$	A:0.12 B:0.16 AB:0.30					A:0.21 B:0.22 AB:0.48				
	Plant fresh weight (g)									
Control	81.44	84.33	87.37	90.41	85.89	85.40	88.30	91.34	94.41	89.85
NPK $_{HRD}$	101.4	105.33	108.37	111.4	106.64	102.4	105.3	108.35	111.4	106.9
FM (1)	89.44	92.33	95.37	98.41	93.89	91.42	94.32	97.36	100.4	95.87
FM (2)	91.44	94.33	97.37	100.4	95.89	96.43	99.33	102.4	105.4	100.9
FM (3)	111.4	114.3	117.4	120.4	115.9	109.4	112.3	115.4	118.45	113.9
Mean (B)	95.04	98.13	101.17	104.2		97.04	99.93	103.0	106.0	
L.S.D $_{0.05}$	A:0.46 B:0.06 AB:0.12					A:0.52 B:0.06 AB:0.12				
	Plant dry weight (g)									
Control	17.41	20.33	23.403	26.44	21.90	21.40	24.33	27.40	30.43	25.90
NPK $_{HRD}$	23.41	26.33	29.403	32.44	27.90	25.40	28.33	31.40	34.44	29.90
FM (1)	21.41	24.33	27.403	30.44	25.90	23.40	26.34	29.41	32.44	27.90
FM (2)	22.41	25.33	28.403	31.44	26.90	24.41	27.40	30.41	33.44	28.90
FM (3)	25.41	28.33	31.403	34.44	29.90	27.41	30.34	33.47	36.44	31.90
Mean (B)	22.01	24.93	28.003	31.04		24.41	27.33	30.40	33.44	
L.S.D $_{0.05}$	A:0.42 B:0.54 AB:1.13					A:0.29 B:0.35 AB:0.68				

NPK (HRD): mineral fertilizers at a half-recommended dose. FM (1): farmyard manure at 10 m^3/fed. FM (2): farmyard manure at 15 m^3/fed. FM (3): farmyard manure at 20 m^3/fed. BM: bacteria mix *A. chroococcum*, *B. megatherium* var. *Phosphaticum* and *B. circulans*. MF: mycorrhizal fungi.

Seed yield parameters

The presented data in Table (4) showed that the main effects of FM and half-recommended dose of NPK fertilizer treatments during both seasons on the umbels number, plant seed yield and seed yield per feddan of coriander plants were significant. The obtained results showed that the increasing FM fertilization (20 m^3/fed.) of coriander resulted in a significant increase in umbels number, yield of seed per plant and yield of seed per feddan. The maximum values of umbels number per plant, yield of seed per plant, and yield of seed per feddan were observed when plants received high rate of FM; the values were ranged 62.02 and 135.31, 102.53 and 65.28 and 102.55 and 65.24% over control in both seasons, respectively.

Table (4): Effect of farmyard manure (FM) and inoculation seeds with bacteria mix (BM) and mycorrhizal fungi (MF) on the seed yield of coriander plants during the 2020/2021 and 2021/2022 growing seasons

FM (A)	Bio-fertilizers (B)									
	Number of umbels/plant									
	Control	BM	MF	BM+MF	Mean (A)	Control	BM	MF	BM+MF	Mean (A)
	First season					Second season				
Control	13.08	16.66	19.55	23.26	18.14	9.08	11.66	11.55	14.26	11.64
NPK HRD	24.08	27.66	27.55	30.26	27.39	21.08	24.66	24.55	27.26	24.39
FM (1)	18.08	21.66	21.55	24.26	21.39	16.08	19.66	19.56	22.27	19.39
FM (2)	21.08	24.66	24.55	27.26	24.39	19.08	22.66	22.56	25.27	22.39
FM (3)	26.08	29.66	29.55	32.26	29.39	24.08	27.66	27.56	30.27	27.39
Mean (B)	20.48	24.06	24.55	27.46		17.88	21.26	21.15	23.86	
L.S.D 0.05	A:1.09 B:0.43 AB:1:37					A:0.36 B:0.40 AB:0.85				
	Seed yield/plant (g)									
Control	8.163	11.48	11.81	14.37	11.46	6.165	9.482	10.82	13.37	9.959
NPK HRD	18.16	21.48	21.81	24.37	21.46	11.17	14.48	14.82	17.37	14.46
FM (1)	13.17	16.48	16.81	19.37	16.46	8.167	11.48	12.82	15.37	11.96
FM (2)	14.17	17.49	17.82	20.37	17.46	9.168	13.49	13.82	16.37	13.21
FM (3)	20.17	23.49	23.82	25.37	23.21	13.17	16.49	16.82	19.37	16.46
Mean (B)	14.77	18.08	18.41	20.77		9.568	13.08	13.82	16.37	
L.S.D 0.05	A:0.44 B:0.27 AB:0.68					A:0.92 B:0.19 AB:0.37				
	Seed yield/fed. (kg)									
Control	326.7	459.3	472.5	574.8	458.3	246.73	379.27	432.6	534.8	398.4
NPK HRD	726.7	859.3	872.5	974.8	858.3	446.7	579.3	592.6	694.8	578.4
FM (1)	526.7	659.3	672.5	761.5	655.0	326.8	459.3	512.6	614.8	478.4
FM (2)	566.7	699.3	712.5	814.8	698.3	366.8	539.2	552.6	654.8	528.4
FM (3)	806.7	939.3	952.5	1014.8	928.3	526.8	659.2	672.5	774.8	658.3
Mean (B)	590.7	723.3	736.5	828.1		382.7	523.3	552.6	654.8	
L.S.D 0.05	A:17.53 B:10.80 AB:27.25					A:0.04 B:7.57 AB:14.66				

NPK (HRD): mineral fertilizers at a half-recommended dose. FM (1): farmyard manure at 10 m^3/fed. FM (2): farmyard manure at 15 m^3/fed. FM (3): farmyard manure at 20 m^3/fed. BM: bacteria mix *A. chroococcum*, *B. megatherium* var. *Phosphaticum* and *B. circulans*. MF: mycorrhizal fungi.

Many researchers found beneficial effects for some natural fertilizers on components of yield on several plants such as black cumin, dill and caraway (Hassan et al., 2009; Hassan, 2015 and Khalil et al., 2018, respectively). Bio-fertilizers like mycorrhiza plus fixing nitrogen bacteria increased water and elements uptake rate from the soil by plants. Migahed et al. (2004) and Tehlan et al. (2004) showed that the umbels number increased significantly by using bio-fertilizers (*Azotobacter* and *Azospirillum*) for celery (*Apium graveolens*) and fennel (*Foeniculum vulgare*) plants.

All mixed bacteria and arbuscular mycorrhizal fungi treatments gave a significant increase in umbels number, seed yield per plant, and total seed yield per feddan in both seasons. The highest umbels number, seed yield per plant, and total yield of seed per feddan attributed to treating coriander with a mixture of bacteria and arbuscular mycorrhizal fungi, which increased these traits over control by 34.08 and 33.45, 40.62 and 71.09 and 40.19 and 71.10 % in both seasons, respectively (Table 4).

Volatile oil yield

Data in Table (5) discovered that the percentage of volatile oil, yield of volatile oil per plant, and yield of volatile oil per feddan of coriander plants were significantly influenced by FM and half-recommended dose of NPK fertilizer treatments in both seasons. Fertilization of coriander plants with FM at rate (20 m^3/fed.) recorded a significant increase in the percentage volatile oil in both seasons. Farmyard manure at rate (20 m^3/fed.) gave the highest values in percentage of volatile oil, yield of volatile oil per plant, and yield of volatile oil per feddan by 141.57 and 112.20, 380.95 and 242.86, 372.37 and 239.11 % over control in the first and second seasons, respectively. Regarding the effect of mixture of bacteria and arbuscular mycorrhizal fungi treatments. The presented data in Table (5) illustrated that yield of volatile oil per plant and yield of volatile oil per feddan of coriander plants were significantly enhanced compared with untreated ones in both seasons.

The percentage of volatile oil, yield of volatile oil per plant and yield of volatile oil per feddan were 58.08 and 30.43, 3.95 and 110.34, 110.05 and 113.06 % in both seasons, respectively, when coriander plants were treated with bacteria plus arbuscular mycorrhizal fungi. The interaction effects between FM and mixture of bacteria and arbuscular mycorrhizal fungi treatments had a significant effect on the percentage of volatile oil, yield of volatile oil per plant, and yield of volatile oil per feddan of coriander plants in both seasons. The results indicate that FM (20 m^3/fed.) is the most effective treatment was obtained when combined with a mixed of bacteria and arbuscular mycorrhizal fungi compared to control treatments during both seasons (Table 5). Meanwhile, promoting growth and production by arbuscular mycorrhizal fungi might be attributed to the increase of available nitrogen in soil, as a result to fix the nitrogen atmospheric and increasing the metabolites formation which heartens the plant growth (Sprent and Sprent, 1990). Phosphorein increases phosphorus uptake in volatile oil, both in percentage and yield (Abdalla, 2009).

Essential oil (EO) components

The results of the GC/MS chromatography analysis of coriander oil, which were obtained from the study, prove that it consists of (17) compounds and shows in Table (6), which illustrated chemical compounds of the pilot oil in the dry coriander seeds under the conditions of the study. When comparing the values of the chemical vehicles of the oil, we notice the distinction of linalool, γ-Terpinene, α-Pinene, p-Cymene, geranyl acetate with the highest rates of pilot oil compounds compared to other vehicles. The highest average of linalool (67.77) was at treatment FM (2) + BM + MF, upon treatment NPK (HRD) + BM + MF. While the highest proportions of the p-Cymene (4.75) for control treatment, and the highest proportions of the geranyl acetate (7.39) were recorded for treatment FM (2) + BM + MF.

Table (5): Effect of farmyard manure (FM) and inoculation seeds with bacteria mix (BM) and mycorrhizal fungi (MF) on the volatile oil yield of coriander seeds with the plant during the 2020/2021 and 2021/2022 growing seasons

FM (A)	Bio-fertilizers (B)									
	Volatile oil (%)									
	Control	BM	MF	BM+MF	Mean (A)	Control	BM	MF	BM+MF	Mean (A)
	First season					Second season				
Control	0.120	0.160	0.190	0.240	0.178	0.160	0.190	0.220	0.250	0.205
NPK_{HRD}	0.320	0.370	0.400	0.460	0.388	0.360	0.390	0.420	0.450	0.405
FM (1)	0.160	0.210	0.240	0.290	0.226	0.210	0.240	0.190	0.270	0.228
FM (2)	0.183	0.250	0.280	0.310	0.256	0.260	0.290	0.320	0.350	0.305
FM (3)	0.360	0.410	0.440	0.510	0.430	0.390	0.420	0.450	0.480	0.435
Mean (B)	0.229	0.280	0.310	0.362		0.276	0.306	0.320	0.360	
$L.S.D_{0.05}$	A:0.243 B:0.193 AB:0.444					A:0.211 B:0.167 AB:0.385				
	Volatile oil yield/plant (ml)									
Control	0.010	0.019	0.023	0.034	0.021	0.010	0.018	0.024	0.034	0.021
NPK_{HRD}	0.248	0.079	0.087	0.112	0.132	0.040	0.057	0.062	0.078	0.059
FM (1)	0.021	0.035	0.040	0.055	0.038	0.017	0.028	0.024	0.042	0.028
FM (2)	0.026	0.044	0.050	0.063	0.046	0.024	0.039	0.044	0.057	0.041
FM (3)	0.073	0.096	0.105	0.129	0.101	0.051	0.069	0.076	0.093	0.072
Mean (B)	0.076	0.055	0.061	0.079		0.029	0.042	0.046	0.061	
$L.S.D_{0.05}$	A:0.071 B:0.054 AB:0.059					A:0.034 B:0.042 AB:0.030				
	Volatile oil yield/fed. (l)									
Control	0.393	0.739	0.901	1.383	0.854	0.397	0.724	0.956	1.341	0.854
NPK_{HRD}	2.327	3.183	3.492	4.485	3.372	1.611	2.263	2.492	3.130	2.374
FM (1)	0.845	1.388	1.618	2.211	1.515	0.689	1.106	0.975	1.664	1.109
FM (2)	1.044	1.752	1.999	2.529	1.831	0.953	1.568	1.772	2.296	1.647
FM (3)	2.907	3.855	4.195	5.179	4.034	2.057	2.773	3.029	3.723	2.896
Mean (B)	1.503	2.183	2.441	3.157		1.141	1.687	1.845	2.431	
$L.S.D_{0.05}$	A:0.061 B:0.025 AB:0.078					A:0.051 B:0.021 AB:0.065				

NPK (HRD): mineral fertilizers at a half-recommended dose. FM (1): farmyard manure at 10 m^3/fed. FM (2): farmyard manure at 15 m^3/fed. FM (3): farmyard manure at 20 m^3/fed. BM: bacteria mix *A. chroococcum*, *B. megatherium* var. *Phosphaticum* and *B. circulans*. MF: mycorrhizal fungi.

This shows the clear effect of transactions in increasing the proportions of some of the main compounds of coriander oil. Also, transactions have a clear impact on some vehicles, and this corresponds to Mahfouz and Sharaf-Eldin (2007), and Msaada et al. (2007), where they found an increase in the percentage of oil and the proportions between the types of fertilization and its reflection on providing all the elements of the plant, and this result is compatible with what the researcher (Mahfouz and Sharaf-Eldin, 2007) that fertilization is the latest increase in vehicles in the fennel plant. Mahfouz and Sharaf-Eldin (2007) found that the effect of nitrogen-fixing bacteria on the beta-pinene was due to increase uptake of nitrogen and improvement of growth. Besides cattle manure increased the limonene in EO, also, more production of biomass and promotion of flowering resulted in an increase of limonene. These results are following the reports of Ateia et al. (2009) on *Thymus vulgaris*, Osman (2009) on fennel, and Biasi et al. (2009) on *Ocimum basilicum*. Likewise, several researches revealed that interaction between bio-fertilizers and organic manures resulted in improving some components of EO (Harshavardhan et al., 2007; Padmapriya and Chezhyian, 2009). The interaction between two factors on EO content of camphor is highly depends on the effect of organic matter content in cattle manure on nitrogen-fixing bacteria activity such as *Azotobacter*.

Table (6): The interaction effects of farmyard manure (FM) and some bio-fertilizers on essential oil (EO) components of coriander seeds as the average of two growing seasons

No.	Compound	RT	Treatments			
			Control	**FM (3) +BM+MF**	**FM (2) +BM+MF**	**NPK HRD +BM+MF**
1	α-Pinene	6.37	3.61	6.29	4.17	6.16
2	β-Pinene	7.435	0.4	0.64	0.6	0.72
3	p-Cymene	8.676	4.75	4.57	4.29	4.3
4	D-Limonene	8.779	3.79	4.29	0.94	1.05
5	γ-Terpinene	9.603	7.62	9.69	11.33	11.45
6	Linalool	10.833	54.4	59.18	67.77	66.34
7	(+)-2-Bornanone	12.081	1.38	0.96	0.63	1.11
8	Terpinen-4-ol	12.985	0.47	--	--	0.56
9	Dill ether	13.225	0.55	--	--	--
10	Decanal	13.689	0.49	--	0.8	0.57
11	trans-Dihydrocarvone	13.746	0.49	--	--	--
12	(-)-Carvone	14.839	9.18	3.27		0.51
13	Geraniol	15.068	0.94	0.71	0.85	0.78
14	Piperitone	15.136	1.48	--	--	--
15	Geranyl acetate	18.467	5.32	5.58	7.39	5.97
16	2-Dodecenal	20.555	--	--	0.65	--
17	Apiol	24.4	5.15	4.82	0.59	--
Number of identified compounds			16	11	12	12
Total % of identified compounds			100	100	100	99.52

NPK (HRD): mineral fertilizers at a half-recommended dose. FM (1): farmyard manure at 10 m^3/fed. FM (2): farmyard manure at 15 m^3/fed. FM (3): farmyard manure at 20 m^3/fed. BM: bacteria mix *A. chroococcum, B. megatherium* var. *Phosphaticum* and *B. circulans*. MF: mycorrhizal fungi.

CONCLUSION

Conclusively, the results of the current study on coriander plants found that the combination of FM at a high rate (20 m^3/fed.) plus inoculation of seeds by mixed bacteria and mycorrhizal fungi enhanced growth, yield of seeds, production of volatile oil, and percentages of the main components of volatile oil compared to untreated plants, in addition to reducing environmental pollution.

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استجابة نباتات الكزبرة لبعض معاملات التسميد العضوي والحيوي

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الملخص العربي

تم إجراء هذه التجربة البحثية خلال موسمي 2021/2020 و2022/2021م بهدف دراسة تأثير التسميد العضوي بمعدل (صفر، 10، 15، 20 م^3/فدان)، ونصف الجرعة الموصى بها من السماد المعدني، والتسميد الحيوي (تلقيح البذور) بخليط من (البكتيريا المثبتة للنيتروجين والبكتيريا الميسرة للفوسفور والبكتيريا الميسرة للبوتاسيوم) مع أو بدون فطر الميكروهيزا، بالإضافة إلى التفاعلات فيما بينها على النمو والمحصول والزيت الطيار في نبات الكزبرة. أظهرت النتائج زيادة في صفات النمو الخضري مثل طول النبات وعدد الأفرع والوزن الطازج والجاف للنبات، ومكونات المحصول مثل عدد النورات في النبات ومحصول البذور في النبات ومحصول البذور في الفدان، بالإضافة إلى إنتاجية الزيت الطيار. معاملة النباتات بالتسميد العضوي عند أعلى معدل أدى إلى تسجيل أعلى قيم لهذه الصفات المدروسة. أيضا إضافة خليط من (البكتيريا المثبتة للنيتروجين والبكتيريا الميسرة للفسفور والبكتيريا الميسرة للبوتاسيوم) مع فطر الميكروهيزا كان أكثر فاعلية في زيادة الصفات المدروسة. جميع الصفات المدروسة تأثرت معنويا بمعاملات التفاعل، وفي هذا الصدد أدى الجمع بين المعاملات إلى زيادة معنوية في جميع الصفات المدروسة. علاوة على ذلك فإن إضافة السماد العضوي عند أعلى معدل (20 م^3/فدان)، وتلقيح بذور الكزبرة بخليط من البكتيريا وفطر الميكروهيزا كانت أكثر المعاملات فعالية. كما تأثرت المكونات الرئيسية للزيت الطيار بإضافة الأسمدة العضوية والحيوية. بشكل عام، الجمع بين إضافة السماد العضوي عند أعلى معدل (20 م^3/فدان)، وتلقيح بذور الكزبرة بخليط من البكتيريا وفطر الميكروهيزا أدى إلى زيادة المكونات الرئيسية للزيت الطيار مقارنة بالنباتات الغير معاملة.

الكلمات المفتاحية:

التسميد العضوي، البكتيريا المثبتة للنيتروجين، البكتيريا الميسرة للفوسفور، البكتيريا الميسرة للبوتاسيوم، فطر الميكروهيزا، نبات الكزبرة.