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The combined effect of compost, *Pseudomonas monteilii* and *Bacillus subtilis* on growth, fruit yield, oil contents and its components of caraway (*Carum carvi* L.) plants

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Abstract

Field experiments were carried out during the 2021/2022 and 2022/2023 agricultural seasons to determine the impact of two important factors: compost levels 5.10 and 15 tons/ha and inoculation with the bacteria *Pseudomonas monteilii* and *Bacillus subtilis*, as well as the effect of the interaction between them on growth, fruit yield, volatile oil percentage and its components of Caraway (*Carum carvi* L.) plants. The results showed a significant increase in plant growth characteristics in of plant height, branches number, fresh & dry weight of plants, yield, i.e. number of umbels per plant, seed yield per plant (g) and hectare (kg), as well as volatile oil production. It was found that treating plants with a high level of compost (15 tons/ha) recorded the highest values for these parameters studied. also, adding *Pseudomonas monteilii* and *Bacillus subtilis* together proved effective in increasing the traits under this study. All treatments were significantly affected by the interaction treatments inbtween two factors under this study. In this regard, most combined treatments resulted in significant increases in all traits under study. High level of compost (12 ton/hectar) plus inoculation caraway plants by mixed with mixture bacteria *Pseudomonas monteilii* and *Bacillus subtilis* were the most effective treatments. The main chemecal components of volatile oil were also impacted by compost and biofertilizers applications. Fifteen components have been identified in the fragrance oil extracted from caraway seeds, which represent a percentage of the total chemecal constituents, and belong to a major group, namely hydrocarbons. The main components of the volatile oils in caraway seeds as detected by GC/MS were Carvone, D-Limonene, and cis-Anethole. Moreover, the highest value was obtained for the main components of the volatile oil from various compost (12 ton/hectar.) with seeds inoculated with *Pseudomonas monteilii* and *Bacillus subtilis* together compared to other combiend treatments.

Keywords: Caraway (*Carum carvi* L.), compost, *Pseudomonas monteilii* and *Bacillus subtilis*.

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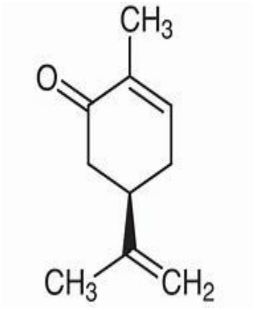
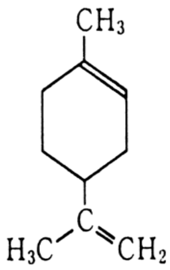
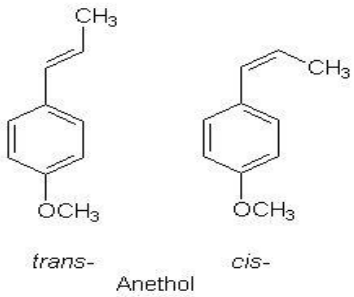
1. Introduction

Caraway (*Carum carvi* L.) is a significant medicinal and aromatic plant from the Apiaceae family. Carvone, limonene and Anethole are the two main components of the 4-8% essential oil found in dried fruit. [1]. Flavonoids, sugars, organic acids, mineral salts, coumarin derivatives, and other chemicals are also found in caraway seeds, along with nitrogen compounds (25–35%), lipids (13-21%), fiber (13–19%), fatty oil (up to 22%), water (9–13%), and protein compounds (up to 25%). [2,3].







Carvone **D-Limonene** **Anethol**

The main compounds of caraway volatile oil

Caraway plants grow to a height of 50 to 80 cm, have feathery, damaged leaves, and tiny white flowers in tent-shaped inflorescences that first appear in February and March and ripen in May. They reproduce by seed (fruits). The usage of seeds to impart a distinctive flavor and scent to foods like meat products, pies, biscuits, and bread has made caraway germs important both economically and medically [4,5]. The Caraway seeds are traditionally used as a treatment for dyspepsia, intestinal colic, and antispasmodic issues. They also add a nice flavor to dishes and are used as a spice [6]. Also the seeds are used as a hot drink to alleviate stomach cramps and intestinal cramps and as a repellant of gases for children. Limonine [7,8]. In organic farming, natural organic additions such as manure and processed bio-fertilizers are natural sources of critical plant nutrients. Organic fertilization has numerous advantages, including enhancing soil health, sustaining soil fertility by compensating for organic matter loss, decreasing environmental damage without reducing productivity, and attaining sustainable agricultural production [9]. The utilization of organic manures is crucial for optimizing the yield and quality of medicinal and aromatic plants. Moreover, the application of organic manures offers a safe and environmentally friendly approach, ensuring the well-being of both human health and the surrounding ecosystem. The method involves the regulated recycling of organic materials, such as plant and animal waste. The long-term application of inorganic fertilizer has a detrimental impact on soil structure. Therefore, it has been suggested by [10 that organic manures can be utilized as a viable substitute for mineral fertilizers in order to enhance soil structure and microbial biomass. In recent times, a variety of fertilizers, including compost, have been extensively employed in different regions globally.

Pseudomonas spp. They are adapted to survive in soil and are found in colonies around plant roots. Bacterial inoculants have been used in agriculture in the form of fertilizers and in the field of biological control and plant growth stimulating rhizobacteria (PGPR). (PGPR) [11,12] Fluorescent *Pseudomonas* spp it is one of the groups of root bacteria most affected by reducing the proportion of diseases transmitted from infected soil [13,14]**.** The infection rate of the disease was low, despite the presence of pathogens and environmental conditions conducive to the spread of the disease. Strains of Pseudomonas spp. Promoting seed germination, and the development of sprouts and roots for plants of all kinds. Some strains have superior ability to combat fungal diseases by secreting hydrogen cyanide and antibiotics. Several methods of action with antagonistic PGPR have been reported, e.g., Pseudomonas spp. producing many antimicrobial compounds as well as stimulating plant defense mechanisms [15,16,17]. *Bacillus subtilis* is a common plant growth promoting rhizobacteria (PGPR) in soil and has a major role in plant tolerance to biotic and abiotic stress via induced systemic resistance (ISR), biofilm formation, and lip peptide production. As an important part of bioremediation techniques, *Bacillus* spp. It can purify soil contaminated with heavy metals. It acts as a powerful denitrifying agent in agricultural ecosystems while improving carbon sequestration when applied at regulated concentration. Although it contains many antibiotic resistance genes (ARGs), it can reduce the horizontal transfer of ARGs during composting by modifying the genetic structure of existing probiotic microbes. Soil texture, type, pH, and bacterial concentration play an important role in regulating all of these vital processes. Complex interactions between microbes and plants can be deciphered using transcriptomics, proteomics, and metabolomics that may be beneficial for both crop productivity and the well-being of soil microorganisms. Plant growth is improved by PGPR through the induction of systemic resistance, antibiosis, and competitive elimination. Thus, microbial application can be used to induce systemic resistance in plants against biotic agents and enhance environmental stress tolerance. [18,19].

2. Materials and Methods

This experiment was conducted at the Farm of Faculty of Agriculture, Al-Azhar University, Assiut, Egypt, throughout the two successive seasons of 2021/2022 and 2022/2023 in order to improve the growth and production of the dill plant. The experiment included two factors: the first was rates of compost and the second was two types of microbial inoculants, as well as, their interactions.

2.1. Experimental Design

The experimental design of this study was a split-plot with three replicates, using a randomized complete blocks design (RCBD), compost (four levels) occupied the main plot and types of microbial inoculants (four treatments) as the sub-plots. There form the interaction treatments were 16 treatments.

2.2. Material and Culture of Plants

Caraway seeds were obtained from the Agricultural Research Centre of the Department of Medicinal and Aromatic Plants in Dokky, Giza, Egypt. On November 7 th, during the two seasons, these fruits were immediately sown in the plot 3 x 3 meters made up the experimental unit area. Each experimental unit had five rows that were each 3 meters long, 60 cm separated the ridges, while 30 cm apart in the hills. Each hill received about 5-6 fruits, which were subsequently thinned to 2 plants/ hill. As a result, the experimental unit included 72 plants. Compost were obtained from El-Ahram Company for Mining and Natural Fertilizers Maadi, Cairo, Egypt. The physical and chemical properties of the experimental soil are tabulated in Table, 1 as reported by [20].

Table1: Physical and chemical properties of the experimental soil

Soil character	Values	Soil character	Values
Soil texture	Clay loam	**Total N%**	0.13
Sand %	23.50	**Available P(ppm)**	0.15
Silt %	40.10	**Available K (mg/100g soil)**	3.6
Clay %	36.40	**Soluble Ions (meq/L)**	
Organic matter %	0.59	**Ca**	3.5
Caco3 %	2.49	**Mg**	1.7
PH (1:2.5)	7.9	**Cl**	2.1
E.C (m.mohs/cm)	2.4	**So4**	6.3
		Co_{3}+Hco_{3}	2.7

2.3. Rates and method of adding compost and microbial inoculants

The compost levels used in this study are 0, 5, 10 and 15 tons/ha. They were added while preparing the soil for planting, in the two agricultural seasons. The physical and chemical characteristics of the compost used are shown in Table (2).

2.4. Bacterial strains used

Both local *Pseudomonas monteilii* and *Bacillus subtilis* bacterial strains were kindly provided by Microbiology Department, Soils, Water and Environment, Research Institute (ARC), Giza, Egypt where both strains were isolated, purified and identified as mentioned by [21]. The biofertilization with bacterial strains developed on plant based culture media temperature 30 °C for 24 - 48 hours.

Table 2: Some chemical characteristics of compost

Content	PH	EC (1:2.5) (d^S/m)	O M %	O C %	C : N Ratio	Total N %	Total P %	Total K%	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Value	7.79	2.78	38.35	19.1	12.1	1.22	1.26	1.08	2344	2.39	45	14

3.5. Sampling and Data Collection

Three plants were randomly selected from each experimental plot 95 days after planting caraway seeds to study the following traits: plant height (cm), number of branches/plant, and weight of fresh and dry grass, g/plant. When harvesting in the second week of April for both seasons, the following data were recorded: umbels number /plant, fruit productivity (grams/plant), fruit productivity (kg/ha) and percentage of volatile oil in the fruits, then the volatile oil yield (ml) was calculated. /plant) by multiplying the percentage of volatile oil by the fruit yield (g) of plant, and then the volatile oil yield (liters/ha) was calculated.

3.6. Volatile oil isolate

Seeds were collected from each treatment during two experimental seasons and weighed for Volatile oil extraction; then 100 g from each repeat of all transactions, Hydro distillation (HD) for 3 hours using a Clevenger type Apparatus [22]. VO content was calculated as relative percentage (v/w). In addition, the total VO where ml/100 plants were calculated using dry weight. The extracted VOs was collected from Caraway (*Carum carvi* L.) plants during the two successive seasons of each treatment and dried Anhydrous Sodium Sulfate for Chemical Determination voters. All data obtained during this study were arranged, recorded, and statistically analyzed according to [23] using the LSD test at 5% to know the differences among all treatments according to [24].

3. Results and Discussion

3.1. Growth measurements

The data obtained in Table 3 showed that plant height (cm), number of branches/plant, and weight of fresh and dry grass (g/plant) of caraway (*Carum carvi* L.) plants were significantly affected by fertilizer treatments in the two growing seasons. It appears that fertilizing plants with compost at all levels resulted in a significant increase in all growth characteristics (plant height, number of branches/plant, and weight of fresh and dry grass) compared to untreated plants in both seasons. From the recorded data, it is clear that the use of a high level of compost (15 tons/ha.) gave the highest values for these characteristics. The positive effect of organic fertilizer in enhancing growth characteristics has been recorded by [25] on *Carum carvi*, [26, 27 and 28] on *Coriandrum sativum* L. plant, [29] on fennel, [30] on dill**,** [31] on Khella and [32] on Black Cumin (*Nigella Sativa* L.) Plants. Regarding the effect of microbial inoculation with bacteria *Pseudomonas monteilii* and *Bacillus subtilis*, the measurements presented in Table (3) showed that the plant length (cm), branches number /plant, and weight of fresh and dry herbs (g/plant) of the caraway plant (*Carum carvi* L.) were statistically significant. Affected by inoculation with these inoculants in the two consecutive seasons. Obviously, the double inoculation of the two strains used significantly increased all the growth traits, it was found that inoculation of caraway plants with *Pseudomonas monteilii* and Bacillus *subtilis* in combination the best results for the growth characteristics that were taken. The response of many plants to organic fertilization and its effect on growth parameters has been observed by [33] on Caraway (*Carum carvi* L.) Plants, [34,35,30] on dill (*Anethum graveolens* L.) plants, [28] on *Coriandrum sativum* L. and [31] on Khella (*Ammi visnaga* L.) plants. The interaction between bio straw manure and microbial inoculant treatments, it had a significant effect on the all growth parameters of Caraway (*Carum carvi* L.) plants in two successive seasons. The data received showed that using compost at the level (15 tons/ha) was effective plus a mixture of inoculation by two bacterial strains as compared to other combination treatments, during the two seasons, as clearly shown in Table (3).

Table 3: Effect of compost, microbial inoculants and their interaction on growth of Caraway (*Carum carvi* L.) plants during the 2021\2022 and 2022/2023 seasons

Compost levels (A)	Microbial inoculants (B)									
	First Season					Second Season				
	Control	B1	B2	B1+B2	Mean	Control	B1	B2	B1+B2	Mean
Plant height										
Control	87.0	94.7	96.7	101.3	94.9	89.7	99.3	101.0	105.7	98.9
Compost (1)	88.3	96.3	99.7	106.3	97.7	91.0	100.7	105.7	111.0	102.1
Compost (2)	91.3	98.3	103.3	108.7	100.4	93.3	102.7	108.0	115.0	104.8
Compost (3)	93.0	100.0	107.7	112.7	103.3	94.3	105.0	112.7	117.0	107.3
Mean	89.9	97.3	101.8	107.3		92.1	101.9	106.8	112.2	
L.S.D 0.05	A:2.68 B:3.53 AB:7.01					A:2.40 B:4.48 AB:8.97				
branches number/plants										
Control	25.3	29.0	34.7	41.7	32.7	27.0	32.7	38.0	46.3	36.0
Compost (1)	26.0	30.0	37.0	44.0	34.3	29.3	34.7	40.0	49.0	38.3
Compost (2)	28.7	33.0	38.0	48.0	36.9	32.0	36.7	42.0	52.7	40.8
Compost (3)	30.3	36.3	43.3	51.0	40.3	34.0	39.3	47.3	56.0	44.2
Mean	27.6	32.1	38.3	46.2		30.6	35.8	41.8	51.0	
L.S.D 0.05	A:1.84 B:1.83 AB:3.66					A:2.85 B:2.38 AB:4.76				
Herb fresh weight g/ plant										
Control	165.0	205.0	207.3	211.7	197.3	167.3	211.7	212.7	216.3	202.0
Compost (1)	167.0	207.7	210.7	213.7	199.8	169.7	214.3	215.7	219.3	204.8
Compost (2)	169.0	210.0	214.0	216.0	202.3	172.3	216.0	218.7	222.0	207.3
Compost (3)	171.0	212.0	219.3	221.3	205.9	174.3	218.3	224.7	227.3	211.2
Mean	168.0	208.7	212.8	215.7		170.9	215.1	217.9	221.3	
L.S.D 0.05	A:2.78 B:3.38 AB:6.75					A:3.79 B:2.41 AB:4.81				
Herb dry weight g/ plant										
Control	36.9	40.2	47.0	51.0	43.8	37.2	40.2	47.7	52.0	44.3
Compost (1)	38.0	41.0	48.3	53.0	45.1	39.8	42.8	50.0	54.2	46.7
Compost (2)	41.0	43.0	51.0	55.7	47.7	42.0	37.8	52.7	56.2	47.2
Compost (3)	42.0	44.0	53.3	56.7	49.0	43.0	45.5	55.3	57.2	50.3
Mean	39.5	42.0	49.9	54.1		40.5	41.6	51.4	54.9	
L.S.D 0.05	A:2.75 B:3.08 AB:6.16					A:2.05 B:2.39 AB:4.78				
B1 = *Pseudomonas monteilii* B2 = *Bacillus subtilis* Compost 1,2 and 3 = 5,10 and 15 ton/hectare										

3.2. Yield parameters

Data in Table 4 reveal the umbels number / plant, seed productivity per plant (g) and per hectare (kg) affected by the use of different rates of compost. The effect of using compost at all levels was significant in these aspects during the two agricultural seasons of the experiment. It is also clear that all levels of compost have led to a significant increase in productivity indicators, and the highest values for the umbels number / plant, fruit yield / plant (g) and /hectare (kg) were obtained when treating caraway plants with a high level of compost (15 tons/ha) during the two study seasons over the control. The effectiveness of organic manure on increasing yield parameters was revealed by [28] on *Coriandrum sativum* L., [36,31] on Khella plant, [35,34,30] on dill (*Anethum graveolens* L.)**,** [37,38] on *Nigella sativa* L. plants, [39] on fennel and [40] on dragon head plant. Concerning bacterial inoculant treatments on caraway (*Carum carvi* L.) plants, data in Table (4) showed that the influence on umbels number/ plant, seed yield (g)/ plant, and fruit yield (kg)/ hectare was significant in both seasons. From the obtained data, it is noticed that the highest umbels number per plant, fruit yield (g)/ plant, and fruit yield (kg)/ feddan were detected due to inoculating caraway plants with *Pseudomonas monteilii* + *Bacillus subtilis* together. The positive effect of bio fertilization on improving yield measurements was observed by [33] on Caraway (*Carum carvi* L.), [28] on *Coriandrum sativum* L. [37] on black cumin (*Nigella sativa* L.) plants, [41] on *Thymus vulgaris* plants and [42 and 43] on rosemary (*Rosmarinus officinalis* L.) plants [30] on dill (*Anethum graveolens* L.) plants and [31] on Khella (*Ammi visnaga* L.) plants. According the interaction between NPK fertilizer, bio straw manure and microbial inoculant treatments, it had a significant effect on the all yield parameters of caraway (*Carum carvi* L.) plants in both seasons. Data indicated that the most effective treatments were obtained due to the high level of compost (15 ton/hectar) plus a mixture of the inoculation by *Pseudomonas monteilii* and Bacillus *subtilis* strains as compared to other combination treatments, during the both experimental seasons, as clearly shown in Table (4).

Table 4: Effect of compost, microbial inoculants and their interaction on yield parameters of Caraway (*Carum carvi* L.) plants during the 2021\2022 and 2022/2023 seasons

Compost levels (A)	Microbial inoculants (B)									
	First Season					Second Season				
	Control	B1	B2	B1+B2	Mean	Control	B1	B2	B1+B2	Mean
Umbels number/plant										
Control	51.7	61.7	69.7	74.7	64.4	53.0	62.7	71.7	78.3	66.4
Compost (1)	53.0	63.0	72.0	77.7	66.4	55.0	65.0	74.7	80.7	68.8
Compost (2)	54.0	64.0	72.7	79.7	67.6	56.0	66.0	75.7	83.0	70.2
Compost (3)	56.3	67.0	75.3	84.0	70.7	58.3	69.7	78.0	87.0	73.3
Mean	53.8	63.9	72.4	79.0		55.6	65.8	75.0	82.3	
L.S.D 0.05	A:4.34 B:2.66 AB:5.32					A:5.46 B:2.99 AB:5.98				
Seed yield/plant (g)										
Control	18.67	27.67	30.00	35.33	27.92	20.67	29.00	32.67	39.00	30.33
Compost (1)	20.50	29.00	33.33	39.67	30.63	22.17	32.00	34.33	40.33	32.21
Compost (2)	21.17	30.67	35.00	41.00	31.96	22.83	34.00	37.00	42.33	34.04
Compost (3)	21.83	32.33	37.67	43.33	33.79	23.67	36.00	40.67	45.67	36.50
Mean	20.54	29.92	34.00	39.83		22.33	32.75	36.17	41.83	
L.S.D 0.05	A:1.38 B:1.97 AB:3.94					A:2.78 B:1.98 AB:3.78				
Fruit yield/ Hectare (kg)										
Control	1493.3	2213.3	2400.0	2826.7	2233.3	1653.3	2320.0	2613.3	3120.0	2426.7
Compost (1)	1640.0	2320.0	2666.7	3173.3	2450.0	1826.7	2560.0	2746.7	3226.7	2590.0
Compost (2)	1693.3	2453.3	2800.0	3280.0	2556.7	1866.7	2720.0	2960.0	3386.7	2733.3
Compost (3)	1746.7	2586.7	3013.3	3466.7	2703.3	1933.3	2880.0	3253.3	3653.3	2930.0
Mean	1643.3	2393.3	2720.0	3186.7		1820.0	2620.0	2893.3	3346.7	
L.S.D 0.05	A:145.49 B:116.08 AB:232.15					A:126.86 B:197.86 AB:395.73				
B1 = *Pseudomonas monteilii* B2 = *Bacillus subtilis* Compost 1,2 and 3 = 5,10 and 15 ton/hectar										

3.3. Volatile oil parameters

The parameters recorded in Table 5, showed that the volatile oil productivity (volatile oil % and it is content ml/plant & liter/ha) of Caraway (*Carum carvi* L.) plants Compost additions at all levels gave significant effects for all measurements of volatile oils compared to the control during the two experimental seasons, and the highest values for these parameters were when using the high level of compost (15 tons/ha). The Role of organic manures in enhancing volatile oil production reported by [37] on black cumin, [45] on anise**,** [42,43] on rosemary, [46] on dragonhead plant and [28] on *Coriandrum sativum* L. Regarding the effect of microbial inoculation by *Pseudomonas monteilii* and *Bacillus subtilis*, measurements in Table (5) pointed that volatile oil %, volatile oil content / plant (ml) / hectare (L) of Caraway (*Carum carvi* L.) plants were significantly increased due to inoculation with these inoculants either individual or together as compared to without treatment in both seasons combined inoculation of the two strains used together was the best. Outstanding influence of bio fertilizers on improving chemical ingredient materials was noticed by [33] on Caraway (*Carum carvi* L.), [28]**,** on *Coriandrum sativum* L., [42] on rosemary (*Rosmarinus officinalis* L.) plants, [30] on dill plant and [31] on Khella (*Ammi visnaga* L.) plants. Regarding the combined effect of the two study factors (compost and microbial incubation), it was positive and significant in all measurements of the volatile oil of the caraway plant (*Carum carvi* L.) in the two experimental seasons. The results obtained showed that the most positive combined effects are when using the high rate of compost (15 tons/ha) with double inoculation with two strains (*Pseudomonas monteilii* and *Bacillus subtilis*) compared to the other combined treatments as listed in Table (5).

Table 5: Impact compost, microbial inoculants and their interaction on volatile oil production of Caraway (*Carum carvi* L.) plants during the 2021\2022 and 2022/2023 seasons

Compost levels (A)	Microbial inoculants (B)									
	First Season					Second Season				
	Control	B1	B2	B1+B2	Mean	Control	B1	B2	B1+B2	Mean
Volatile oil %										
Control	1.110	1.320	1.410	1.480	1.330	1.133	1.350	1.447	1.510	1.360
Compost (1)	1.150	1.360	1.450	1.537	1.374	1.180	1.390	1.483	1.577	1.408
Compost (2)	1.170	1.380	1.527	1.553	1.408	1.200	1.410	1.567	1.600	1.444
Compost (3)	1.217	1.430	1.553	1.590	1.448	1.220	1.457	1.580	1.713	1.493
Mean	1.162	1.373	1.485	1.540		1.183	1.402	1.519	1.600	
L.S.D 0.05	A:0.117 B:0.069 AB:0.139					A:0.117 B:0.069 AB:0.139				
Volatile oil / plant(ml)										
Control	0.877	0.927	1.018	1.123	0.986	0.219	0.378	0.459	0.568	0.406
Compost (1)	0.914	0.960	1.056	1.228	1.040	0.262	0.445	0.510	0.636	0.463
Compost (2)	0.946	0.998	1.155	1.308	1.102	0.274	0.480	0.580	0.678	0.503
Compost (3)	0.970	1.085	1.201	1.370	1.157	0.299	0.535	0.653	0.762	0.562
Mean	0.927	0.992	1.108	1.257		0.263	0.459	0.551	0.661	
L.S.D 0.05	A:0.039 B:0.040 AB: 0.080					A:0.083 B:0.095 AB:0.190				
Volatile oil / ha (L)										
Control	16.88	29.65	34.35	42.43	30.83	19.09	31.81	38.35	47.07	34.08
Compost (1)	18.88	31.57	38.69	48.80	34.49	20.93	35.60	40.77	50.91	37.05
Compost (2)	19.84	33.89	42.80	50.96	36.87	21.95	38.37	46.40	54.21	40.23
Compost (3)	20.37	36.77	46.53	54.83	39.63	23.12	41.97	51.44	59.68	44.05
Mean	18.99	32.97	40.59	49.25		21.27	36.94	44.24	52.97	
L.S.D 0.05	A:2.16 B:2.77 AB:5.55					A:6.69 B:5.09 AB:10.19				

B1 = *Pseudomonas monteilii*
B2 = *Bacillus subtilis*
Compost 1,2 and 3 = 5,10 and 15 ton/hectar

3.4. Volatile oil Components

The results shown in Table 6 revealed that the gas chromatographic (GC/MS) analysis of caraway volatile oil obtained in this study, in which the plants were treated with some levels of compost and inoculated with some microbial inoculants, showed that it consists of (15) components. When comparing the values of the chemical compounds of the oil, we notice that the Carvone-D-Limonene-cis-Anethole compounds contain the highest percentages of volatile oil compounds compared to other compounds. The highest rate of carvone compound was recorded when adding high level of Compost (15 ton/hectar) with double inoculation by *Pseudomonas monteilii* and *Bacillus subtilis* (77.00), followed by the compost (15 ton/hectare) with inoculation by *Bacillus subtilis*, which recorded (75.49), followed by the Compost (15 ton/hectar) with inoculation by *Pseudomonas monteilii*, which reached (64.89). The lowest percentage of the carvone compound is (61.58) in the control treatment. While the highest average was for compound D. - Limonene (33.93) when adding high level of Compost (10 ton/hectare) with double inoculation by *Pseudomonas monteilii* and *Bacillus subtilis*, followed by the Compost (15 ton/hectar) with inoculation by *Pseudomonas monteilii*, which recorded (31.63). The highest percentage of the compounds cis-anethol (1.33) and cuminaldehyde (2.31) was in the control treatment (no fertilization treatments). This confirms the positive effect of the treatments in enhancing the proportions of the main important compounds of caraway oil. The treatments used in this experiment also have a clear effect on some compounds, and this is consistent with the results reached by [47,48,28] on *Coriandrum sativum* L. and *Foeniculum vulgare* Mill where they confirmed the improvement of the oil percentage of volatile oil and its components as a result of the use of organic and biofertilizers. This is due to the complementarity between the two types of fertilization and its effect in making all the necessary nutrients available to the plant.

Table 6: The interaction between of compost and microbial inoculants on volatile oil components of Caraway (*Carum carvi* L.) plants during the 2022/2023 season

No	Component Name	R T	Treatments				
			control	Compost(2) +B1+B2	Compost(3) +B1	Compost(3) + B2	Compost(3) +B1+B2
1	β-Myrcene	7.7	---	0.4	0.34	0.33	0.35
2	p-Cymene	8.615	0.36	---	---	---	0.29
3	D-Limonene	8.731	27.99	33.93	31.63	22.46	19.28
4	trans-Chrysanthenyl acetate	11.283	---	0.23	---	---	--
5	Limonene oxide	11.763	---	0.27	0.25	---	--
6	cis-Anethole	13.455	3.33	0.37	0.60	0.42	.129
7	trans-Dihydrocarvone	13.657	0.43	0.38	0.34	0.29	0.45
8	trans-Carveol	14.073	0.41	0.72	0.71	0.59	0.40
9	Dihydrocarveol	14.367	---	0.32	---	---	---
10	cis-Carveol	14.46	---	0.39	0.35	---	---
11	Cuminaldehyde	14.645	2.53	---	---	0.52	0.45
12	Carvone	14.841	61.58	62.5	64.89	75.49	77.00
13	Perillaldehyde	15.574	0.48	0.47	0.48	0.48	0.49
14	γ-Terpinen-7-al	16.008	1.67	---	---	---	---
15	β-Copaene	20.957	1.21	---	---	---	---
Number of identified compounds			10	11	9	8	9
Total % of identified compounds			99.99	99.98	99.99	99.99	100

This field experiment was conducted to examine the effect of compost and microbial inoculation (*Pseudomonas monteilii* and *Bacillus subtilis*) as well as, their interactions on vegetative growth, fruit yield and chemical ingredient materials of caraway (*Carum carvi* L.) plants. The improvement of plant growth, yield components and chemical constituents of caraway plants as a result as follows, the registered results in this work revealed the capability of compost on augmenting the plant growth, yield components and chemical contents of caraway (*Carum carvi* L.) plants. The increment of these previous traits might be attributed to the important roles of organic manures in the biological and physiological processes which were mentioned by many investigators such as, [49] who showed that augmenting the content of organic matter in soils caused an increase in dehydrogenase activity. In addition, organic manure holds moisture, maintains sufficient pore spaces to permit good air circulation and excessive water drainage [50,51] concluded that organic matter as a main source of N, P, S and contains high content of B and Mo and also, it is considered as a source of energy for Azotobacter growth. Organic manure minimize the loss of nutrients by leaching [52] and it caused an increase in microbial activities in the root zone when supplied it to the soil [53]**.** [54] demonstrated that incorporation of organic manure in the soil, improves permeability of soil and release carbon dioxide and certain organic acids during decomposition.

The promoting effect of bio-fertilization treatments on vegetative growth, yield components and chemical constituents of caraway (*Carum carvi* L.) plants reflected the biological and physiological roles of these inoculants which were explained by many authors such as [55]. *Pseudomonas* spp. was adapted to survive in soil and colonize plant roots. The microbial inoculants have been utilized in agriculture as biofertilizers, biocontrol agents and plant growth promoting

4. Conclusion

The results obtained in this study, it is clear that by combining compost at a high rate (15 tons/ha) in addition to inoculating plants with *Pseudomonas monteilii* and *Bacillus subtilis* strains, it led to a significant increase in plant growth characteristics in terms of plant height, number of branches and plants. Fresh and dry weight, yield, i.e. the number of umbels per plant, seed yield per plant and per hectare, as well as volatile oil production (percentage of oil, plant content in milliliters, yield per hectare in liters, as well as volatile oil components).

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