Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL

Volume 6, Issue 2, 2023, Pages 165–178

Available online at www.agricuta.edu.eg

DOI: https://dx.doi.org/10.21608/aasj.2023.318348

Effect of some microbial inoculants and bio straw treatments on growth, yield and volatile oil of dill (*Anethum graveolens* L.) plants

Mohamed A. K.[a*], Hassan E. A.[a], Hamad E. H.[a], Shehata Heba Sh.[b]

[a]*Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt*

[b]*Department of Microbiology, Soils, Water and Environment Research Institute, Agriculture Research Center, Giza, Egypt*

Abstract

A field experiment was conducted during the two successive seasons of 2021/2022 and 2022/2023 at the Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt to examine the effect of bio straw (spent mushroom compost "SMC") at 0, 15, 20, 25 m^3/feddan (feddan = 4200 m^2) and half of the recommended doses of NPK fertilizer and microbial inoculation *(Pseudomonas monteilii* (MA-5) and *Pseudomonas fluorescens* (MP-4)) either alone or in combination, as well as, their interactions on plant growth, yield characteristics and volatile oil production of dill (*Anethum graveolens* L.) plants. The obtained results showed that the use of bio straw at all levels and NPK_{HR}, expect for the low level of bio straw in some cases led to a significant increase in plant height, number of branches/plant, weight of fresh and dry herbs g/plant, number of umbels/plant, fruit yield g/plant and kg/feddan and the percentage of volatile oil and volatile oil yield ml/plant and liter/fed. The application of a high level of bio straw (25 m^3/feddan.) gave the highest values of these traits. Apparently, application of microbial inoculation by MA-5 or MP-4 alone particularly MA-5 resulted no effect significant in the studied parameters, in most cases, in contrary, the mixture inoculation (*P monteilii and P fluorescents*) significantly augmented all growth attributes. The highest values of these parameters were detected when inoculation in most cases two strains together during the two seasons. The interaction effect on all studied variables was statistically significant and it is clear that the use of most combined treatments led to a significant increase in all parameters. The addition of the high rate of bio straw plus inoculation mixed of bacteria was the most effective treatment in increasing these aspects.

Keywords: dill, *Anethum graveolens*, bio straw, microbial inoculants, *Pseudomonas monteilii*, *Pseudomonas fluorescens*, volatile oil.

*Corresponding author: Mohamed A. K.,
E-mail address: ak4666666@gmail.com

1. Introduction

Dill *(Anethum graveolens*, L.) is an herbaceous plant of the Apiaceae family that has been mostly imported from the Eastern Mediterranean (Sokhangoy *et al*. 2012). Dill plant leaves are one of the most often used green herbs. It is used in perfume, domestic cosmetics, and medicine. It has a decent taste and a high quantity of nutrients for an altitude (Rashed, 2002). Dill leaves are used to prepare foods like salads, soups, and seafood that are popular in Egypt. Dill fruits are utilized in flavor bread and pickles (Elsayed *et al*., 2020). Among the important agronomic systems that have been proved to enhance the vegetative growth, fruit yield and oil production of dill plants are organic manures and microbial inoculants. Fertilizers and additives have become a way of plant life, creating their nutrient request. But from the point of environmental view, it is necessary to demonstrate the risks of mineral fertilizers and find out new possibilities for a good sensorial aspect of other eco- friendly amendments. Consequently, there is a demand for clean and safe natural biofertilizers and this could apply by using biofertilizers of microbial origin. Synthetic fertilizers, especially nitrogen, can seriously deplete the nutritional content of foods. Nitrate, the final breakdown product of nitrogen fertilizers, accumulates in ground water due to steep increase using mineral nitrogen and thus can be severely affect human health. N2-fixing cyanobacteria, blue-green algae (BGA), can be used as an alternative to synthetic nitrogen and make a major contribution to the soil fertility and assist crops by supplying the plant growth substances (Shariatmadari *et al*. 2011). The application of organic fertilizer is preferable to mineral fertilization for improving the quality of crops, especially medicinal and aromatic plants and organic farming has become a quality standard that small farmers in Egypt can match (Abou El-Fadl *et al*., 1990). The use of organic fertilization is more acceptable than the use of inorganic fertilizers and small farmers in Egypt could effectively match the high standards of organic farming. Several researchers have found that organic fertilization increases herb dry weight, umbels number, seed yield, volatile oil% and volatile oil yield. These investigators also provided by Khalid and Shafei (2005) on dill plant, Badran and Safwat (2004), Azzaz *et al*. (2009) on fennel, Shehata *et al*. (2011) on snap bean, Rekaby (2013) on coriander, Hassan (2005) on guar and fenugreek plants. *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 rhizobacteria (PGPR) (Kiely *et al*., 2006; Otieno *et al*., 2015). Fluorescent *Pseudomonas* spp. were among the most effective rhizosphere bacteria in diminishing soil-borne diseases in infected soils (Oteino *et al*., 2015; Weller, 1988), where disease incidence was low, despite the presence of pathogens and environmental conditions conductive to disease popularity. Strains of *Pseudomonas spp*. enhance seed germination, shoot and root development of different crops. Some strains have the ability to devastate the fungal cell wall via secreting lytic enzymes and suppress the growth of fungal pathogens via secreting hydrogen cyanide and antibiotics. Several modes of action for antagonistic PGPR had been reported, for instance, *Pseudomonas spp*. production of various antimicrobial compounds and induction of plant defense mechanisms (Alemu and Alemu, 2015; Sindhu *et al*., 2016; Zian and Aly, 2020). Thus, this field experiment was conducted to evaluate the influence of bio-straw and half the recommended dose of mineral fertilizer and some microbial inoculants, as well as their interactions on the growth, yield and volatile oil productions of dill plants.

2. Materials and methods

2.1 Experimental site and treatments description

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 bio-straw and half the recommended dose of mineral fertilizer and the second was two types of microbial inoculants, as well as their interactions. The experimental design of this study was a split-plot with three replicates, using a randomized complete blocks design (RCBD), bio-straw and half the recommended dose of mineral fertilizer (five levels) occupied the main plot and types of microbial inoculants (four treatments) as the sub-plots. There form the interaction treatments were 20 treatments. Dill fruits were obtained from the Agricultural Research Centre of the Department of Medicinal and Aromatic Plants in Dokky, Giza, Egypt. On November 5th, during the two seasons, these fruits were immediately sown in the plot 3 × 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 90 plants. The physical and chemical properties of the experimental soil are tabulated in Table (1) as reported by Chapman and Pratt (1975).

2.2 Rates and method of adding bio straw and microbial inoculants

Bio straw levels at 0, 15, 20 and 25 m^3/feddan were added during the preparation of soil to the cultivation, in the two seasons. Physical and chemical properties of the applied compost are shown in Table (2). Ammonium sulphate (20.5% N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate

(48.5% K_2O) were the three NPK rates that were the half-recommended dos: 100, 100 and 50 kg/feddan, respectively. During soil preparation, phosphorus fertilizer was added in its entirety. Whereas nitrogen and potassium fertilizers were administered 30, 45 and 60 days following the date of planting in 3 equal amounts.

Table (1): Physical and chemical properties of the experimental soil.

Soil character	Values	Soil character	Values
Soil texture	Clay loam	Total N%	0.12
Sand (%)	25.30	Available P(ppm)	0.14
Silt (%)	39.40	Available K (mg/100g soil)	3.5
Clay (%)	35.30	Soluble Ions (meq/L)	
Organic matter %	0.57	Ca	3.4
Caco3 (%)	2.53	Mg	1.9
PH (1:2.5)	7.5	Cl	2.2
E.C (m.mohs/cm)	2.2	So4	6.6
		Co_3 + Hco_3	2.9
		Ca	3.4

Table (2): The physical and chemical properties of the used bio straw.

Properties	Value	Properties	Value
Dry weight of 1 m3	430 kg	Total N (%)	2.72
Moisture (%)	25-30	Total P (%)	0.92
pH (1:2.5)	7.84	Total K (%)	2.88
EC(dSm^{-1})	4.17	Fe (ppm)	124
Organic matter %	54	Mn (ppm)	85
Organic carbon %	31.4	Zn (ppm)	32
C/N ratio	13.79		

2.3 Bacterial strains

Both local *Pseudomonas monteilii* and *Pseudomonas fluorescens* bacterial strains were kindly provided by Microbiology Department of Soils, Water and Environment, Research Institute, Giza, Egypt where both strains were isolated, purified and identified as mentioned by Ibrahim *et al*. (2020). The biofertilization with bacterial strains developed on plant-based culture media temperature 30 °C for 24 - 48 hours**.** These amounts of addition to both strains, either individually or together, were 20 liters per feddan with irrigation in three times, the first after 30 days, the second after 45, and the third after 60 days of planting.

2.4 Preparation of plant-based culture media

The vegetative parts (leaves and stems) of *Mentha viridis*. L (spearmint) were washed, sliced, and then blended with equal aliquots of distilled water (w/v) for 5 min in the blender. The resulting slurry homogenate was coarsely filtered through cheesecloth to obtain plant juice; almost 73-82% of the plant's fresh weight was recovered as juice. The pH for juice was

5.8-6.5. The obtained plant juice was further diluted with distilled water (v/v) at 1:10, 1:20, 1:40, 1:80 and 1:100. Exclusively, such diluted juice was used to prepare the plant-based agar culture media (2% agar, w/v). The media was adjusted to pH 7.0 and autoclaved at 1.5 atm., 121°C for 20 mints. The cultures were diluted 10 times with distilled water re-sulting 108 colony-forming units (cfu) mL^{-1}. After the successful growth of microorganisms, pick up the individual colonies and purify them.

2.5 Spent mushroom compost (SMC)

To prepare grain master spawn: sorghum seeds were cleaned and then soaked in water overnight. Dead seeds were removed then boiled in water for 15 min. After cooling the seeds were transferred to a round bottle (⅔ of its volume) and mixed with calcium carbonate 2% w/w and calcium sulphate 1% w\w. Bottles were sterilized for 1 hour at 121^{o} C. After cooling, the bottles were inoculated with mycelia discs (5 mm) diameter of 6 days old culture of white root *Pleurotus ostreatus* (was obtained from Department of Microbiology, Soils, water and Environment Research Institute, Agricultural Research Center, Giza, Egypt) then, the inoculated bottles were incubated at 25^{o}C for 15-20 days. Rice straws were chopped to lengths of 2-3 cm, soaked in water (approximately three times the weight of the straw) and left for 24 hr. to allow the water to completely penetrate into the straws. The soaked rice straw was transferred to autoclavable plastic bags (100 Kg/pile), were sealed and were pasteurized (90^{o}C for 2 hr), this process was followed by cooling to room temperature for 24 hr. After cooling, each bag was inoculated with 50 g of previously prepared spawn (culture) of *P. ostreatus*, immediately sealed. The inoculated rice straw was incubated at 30± 2 ^{o}C under relative humidity of 60-70 % for not less than 30 days until it became well decomposed. The spent mushroom compost (SMC) and its extract was chemical analysed (Table 2) according to standard methods as described by Brunner (1978); Nasef *et al*. (2009).

2.6 Sampling and data collection

Three plants were randomly selected from each plot 100 days after dill sown to determine the following variables: plant height (cm), branches number/plant and herb fresh and dry weighs (g/plant). At the harvesting time on the second week of April in both seasons, the following data were recorded: number of umbels/ plant, fruit yield (g/plant), fruit yield (kg/feddan), volatile oil (%) in the fruits, then volatile oil yield (ml/plant) was calculated by multiplying volatile oil (%) in fruit yield (g)/plant and then volatile oil yield (l/feddan) was calculated.

2.7 Volatile oil isolate

Seeds were collected from each treatment during both seasons and weighed for EO extraction; then 100 g from each repeat of all transactions, Hydrodistillation (HD) for 3 hours using a Clevenger type Apparatus (Clevenger, 1928). EO content was calculated as relative percentage (v/w). In addition, the total EO where ml/100 plants were calculated using dry weight. The extracted EOs was collected from abrotanum during the two seasons of each treatment and dried anhydrous sodium sulphate for chemical determination voters.

2.8 Statistical analysis

All obtained data were tabulated and statistically analyzed according to MSTAT-C (1986) using the L.S.D. test at 5% to know the differences among all treatments according to Mead *et al*. (1993).

3. Results and Discussion

3.1 Growth parameters

Obtained data in Table (3) revealed that plant height (cm), number of branches/ plant and herb fresh & dry weight (g/plant) of dill (*Anethum graveolens* L.) plants were significantly influenced by bio straw treatments in the two growing seasons. It appears that fertilizing the plants with bio straw at all levels, besides the half-recommended dose of NPK, except for the low level of bio straw, in some cases, led to a significant increase in plant height, number of branches/plant, and herb fresh & dry weight as compared to untreated plants in both seasons. From the recorded data, it is noticed that the addition of the high level of bio straw fertilizer (25 m^3/feddan) gave the highest values of these traits, whereas increased plant height, the number of branches/ plant and the herb fresh and dry weights/ g/plant by 23.13 and 23.27, 66.67 and 66.67, 21.64 and 22.62, and 29.89 and 25.42% over untreated plants in the two experimental seasons, respectively. The beneficial effect of organic manures on increasing the growth traits was obtained by Gahory *et al.* (2022); Ashwini and Jain (2017) on *Coriandrum sativum* L. plant, Abd El-Latif (2002) on *Carum carvi*, Sharaf and Khattab (2004) on fennel, Sakr (2005) on *Cassia acutifolia* plants, Hassan *et al.* (2015) on rosemary and Hegazi *et al.* (2015) on squash plants. Concerning the effect of microbial inoculants treatments, data in Table (3) showed that plant height (cm), number of branches/plant, and herb fresh and dry weighs (g/plant) of dill (*Anethum graveolens* L.) were significantly affected by inoculation with these inoculants in the two consecutive seasons. Obviously, the double inoculants significantly increased all the growth traits, while inoculation with single microorganism recorded no significant effect on these parameters, in many cases. It was found that inoculation of dill plants with *Pseudomonas monteilii* and *Pseudomonas fluorescens* in combination gave the tallest plants, highest number of branches/plant, and heaviest herb fresh and dry weighs/g/plant as ranged 8.82 and 8.10, 22.89 and 25.00, 3.52 and 3.95, and 10.37 and 6.71% over control in the first and second seasons, respectively. The positive effect of bio fertilization on enhancing growth parameters was observed by Hussein *et al.* (2016), Jeet and Baldi (2021) on dill (*Anethum graveolens* L.) plants, Somayeh and Hashem (2015) on faba bean (*Vicia faba*). According to the interaction between bio straw manure and microbial inoculant treatments, it had a significant effect on all growth parameters of dill (*Anethum graveolens* L.) plants in both seasons. Data indicated that the most effective treatments were obtained due to the high level of bio straw (25 m^3/feddan) plus a mixture of inoculation by two bacterial strains as compared to other combination complex treatments, during the two experimental seasons, as clearly shown in Table (3).

Table (3): Effect of mineral fertilizer, bio straw (BI), microbial inoculants (MI) and their interactions on the growth of dill (*Anethum grraveolens* L.) plants during the 2021/2022 and 2022/2023 seasons.

Microbial inoculants (B)	Bio straw levels (A)											
	Plant height (cm)											
	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)
	First season						Second season					
Control	67.0	75.7	72.0	77.0	82.3	74.8	68.7	77.0	74.0	78.7	84.3	76.5
MI (1)	69.0	77.0	75.0	79.3	84.7	77.0	70.0	78.7	76.7	81.0	85.7	78.4
MI (2)	70.3	79.0	76.0	81.7	86.3	78.7	71.7	80.7	78.0	83.0	88.3	80.3
MI (3)	72.0	81.7	80.0	84.0	89.3	81.4	73.3	82.7	81.0	85.0	91.3	82.7
Mean (A)	69.6	78.3	75.8	80.5	85.7		70.9	79.8	77.4	81.9	87.4	
L.S.D. 5%	A: 6.9		B: 4.8		AB:9.6		A:2.2		B:2.5		AB:5.0	
	Number of branches/plants											
Control	6.0	9.0	7.0	9.3	10.2	8.3	6.5	9.5	7.2	9.7	11.0	8.8
MI (1)	6.8	9.7	7.5	10.2	11.0	9.0	7.3	10.2	7.8	10.5	11.8	9.5
MI (2)	7.2	10.3	8.0	10.8	12.0	9.7	8.0	10.7	8.5	11.2	13.0	10.3
MI (3)	7.7	10.7	8.5	11.3	13.0	10.2	8.3	11.3	9.2	12.2	14.0	11.0
Mean (A)	6.9	9.9	7.8	10.4	11.5		7.5	10.4	8.2	10.9	12.5	
L.S.D. 5%	A: 1.1		B: 1.0		AB:2.0		A: 0.8		B: 1.2		AB:2.4	
	Herb fresh weight (g/plant)											
Control	117.5	132.5	121.5	138.3	143.8	130.7	118.3	133.0	122.7	139.0	146.0	131.8
MI (1)	118.5	134.4	124.7	139.3	145.7	132.5	119.3	135.3	125.7	141.0	147.0	133.7
MI (2)	120.7	135.7	126.8	140.2	145.8	133.8	121.7	136.7	127.7	142.7	149.0	135.5
MI (3)	122.0	137.0	128.8	141.3	147.2	135.3	123.3	138.0	129.7	144.0	150.0	137.0
Mean(A)	119.7	134.9	125.5	139.8	145.6		120.7	135.8	126.4	141.7	148.0	
L.S.D. 5%	A:6.0		B: 4.6		AB: 9.2		A:5.1		B:4.5		AB:9.0	
	Herb dry weight (g/plant)											
Control	25.3	29.7	29.0	32.0	33.7	29.9	29.38	33.1	31.0	34.6	36.0	32.8
MI (1)	26.7	31.0	30.0	33.0	34.7	31.1	29.8	33.4	31.4	34.8	36.6	33.2
MI (2)	27.7	32.0	31.0	34.0	35.7	32.1	30.0	33.8	33.0	35.7	37.8	34.1
MI (3)	28.7	33.0	32.0	34.7	36.7	33.0	30.4	34.3	33.9	36.7	39.6	35.0
Mean (A)	27.1	31.4	30.5	33.4	35.2		29.9	33.7	32.3	35.4	37.5	
L.S.D. 5%	A:3.2		B:2.6		AB:5.2		A:0.8		B:0.5		AB:1.0	

BS1 = 15, BS2 = 20 and BS3 = 25 m^3/feddan for bio straw. MI (1) = *Pseudomonas monteilii*, MI (2) = *Pseudomonas fluorescens* and MI (3) = MI (1) + MI (2).

3.2 Yield parameters

The data in Table (4) showed the number of umbels per plant, seed yield per plant (g), and feddan (kg). The effect was significant on Dill (*Anethum graveolens*

L.) Plants by using bio straw during the two study seasons. It was clear that all of them led to significantly increased the except for the low one, in the first season, concerning umbel numbers plant compared to control yield parameter. Moreover, the highest values of the number of umbels per plant and the total seed yield per plant (gm) and feddan (kg) were obtained when supplying dill plants with per a high rate (25 m^3/feddan) as ranged 59.68, 32.65 and 68.51% in the first season, and 63.86, 38.99 and 37.70% in the second season over the control, respectively. The effectiveness of organic minaret on increasing yield measurements was revealed by Hassan *et al.* (2015) on dill, Sanjeeva *et al*. (2018), and Ali and Hassan (2014) on *Nigella sativa* L. plants, Abd El-Azim *et al.* (2017) on fennel and Horia (2018) on dragonhead plant.

Table (4): Effect of mineral fertilizer, bio straw (BI), microbial inoculants (MI) and their interactions on the yield of dill (*Anethum grraveolens* L.) plants during the 2021/2022 and 2022/2023 seasons.

Microbial inoculants (B)	Bio straw levels (A)											
	Umbels number/plant											
	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)
	First season						Second season					
Control	17.0	26.0	18.0	26.3	27.3	22.9	18.3	27.0	20.3	28.0	29.7	24.7
MI (1)	18.0	27.0	20.0	27.7	29.0	24.3	19.7	28.0	22.7	29.3	32.0	26.3
MI (2)	19.0	28.0	21.0	28.7	30.3	25.4	20.7	29.0	23.7	30.7	34.0	27.6
MI (3)	20.3	29.0	22.3	29.7	32.0	26.7	22.0	30.3	25.3	32.0	36.7	29.3
Mean (A)	18.6	27.5	20.3	28.1	29.7		20.2	28.6	23.0	30.0	33.1	
L.S.D. 5%	A:2.2 B:2.5 AB:5.0						A:2.6 B:3.0 AB:6.0					
Seed yield (g) /plant												
Control	13.6	17.1	16.3	16.5	18.0	16.3	14.6	18.4	17.4	17.5	20.0	17.6
MI (1)	14.3	18.0	17.3	17.7	19.0	17.3	15.4	19.8	18.4	18.5	22.0	18.8
MI (2)	15.1	19.0	18.1	18.1	19.8	18.0	16.3	20.8	19.1	19.2	22.8	19.7
MI (3)	16.0	20.0	19.2	18.6	21.0	18.9	17.3	21.8	20.4	20.0	23.7	20.7
Mean (A)	14.7	18.5	17.7	17.7	19.5		15.9	20.2	18.9	18.8	22.1	
L.S.D. 5%	A:2.7 B:1.7 AB:3.4						A:2.1 B:1.9 AB:2.8					
Seed yield (Kg) / feddan												
Control	425.2	461.8	478.4	693.5	756.5	563.1	613.6	774.8	732.7	734.1	840.6	739.2
MI (1)	467.5	535.5	542.8	742.5	798.6	617.4	648.7	833.6	773.3	777.6	891.3	784.9
MI (2)	477.8	532.9	759.3	762.1	833.6	673.1	686.5	875.6	804.2	805.6	959.7	826.3
MI (3)	570.8	653.5	805.6	780.4	882.6	738.6	728.5	917.7	858.8	840.6	994.7	868.1
Mean(A)	485.3	545.9	646.5	744.6	817.8		669.3	850.4	792.3	789.5	921.6	
L.S.D. 5%	A:105.1 B:57.9 AB:115.8						A:30.5 B:76.3 AB:152.6					

BS1 = 15, BS2 = 20 and BS3 = 25 m^3/feddan for bio straw. MI (1) = *Pseudomonas monteilii*, MI (2) = *Pseudomonas fluorescens* and MI (3) = MI (1) + MI (2).

Concerning bacterial inoculants treatment, data in Table (4) showed that the influence of them on umbels number/ plant, seed yield (g)/plant and seed yield (kg)/feddan was significant in both seasons. All examined microbial inoculants, either single or in combination resulted a significant elevate in yield attributes, except for *pseudomonas monteilii*, comparing to un inoculated ones, in both seasons. From the obtained data, it is noticed that the highest umbels number/plant, seed yield (g)/ plant, and seed yield (kg)/feddan were detected due to inoculating dill plants with *Pseudomonas monteilii* + *Pseudomonas fluorescens* reached 16.59 and 18.62, 15.95 and 17.61, and 31.17 and 17.44% over the check control for the two seasons, respectively. The positive effect of bio fertilization on enhancing the yield parameters was observed by Ali and Hassan (2014) on black cumin (*Nigella sativa* L.) plants, Hassan *et al.* (2015) and Abdullah *et al.* (2012) on rosemary (*Rosmarinus officinalis* L.) plants, Hendawy *et al*. (2010) on *Thymus vulgaris* plants. According to the interaction between bio straw manure and microbial inoculants treatments, it had a significant effect on all yield parameters of dill (*Anethum graveolens* L.) plants in both seasons. Data indicated that the most effective treatments were obtained due to the high level of bio straw (25 m^3/feddan) plus a mixture of inoculation by two bacterial strains as compared to other combination treatments, during the two experimental seasons, as clearly shown in Table (4).

3.3 Volatile oil production

The measurements recorded in Table (5) showed the volatile oil production (volatile oil percentage, yield of volatile oil ml/plant, and l/feddan) of dill (*Anethum graveolens* L.) It had a significant effect by adding bio straw levels in the two growing seasons. All levels of bio straw significance increased these aspects, most comparing to control in the two season the highest values of these parameters were obtained to applying the high level of bio straw as was gradually increased by increasing the bio straw fertilizer levels to ranged 24.79, 64.25 and 65.41 in the first season and 20.31, 68.14 and 67.45 in the second season over the control respectively. The role of organic manures in enhancing volatile oil production was reported by Ali and Hassan (2014) on black cumin, Hemdan (2008) on anise, Abdullah *et al.* (2012) and Hassan *et al.* (2015) on rosemary, Horia (2018) on dragonhead plant. Regarding the effect of microbial inoculation by *Pseudomonas monteilii* and *Pseudomonas fluorescens*, data in Table (5) showed that volatile oil percentage, volatile oil yield (ml)/pant and volatile oil yield (L)/feddan were significantly increased due to inoculation with these inoculants either individual or together except for *pseudomonas monteliti*, mostly, as compared to control in the two seasons. It was found that inoculation of highest values of dill plants with *Pseudomonas monteilii* + *Pseudomonas fluorescens* gave the increase volatile oil percentage, volatile oil yield (ml)/plant and volatile oil yield (L)/feddan as ranged 7.58 and 14.71, 24.42 and 26.67, and 24.70 and 26.46% over control in the first and second seasons, respectively. As for the interaction between the two factors under study, the effect was significant on all measurements of the volatile oil of dill plants in both seasons.

Table (5): Effect of mineral fertilizer bio straw (BI), microbial inoculants (MI), and their interactions on the volatile oil production of dill (*Anethum graveolens* L.) plants during the 2021/2022 and 2022/2023 seasons.

Microbial inoculants (B)	Bio straw levels (A)											
	Volatile oil (%)											
	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)	Co.	NPK_{HR}	BS1	BS2	BS3	Mean (B)
	First season						Second season					
Control	1.17	1.35	1.34	1.32	1.44	1.32	1.25	1.37	1.35	1.35	1.47	1.36
MI (1)	1.20	1.37	1.35	1.34	1.48	1.35	1.27	1.41	1.40	1.39	1.52	1.40
MI (2)	1.22	1.40	1.37	1.35	1.53	1.38	1.29	1.44	1.41	1.41	1.56	1.42
MI (3)	1.25	1.45	1.42	1.37	1.59	1.42	1.31	1.48	1.46	1.41	1.63	1.46
Mean (A)	1.21	1.39	1.37	1.35	1.51		1.28	1.43	1.41	1.39	1.54	
L.S.D. 5%	A:0.103 B:0.072 AB:0.144						A:0.062 B:0.054 AB:0.108					
	Volatile oil (ml/plant)											
Control	0.158	0.232	0.218	0.217	0.259	0.217	0.182	0.253	0.236	0.236	0.294	0.240
MI (1)	0.172	0.247	0.235	0.237	0.281	0.234	0.196	0.280	0.257	0.257	0.335	0.265
MI (2)	0.184	0.266	0.248	0.246	0.304	0.250	0.210	0.301	0.270	0.270	0.357	0.282
MI (3)	0.200	0.290	0.273	0.255	0.333	0.270	0.227	0.324	0.299	0.283	0.385	0.304
Mean (A)	0.179	0.259	0.244	0.239	0.294		0.204	0.289	0.265	0.261	0.343	
L.S.D. 5%	A:0.074 B:0.046 AB:0.092						A:0.071 B:0.047 AB:0.084					
	Volatile oil (l/feddan)											
Control	6.65	9.74	9.16	9.13	10.87	9.11	7.66	10.63	9.91	9.92	12.34	10.09
MI (1)	7.24	10.39	9.86	9.95	11.80	9.85	8.25	11.75	10.82	10.82	14.07	11.14
MI (2)	7.50	11.18	10.44	10.32	12.76	10.44	8.84	12.65	11.35	11.33	15.02	11.84
MI (3)	8.42	12.18	11.47	10.72	14.01	11.36	9.55	13.62	12.55	11.86	16.19	12.76
Mean(A)	7.45	10.87	10.23	10.03	12.36		8.58	12.16	11.16	10.98	14.41	
L.S.D. 5%	A:0.83 B:1.25 AB:2.50						A:2.71 B:1.75 AB:3.50					

BS1 = 15, BS2 = 20 and BS3 = 25 m^3/feddan for bio straw. MI (1) = *Pseudomonas monteilii*, MI (2) = *Pseudomonas fluorescens* and MI (3) = MI (1) + MI (2).

The data indicate that the most effective treatments were obtained by adding a high rate of bio straw (25 m^3/feddan) with double inoculants (*Pseudomonas monteilii + Pseudomonas fluorescens)* as compared to those revealed by other combined treatments for both seasons, as shown in Table (5).

References

Abd El-Azim, W. M., Reda, R. M., Badawy, M. Y. M. (2017), "Effect of bio-fertilization and different licorice extracts on growth and productivity of *Foeniculum vulgare*, Mill. Plant", *Middle East Journal of Agriculture Research*, Vol. 06 No. 01, pp. 1–12.

Abd El-Latif, A. (2002), "Effect of organic manure and biofertilizer on caraway plants (*Carum carvi*, L.)", *Journal of Plant Production*, Vol. 27 No. 5, pp. 3459–3468.

Abdullah, A. T., Hanafy, M. S., El-Ghawwas, E. O. and Ali, Z. H. (2012), "Effect of compost and some biofertilizers on growth, yield, essential oil productivity and chemical composition of *Rosmarinus officinalis* L. plants", *Journal of Horticultural Science & Ornamental Plants*, Vol. 4 No. 2, pp. 201–214.

Abou El-Fadl, I. A., M. Abou-Baker and A. M. El-Gamal, (1990), "Effect of different organic manure composts on roselle (*Hibiscus sabdariffa* L.)

plants and soil characteristics", *Agricultural Research Review*, Vol. 68 No. 5, pp. 1077–1087.

Alemu, F. and Alemu, T. (2015), "*Pseudomonas fluorescens* isolates used as a plant growth promoter of Faba Bean (*Vicia faba*) in-vitro, as well as, in-vivo study in Ethiopia", *American Journal Life Sciences*, Vol. 3 No. 2, pp. 100–108.

Ali, E, and Hassan, F. (2014), "Bio-production seeds and oil of *Nigella sativa* L. in Taif area", *International Journal of Current Microbiology and Applied Sciences*, Vol. 3 No. 1, pp. 315–328.

Ashwini, A. and Jain P. K. (2017), "Interaction effect of organic manures and fertilizers levels on growth and yield of coriander (*Coriandram sativum* L.)", *Agriculture Update*, Vol. 12, pp. 2194–2201.

Azzaz, N. A., Hassan, E. A. and Hamad, E. H. (2009), "The chemical constituent and vegetative and yielding characteristics of fennel plants treated with organic and bio-fertilizer instead of mineral fertilizer", *Australian Journal of Basic and Applied Sciences*, Vol. 3 No. 2, pp. 579–587.

Badran, F. S. and Safwat, M. S. (2004), *Response of fennel plants to organic and biofertilizers in replacement of chemical fertilization*, Second International Conference of Organic Agriculture, Cairo, Egypt, pp. 25–27.

Brunner, P. H. (1978), *Methods of analysis of sewage sludge solid wastes and compost*, International Reference Centre for Wastes Disposal, Duebendorf, Switzerland.

Chapman, H. D. and Pratt, P. F. (1975), *Methods of analysis for soil, plant and water*, Division of Agricultural Sciences, University of California, USA.

Clevenger, J. F. (1928), "Apparatus for determination of essential oil", *Journal of the American Pharmaceutical Association*, Vol. 17, pp. 346–349.

Elsayed, S. I., Glala, A. A., Abdalla, A. M., El-Sayed, A. E. G. A. and Darwish, M. A. (2020), "Effect of biofertilizer and organic fertilization on growth, nutrient contents and fresh yield of dill (*Anethum graveolens*)", *Bulletin of the National Research Centre*, Vol. 44, pp. 1–10.

Gahory, A. M., Ayyat, A. M. and Soliman, T. M. A. (2022), "Growth, yield and its component of coriander (*Coriandrum sativum* L.) in response to the addition of compost, ascorbic acid and salicylic acid under Aswan governorate conditions, Egypt", *Journal of Plant Production*, Vol. 13 No. 12, pp. 899–905.

Hassan E. A. (2005), *Using some bio fertilizers and their effect on the growth, yield and active ingredient materials in some medicinal and aromatic plants*, Ph.D. Thesis, Faculty of Agriculture, Al Azhar

University, Egypt.

Hassan, E. A., Ali, A. F. and El- Gohary, A. E. (2015), "Enhancement of growth, yield, and chemical constituents of rosemary (*Rosmarinus officinalis*, L.) plants by application of compost and biofertilization treatments", *Middle East Journal of Agriculture Research*, Vol. 4 No. 1, pp. 99–111.

Hegazi, A. Z., Khattab E. A., Shehata H. S. and Mostafa, S. S. M. (2015), "Application efficiency of spent mushroom compost extract, cyanobacteria and bacteria on green fruit and seed yield of squash under drip irrigation system", *Middle East Journal of Agriculture Research*, Vol. 4 No. 4, pp. 887–898.

Hemdan, S. H. (2008), *Effect of some organic and biofertilization treatments on anise plants*, M.Sc. Thesis, Faculty of Agriculture, Minia University, Egypt.

Hendawy, S. F., Azza, A., Aziz, E. and Omer, E. A. (2010), "Productivity and oil quality of *Thymus vulgaris* L. under organic fertilization conditions", *Ozean Journal of Applied Sciences*, Vol. 3 No. 2, pp. 203–216.

Horia M. Sh. (2018), "Complementary effect between compost rate and ascorbic acid concentration on enhancing dragonhead (*Dracocephalum moldavica*) plant on growth and productivity", *Middle East Journal of Agriculture Research*, Vol. 7 No. 4, pp. 1811–1818.

Hussein A. H. Said-Al., Atef M. Z. S., Abou Dahab M. A., El-Shahat N. Ab., Mohamed S. A. and Nabila Y. N. (2016), "Dill (*Anethum graveolens* L.) growth and yield responses to Gamma radiation and bio-fertilization", *Journal of Agricultural Science and Engineering*, Vol. 1 No. 2, pp. 68–74.

Ibrahim, S. E., Mohamed, H. F., Shehata, H. S. and Salah El Din, R. A. (2020), "Perineal plant extract as a culture medium for production of plant growth regulators by molecularly identified rhizospheric microorganisms", *Global Advanced Research Journal of Agricultural Science*, Vol. 9 No. 2, pp. 27–39.

Jeet, K. and Baldi, A. (2021), "Trending microbiologicals and their role to enhance growth and essential oil content of dill (*Anethum graveolens*)", *International Journal of Pharmaceutical Sciences and Research*, Vol. 12 No. 2, pp. 875–888.

Khalid, K. A. and Shafei, A. M. (2005), "Productivity of dill (*Anethum graveolens* L.) as influenced by different organic manure rates and sources", *Arab Universities Journal of Agricultural Sciences*, Vol. 13 No. 3, pp. 901–913.

Kiely, P. D., Haynes, J. M., Higgins, C. H., Franks, A., Mark, G. L., Morrissey, J. P. and O'Gara, F.

(2006), "Exploiting new systems-based strategies to elucidate plant-bacterial interactions in the rhizosphere", *Microbial Ecology*, Vol. 51, pp. 257–266.

Mead, R. N., Currow R. N. and Harted, A. M. (1993), *Statistical Methods in Agricultural and Experimented Biology*, Chapman and Hall, London, England, pp.10–44.

MSTAT-C (1986), A Microcomputer Program for the Design, Management, and Analysis of Agronomic Research Experiments, Version 4.0, Michigan State University, USA.

Nasef, M. A., Shaban, K. A., El-Hamid, A. and Amal, F. (2009), "Effect of compost, compost tea and bio-fertilizer application on some chemical soil properties and rice productivity under saline soil condition", *Journal of Agricultural Chemistry and Biotechnology*, Vol. 34 No. 4, pp. 2609–2623.

Oteino, N., Lally, R. D., Kiwanuka, S., Lloyd, A., Ryan, D., Germaine, K. J. and Dowling, D. N. (2015), "Plant growth promotion induced by phosphate solubilizing endophytic Pseudomonas isolates", *Frontiers in Microbiology*, Vol. 6, pp. 745.

Rashed, N. M. M. (2002), *Effect of fertilization on the growth and storability of some aromatic plants*, M.Sc. Thesis, Faculty of Agriculture, Kafer ElSheikh, Tanta University, Egypt.

Rekaby, A. M. (2013), *Improving the productively of coriander plants by the use of some unconventional treatments*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Egypt.

Sakr, W. R. (2005), *Effect of organic and bio fertilization on growth and active constituent production of senna plants*, Ph.D. Thesis, Faculty of Agriculture, Cairo University, Egypt.

Sanjeeva, M. B., Gangadhar, G., Rao, Eswar and Venkatachalapathi, V. (2018), "Effect of sources and levels of organic manures on growth and yield of black cumin", *International Journal of Science, and Research*, Vol. 8 No. 8, pp. 229–231.

Sharaf, M. S. and Khattab, M. E. (2004), "Effect of fertilization with inorganic, organic and biofetilizer on growth, yield and volatile oil constituents of fennel (*Foeniculum vulgare*, Mill.)", *Journal of Agriculture Sciences*, Vol. 29 No. 9, pp. 5245–5264.

Shariatmadari, Z., Riahi, H. and Shokravi, S. (2011), "Study of soil blue-green algae and their effect on seed germination and plant growth of vegetable crops", *Rostaniha*, Vol. 12 No. 2, pp. 101–110.

Shehata, S. A., Ahmed, Y. M., Emad, A. and Darwish, O. (2011), "Influence of compost rates and application time on growth, yield and chemical composition of snap bean (*Phaseolus vulgaris*, L.)", *Australian Journal of*

Basic and Applied Sciences, Vol. 5 No. 9, pp. 530–536.

Sindhu, S. S., Sehrawat, A., Sharma, R. and Dahiya, A. (2016), "Biopesticides: use of rhizosphere bacteria for biological control of plant pathogens", *Defence Life Science Journal*, Vol. 1 No. 2, pp. 135–148.

Sokhangoy, S. H., Ansari, Kh. and Asli, D. E. (2012), "Effect of bio-fertilizers on performance of dill (*Anethum graveolens*)", *Iranian Journal of Plant Physiology*, Vol. 2 No. 4, pp. 547–552.

Somayeh, Gh. N. and Hashem, A. (2015), "Effects of phosphorus fertilization and Pseudomonas fluorescens strain on the growth and yield of faba bean (*Vicia faba* L.)", *Idesia (Arica)*, Vol. 33 No. 4, pp. 15–21.

Weller, D. M. (1988), "Biological Control of Soilborne Plant Pathogens in the Rhizosphere with Bacteria", *Annual Review of Phytopathology*, Vol. 26, pp. 379–407.

Zian, A. H. and Aly, M. M. (2020), "Impact of co-inoculation with *Rhizobium leguminosarum* and some plant growth promoting Rhizobacteria against *Rhizoctonia solani* and *Fusarium oxysporum* infected faba bean", *Journal of Plant Protection and Pathology*, Vol. 11 No. 9, pp. 441–453.