RESEARCH ARTICLE OPEN ACCESS

NEW VALLEY JOURNAL OF AGRICULTURAL SCIENCE
Published by Faculty of Agriculture, New Valley University, Egypt

Print ISSN 2805-2420 Online ISSN 2805-2439

10.21608/nvjas.2024.284464.1282

Enhancing the Productivity of Fennel (Foeniculum Vulgare Mill.) Plants Using Some Organic and Bio Fertilizers Treatments

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Received: 10/05/2024

Revised: 18/06/2024

Accepted: 25/06/2024

Published: 01/07/2024

Abstract

This study, conducted on a private farm in Kuwait Village, El-Kharga New Valley Governorate, Egypt, over two seasons (2022/2023 and 2023/2024), investigated the effects of organic fertilizers and biofertilizers on fennel (Foeniculum vulgare Miller) plants. The research aimed to improve yield productivity and quality. The study examined two organic fertilizers (poultry and cattle manure) and biofertilizers including a mixture of bacteria (*Azotobacter chrococum*, *Azospirulm bracilianse*, *Bacillus polymaxa*) and Azolla extract. Results showed that all treatments significantly improved plant growth characteristics, fruit yield, and volatile oil yield compared to untreated plants. The highest values for studied parameters were recorded with high-level poultry manure (10 m3/feddan). Combining the bacterial mixture with Azolla extract also proved effective. The interaction of organic and biofertilizers significantly affected all studied parameters, with the most effective treatment being high-level poultry manure combined with bacterial mixture and Azolla extract. Gas chromatographic analysis revealed 12 compounds in the fennel oil. The main chemical compounds (estragole, d-limonene, l-fenchone, and anethole) showed the highest percentages among volatile oil constituents. The study demonstrates the potential of organic and biofertilizers to enhance fennel growth, yield, and oil quality.

Keywords: Poultry manure, cattle manure, bio-fertilizers, Azolla, fennel

Introduction

Fennel (*Foeniculum vulgare,* Mill.) is an herbaceous plant belonging to the Umbelliferae (*Apiaceae*) family; it is native to North Africa, the Mediterranean Region, southern Europe, and Asia. Where it is cultivated mainly in Egypt's upper governors such as Minia, Fayoum, Beni Suef, and Assiut. Egypt comes fifth among countries, producing fennel fruits as it produces 3.3% of total amounts of world exports (**Choi and Hwang, 2004; Abd El-Wahab and Mehasen, 2009; Trade Map, 2022**).

The fennel plant contains volatile oil in all parts of the plant (leaves 1-1.5%, root 0.6-0.7%, and seeds 2-6%). The main components of fennel volatile oil are anethole, methyl chavicol, fenchone and limonene, making it exploitable in the medical, food, and cosmetic industries. The active ingredients in the fennel plant are used in many pharmaceutical industries (treating coughs, stomach pain, flatulence, indigestion in children, and increasing milk production in mothers). In addition, fennel fruits are considered to have high nutritional value, as they contain protein (18-20%), fixed oil (12-18%) and fiber (45%), which helps reduce cholesterol and regulate its levels in the human liver **(Ghanbari *et al*., 2013; Telci *et al*., 2019; Rezaei-Chiyaneh *et al*., 2020).**

On the other hand, organic fertilizers are important for aromatic plants to productivity the best in terms of clean agriculture, it provides safety for human health and is environmentally friendly, therefore, organic fertilizers can be relied upon as a suitable alternative to mineral fertilizers, in addition to their clear role in improving the nature and structure of the soil and also improving its ability to retain moisture **(Bhattacharyya et *al*., 2008; Dauda *et al*., 2008; Abd El-Latif *et al*., 2010; El Husieny *et al*., 2020; Singh *et al*., 2020).** Organic manure is one of the main components of soil, which improves the natural, chemical, and biological characters of Soils and the processes that occur in them. Provides the nutrients needed for plant growth. It contains organic fertilizers and many beneficial microorganisms. Their metabolism Products can transform a look that cannot be achieved any other way Nutrients exist in forms that are accessible during biological processes, thus improving soil and seed fertility Germination, root system development and plant biomass **(Rajendran and Devaraj., 2004; Madrid *et al*., 2007).** Organic fertilizers (livestock and poultry manure) improve soil compaction, raise soil fertility, improve pH of the soil, increase microorganisms activity, improve root distribution, and produce better crops in the long term, of course along with providing the necessary nutrients for the plant **(Mohammed and Khattak., 2009).** Focusing on cattle manure for medicinal plants, it has been shown that these materials increase the productivity of fertilized plants and effectively affect the physical, chemical and biological properties of the oil. Cattle manure has many advantages, such as retaining water in the soil and containing nutrients **(Sharma., 2002; Chatterjee., 2002; Akbarinia *et al*., 2003).** Chicken manure is one of the greatest sources of organic fertilizer compared to other manures. Research reported that treating chicken manure on crops gave a significant response. This happens because chicken manure decomposes relatively quickly it contains an appropriate nutrient level compared to equivalent fertilizer (**Widowati *et al*., 2005).**

Biofertilizers can help plants absorb and facilitate nitrogen, phosphorus and potassium more efficiently and safely. Biofertilizers are products that contain living cells of many different microorganisms. This can be inoculated with soil or plant seeds. It can help enrich the root zone or inner part of the plant to improve growth by facilitating elements that are nutritionally important to the plant from an unsuitable form to a readily available form. Biofertilizers have different roles than mineral and organic fertilizers, as they do not provide any nutrients directly to plants. Its production is

simple and relatively cheap compared to chemical and organic fertilizers. The use of biofertilizers containing many microbial strains can lead to a significant reduction in the use of mineral fertilizers and thus obtain high-quality products without harming public health. Soil microorganisms can also be used by fixing atmospheric nitrogen and increasing nutrient availability. Soil, as well as decomposing plant materials and converting them into valuable organic materials. Biofertilizers can reduce production costs and increase yields by providing the soil with available nutrients and growth-promoting substances **(Mitin *et al*., 2010).** Biofertilizers mainly contain nitrogen fixers, phosphate solutes, silicate bacteria, etc. These microorganisms may affect plants through one or more mechanisms, such as fixing nitrogen and mineralizing phosphorus, producing a growth-promoting substance, producing organic acids, enhancing the absorption of micronutrients, as well as protecting against and resisting pathogens. The use of biofertilizers has increased production of various plants through a high percentage of some vitamins, key amino acids, as well as proteins. The positive effects of rhizobacteria on growth are not only due to nitrogen fixation in the rhizosphere, but also related to the provision of antibiotics and growth enhancing substances such as phytohormones. Some bacteria and fungi can also dissolve and facilitate phosphate **(Hassan *et al*., 2012; Glala *et al*., 2010; Hasan *et al*., 2019; Abdel Wahab and Hassan., 2013).**

Azolla is an effective nitrogen fixer in freshwater. Azolla works to fix nitrogen in the atmosphere through symbiotic living and mutual benefit with the cyan bacterium *Anabaena azolla*. Found in the cavity of the dorsal lobe of its leaves. Azolla is also considered a rich source of protein and essential amino acids, and also contains many vitamins, such as vitamin A, vitamin B12, and beta carotene. It is also rich in minerals, such as calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn). The protein composition of Azolla is 25-35% on a dry weight basis **(Parashuramulu *et al*., 2013; Bhuvaneshwari and Singh., 2015).**

Material and Methods

Explanation of study location

The procedures for this study were completed on a private farm in the village of Kuwait in Kharga, New Valley Governorate, Egypt, during 2022/2023 and 2023/2024 seasons, to determine the effect of two organic fertilizers (poultry and livestock manure) and biofertilizers (bacteria mixture of Sewairi (MBS) and Azolla (AZ) on vegetative traits, fruit yield, volatile oil percentage, oil yield and its chemical components of fennel (*Foeniculum vulgare,* Mill.) plants as an attempt to improve the yield productivity and quality.

Fennel fruits were obtained from the Department of Medicinal and Aromatic Plants, Agricultural Research Center in Giza, Egypt. In addition, cattle manure was obtained from a private cattle manure farm in the city of Al-Kharga, and poultry fertilizer was also obtained from a private poultry farm in the city of Al-Kharga, Egypt. Azolla and bacteria mixture (Al-Sewairi) were purchased from the Microbiology Department at the Land and Water Research Center in Egypt

Experimental Soil Analysis

Black. (1965) and Page *et al*. (1982) Methodologies were used to analyze the physical and chemical properties of five soil samples randomly selected from the soil surface used in this study (0-30 cm depth). The following table includes the complete soil analysis.

Table (1): Natural and chemical properties of the soil used in the study (average of the two agricultural seasons)

Physical properties					Chemical properties		Soluble ions meq/100 g soil (Extract 1:5)							Available nutrients		
							Cations				Anions					
Soil type	Sand (%)	Silt %	Clay%	E.C. (dS/m)	pH 1:2.5	CaCO3	Ca2+	Mg2+	Na+	K+	Hco3-	Cl-	SO4 =	K PPM	P PPM	N PPM
Light clay sand	58	15	27	1.4	6.7	5.2	3.1	1.9	0.9	0.1	1	6.9	7	170	7.5	10

Table (2): chemical properties of poultry and cattle manure (Average of both seasons)

SER.	COMPONENT	POULTRY MANURE	CATTLE MANURE
1	EC.dsm-1(1:2 ex.)	4.4	9.4
2	pH (1:2 w/v)	7.1	9.5
3	C/N%	23	21
4	Mg (PPM)	600	750
5	Mn (PPM)	300	400
6	Zn (PPM)	140	1700
7	Fe (PPM)	1400	1700
8	N%	2.1	2.5
9	P %	1.8	4.6
10	K %	0.8	1.3

Experimental design and tested treatments

A randomized complete block design (RCBD) was used and three replications were conducted to conduct this experiment. The main plot were poultry manure rates (PM1=5 and PM2=10) m^3/fed, and cattle manure rates (CM1=15 and CM2=30) m^3/fed, and NPK at half recommended dos as follows; ammonium nitrate (33.5%) at 100 kg/fed, calcium superphosphate (15.5% P_2O5) at 100 kg/fed, and potassium sulfate (48% K_2O) at 25 kg/fed. While in the sub-plots, was used mixture of Seweiri bacteria (*Azotobacter chrococum, Azospirulm bracilianse, Bacillus polymaxa*) Concentration of microorganisms and Azolla fertilizer.

Cattle manure and poultry manure were added 30 days before planting, the land was turned and irrigated, and each subplot with dimensions of 3.0 x 2.5 m^2 contained 3 rows spaced 60 cm apart. Plants are placed at a distance of 30 cm^2 from each other. The direction of the lines was from north to south. Planting took place on the eastern half of the line on 5th November in both seasons. A mixture of Seweiri bacteria (MBS) was added to the fruits with gum Arabic before planting. Germination occurred a 7days after planting. The thinning process was done twice, 30 to 60

days after planting. Calcium super phosphate was added with planting, and after 30 days of planting, potassium and half an amount of ammonia nitrate were added, and the other half was added after 60 days of planting. Azolla (AZ) was added by injecting it under the plants in an amount of 45 ml/l per plant 10 days after planting, and the confirmation dose was 40 days after planting. The number of irrigations during the planting season reached 10 irrigations. The flowering stage begins 60days after planting, and the holding fruits begins 60 days after flowering. Chlorophyll samples were taken 50 days after planting, and all other standard agricultural operations were done.

Recorded data

Growth measurements were recorded during the first week of May, including plant height (cm), branch number/plant, herb dry weight (g), umbel number /plant, fruit yield/plant (g) and /fed. (kg). volatile oil percentage, volatile oil yield per plant (ml) and feddan (L) and volatile oil components.

Volatile oil components

Volatile oil sampling was performed using a Hewlett-Packard 5890 A series 11 instrument equipped with a flame ionization detector (FID) and a carbon-wax fused silica column (50 m × 0.25 mm, 0.32 μm film thickness). Helium was used as the carrier gas at a flow rate of 3 ml/min. The oven temperature was around 40°C for two minutes, then it was programmed to rise from 40 to 190°C at a rate of 4°C every minute. The operating time was 35.60 minutes. A 1 microliter sample of volatile oil was injected (spill ratio 1:30).) manually. Using a Hewlett-Packard 3396 integrator, peak area percentages were calculated. Components of the volatile oil were identified by comparing mass spectra and retention times with those of standards, the NIST library of GC-MS system, and literature data **(Mazrou., 2019).**

Statistical analysis

All measurements obtained in this study were reviewed and statistically analyzed according to **MSTATE-C (1986)** and means were compared using L.S.D. The 5% test according to **Mead *et al*. (1993).**

Results

Growth measurements

The obtained data in Table 3 shows the effect of three different levels of poultry and livestock manure and half the recommended dose of NPK on plant height, branch number /plant and herb dry weight (g/plant) of fennel (*Foeniculum vulgare*, Mill.) plants. All growth parameters were significantly affected by poultry levels, livestock manure and half the recommended dose of NPK when compared to untreated plants. However, the best growth was obtained from plants treated with poultry manure at $10m^3$/fed., followed by cattle manure at 30 m^3/fed. Generally, growth measurements were increased with increasing organic manure levels. These results are consistent with his findings of **El-maged *et al*. (2008), El-Leithy *et al*. (2009), Kassem *et al.* (2016), Ali *et al.* (2017) and Ali. (2023),** who reported that fennel plants responded well to organic manure**.**

From data presented in Table 3, it is cleared that bacteria mixture of Seweiri with Azola (AZ) addition alone or together significantly increased plant growth compared to unfertilized in both seasons. The best values of growth parameters were obtained from Double inoculation fennel plants by mixture of Seweiri bacteria (*Azotobacter chrococum, Azospirulm bracilianse, Bacillus polymaxa*) with Azolla extraction. The positive effect of bio fertilization on enhancing plant growth was reported by **Silem (2013), Kassem (2016), Badran (2017), Youssef (2020) and Allam (2021)** on fennel plants, **Abou Hussien (2020)** on rice plants and **Atteya (2022)** on jojoba plant**.**

The obtained results in Table (3) indicated that the best results of growth measurements were obtained by adding poultry manure at a rate of 10 m^3/fed. and bacteria mixture and Azolla extract compared to the rest combined treatments in both seasons.

Table (3): Impact of organic and biofertilizers on vegetative growth parameters of fennel (*Foeniculum vulgare* Mill.) plants during 2022/2023 and 2023/2024 seasons

Organic matter (A)	2022/2023 season					2023/2024season				
	Biofrtilizers (B)									
	Control	MBS	AZ	MBS +AZ	Mean (A)	Control	MBS	AZ	MBS +AZ	Mean (A)
	Plant height (cm)									
Control	145.2	148.6	147.6	150.0	147.8	148.8	155.3	150.0	153.3	150.8
NPK 50 %	153.5	160.9	155.7	164.8	158.7	155.8	163.0	159.1	168.2	161.5
PM (1)	155.3	161.2	157.0	167.1	160.1	158.0	164.2	160.3	169.4	163.0
PM (2)	164.3	173.1	168.0	178.8	171.0	170.6	178.4	175.8	181.9	176.7
CM (1)	152.8	157.4	154.0	159.4	155.9	154.2	159.2	156.0	160.5	157.5
CM (2)	162.8	171.2	166.3	174.2	168.6	165.8	175.6	170.0	178.6	172.5
Mean (B)	155.6	162.1	158.1	165.7		158.8	165.3	161.8	168.6	
L.S.D at$_{5\%}$	A= 1.19	B=0.45		A+B= 1.10		A= 1.30	B= 0.49		AB= 1.21	
Number of branches										
Control	8.16	9.58	8.91	10.33	9.25	9.16	11.16	10.58	11.58	10.62
NPK 50 %	11.00	14.16	12.25	15.08	13.12	12.00	14.91	13.25	15.50	13.91
PM (1)	11.5	14.75	13.00	15.33	13.64	12.66	15.00	13.91	15.83	14.35
PM (2)	15.58	19.16	17.25	22.58	18.64	16.33	21.00	19.41	24.08	20.20
CM (1)	10.58	11.83	11.08	13.08	11.64	11.75	13.00	12.00	14.00	12.68
CM (2)	14.08	16.33	15.41	17.08	15.72	14.41	16.91	16.00	18.33	16.41
Mean (B)	11.81	14.30	12.98	15.58		12.72	15.33	14.19	16.33	
L.S.D at$_{5\%}$	A= 0.33	B= 0.2		AB= .51		A= 0.44	B= 0.29		AB=0.72	
Herb dry weight (g)										
Control	102.4	110.5	107.3	112.5	108.2	103.8	111.5	108.2	113.4	109.2
NPK 50 %	120.8	126.0	123.3	128.6	124.6	121.3	128.2	125.1	131.2	126.4
PM (1)	122.3	127.7	125.3	130.7	126.5	124.0	129.0	127.1	133.0	128.3
PM (2)	135.4	141.2	138.9	143.8	139.8	136.7	143.7	140.4	146.0	141.7
CM (1)	114.6	121.0	117.6	123.8	119.3	116.4	122.9	119.7	126.5	121.4
CM (2)	128.0	136.3	131.2	140.9	134.1	129.5	137.6	132.8	141.8	135.4
Mean (B)	120.6	127.1	123.9	130.1		121.9	128.8	125.5	132.0	
L.S.D at$_{5\%}$	A= 0.59	B= 0.49		AB= 1.20		A= 0.50	B=0.49		AB=1.20	

Yield characteristics

As shown in Table 4, it is cleared that umbel number /plant, fruit yield per plant (g) and fed. (Kg) of fennel (*Foeniculum vulgare,* Mill.) plants were significantly affected by different rates of poultry, cattle manure and half the recommended dose of NPK compared to untreated plants in both seasons. However, the best growth parameters were recorded with poultry manure at 10m^3/fed., followed by cattle manure at 30 m^3/fed. Generally, yield trials were increased gradually with increasing organic manure rates. The results obtained are consistent with those obtained by **El-Leithy *et al*. (2009), Godara (2014), Wafaa, (2017), Ali *et al*. (2017), Gahory *et al*. (2022) and Ali. (2023),** who reported that fennel plants responded well to organic manure.

From obtained data presented in Table 4, it is clearly indicated that adding mixture of Seweiri bacteria with Azola (AZ) alone or together significantly increased fruit yield

compared to untreated plants in both seasons. The best values of yield parameters were obtained from plants treated with Double inoculation of mixture of Seweiri bacteria (*Azrotobacte chrococum, Azospirulm bracilianse, Bacillus polymaxa*) with Azolla extraction. The positive effect of bio fertilization on enhancing yield characteristics was observed by **Selim (2013), Kassem (2016), Wafaa (2017), Mazrou (2019), Ibrahim (2020) and Ghaderimokri (2022)** on fennel plants.

The obtained results in Table 4 indicate that the combined treatment of organic and biological fertilization was significant in the two seasons. Accordingly, the best results of yield parameters were obtained by poultry manure at a rate of 10 m^3/fed. with bacteria mixture and Azolla extraction compared to the rest of the overlapping treatments in two experimental seasons.

Table (4): Impact of organic and some biofertilizers on yield measurements of fennel (*Foeniculum vulgare* Mill.) during 2022/2023 and 2023/2024 seasons

Organic matter (A)	2022/2023 season					2023/2024 season				
	Biofrtilizers (B)									
	Control	MBS	AZ	MBS +AZ	Mean (A)	Control	MBS	AZ	MBS +AZ	Mean (A)
	Umbel number/plant									
Control	35.50	39.00	37.25	40.16	37.97	38.25	41.25	39.50	42.33	40.33
NPK 50 %	42.16	46.91	44.25	49.58	45.85	43.50	47.41	45.50	50.25	46.66
PM (1)	43.08	49.00	45.58	51.33	47.25	45.08	50.00	46.58	52.58	48.56
PM (2)	55.25	58.75	57.00	61.75	58.18	56.66	61.66	59.75	64.25	60.58
CM (1)	41.91	45.08	43.50	47.83	44.58	43.00	46.08	44.41	48.16	45.41
CM (2)	50.5	55.25	52.08	58.25	54.02	51.41	57.00	55.33	59.91	55.91
Mean (B)	44.73	49.00	46.69	51.48		46.31	50.56	48.51	52.91	
L.S.D at$_{5\%}$	A= 0.64	B= 0.34		AB= 0.84		A= 0.40	B= 0.42		AB=1.04	
Fruit yield/plant (g)										
Control	45.16	48.57	47.65	50.58	47.99	46.83	51.08	49.08	52.25	49.81
NPK 50 %	58.41	65.5	62.00	68.00	63.47	59.66	67.25	64.41	69.00	65.08
PM (1)	59.08	66.91	63.00	68.66	64.41	60.33	69.00	65.58	70.08	66.25
PM (2)	72.75	77.91	75.08	80.50	76.56	74.25	79.50	77.58	82.66	78.50
CM (1)	52.91	57.08	55.08	59.75	56.20	54.16	58.75	56.41	61.50	57.70
CM (2)	67.08	71.66	69.58	74.08	70.60	68.16	73.16	70.91	76.08	72.08
Mean (B)	59.23	64.61	62.06	66.93		60.56	66.45	64.00	68.59	
L.S.D at$_{5\%}$	A= 0.44	B= 0.40		AB= 0.99		A= 0.60	B=0.34		AB=0.84	
Fruit yield /fed. (kg)										
Control	1445.3	1554.5	1524.8	1618.7	1535.8	1498.7	1634.7	1570.7	1672.0	1594.0

NPK 50 %	1869.3	2096.0	1984.0	2176.0	2031.3	1909.3	2152.0	2061.3	2208.0	2082.7
PM (1)	1890.7	2141.3	2016.0	2197.3	2061.3	1930.7	2208.0	2098.7	2242.7	2120.0
PM (2)	2328.0	2493.3	2402.7	2576.0	2450.0	2376	2544.0	2482.7	2645.3	2512.0
CM (1)	1693.3	1826.7	1762.7	1912.0	1798.7	1733.3	1880.0	1805.3	1968.0	1846.7
CM (2)	2146.7	2293.3	2226.7	2370.7	2259.3	2181.3	2341.3	2269.3	2434.7	2306.7
Mean (B)	1895.6	2067.5	1986.1	2141.8		1938.2	2126.7	2048.0	2195.1	
L.S.D at$_{5\%}$	A= 14.08		B= 13.05		AB= 31.97	A= 19.42		B= 11.08		AB= 27.14

Volatile oil production

Data presented in Table (5) revealed that volatile oil percentage, volatile oil yield/plant (ml) and /fed. (L) of fennel plants considerably increased as a result of poultry levels, cattle manure and half the recognized dose of NPK treatments in both seasons. Application of poultry manure at 10 m^3/fed. led to a significant increase in volatile oil percentage, volatile oil yield per plant and fed., followed by cattle manure at 30 m^3/fed. in two successive seasons. These results are in agreement with those reported by **Mohamed and Abdu (2004), El-Leithy *et al.* (2009), Moradi (2011) and Ali (2023),** who stated that fennel plants responded well to organic manure compared to chemical fertilizers.

Regarding the effect of treatments of mixture of Seweiri bacteria (*Azotobacter chrococum, Azospirulm bracilianse, Bacillus polymaxa*) and Azolla extract (AZ), the presented data in Table (5) showed that volatile oil percentage, volatile oil yield per plant and feddan of fennel plants were significantly increased by mixture of Seweiri bacteria and Azolla extract compared to the untreated plants in both seasons. Plants treated with mixture of Seweiri bacteria (MBS) with Azolla extract (AZ) led to an improvement in the volatile oil %, the volatile oil yield per plant and feddan. The positive effect of bio fertilization on enhancing volatile oil parameters was observed by **Selim (2013), Kassem (2016), Ali (2017), Ibrahim (2020) and Allam (2021)** on fennel plants**.**

The interaction effect between different rates of poultry, cattle manure and half the recommended dose of NPK, mixture of Seweiri bacteria (MBS) and Azolla extract (AZ) was significant in volatile oil percentage, oil yield per plant and feddan in two seasons. Maximum values of fruit characteristics were recorded when plants treated with high levels of poultry manure (10 m^3/fed.) combined with mixture of Seweiri bacteria (MBS) and Azolla extract (AZ) compared to the untreated plants during the two growing seasons, as shown in Table (5).

Table 5. Impact of organic and bio-fertilizers on volatile oil parameters of fennel (*Foeniculum vulgare* Mill.) during 2022/2023 and 2023/2024 seasons

Organic matter (A)	2022/2023 season					2023/2024 season				
	Biofrtilizers (B)									
	Control	MBS	AZ	MBS +AZ	Mean (A)	Control	MBS	AZ	MBS +AZ	Mean (A)
	Volatile oil (%)									
Control	1.26	1.38	1.33	1.45	1.35	1.36	1.43	1.41	1.54	1.43

NPK 50 %	1.44	1.6	1.52	1.63	1.54	1.51	1.64	1.59	1.68	1.60
PM (1)	1.49	1.61	1.54	1.66	1.58	1.53	1.67	1.60	1.73	1.63
PM (2)	1.73	1.83	1.78	1.87	1.80	1.78	1.90	1.84	1.91	1.86
CM (1)	1.38	1.46	1.42	1.50	1.44	1.45	1.56	1.51	1.59	1.53
CM (2)	1.63	1.75	1.69	1.79	1.71	1.69	1.79	1.74	1.85	1.76
Mean (B)	1.45	1.60	1.55	1.65		1.55	1.67	1.61	1.71	
L.S.D at5%	A=0.015		B=0.008		AB=0.021	A=0.008		B= 0.005		AB= 0.013
Volatile oil yield/plant (ml)										
Control	0.57	0.67	0.63	0.73	0.65	0.63	0.73	0.69	0.80	0.71
NPK 50 %	0.84	1.02	0.94	1.11	0.98	0.90	1.10	1.02	1.15	1.04
PM (1)	0.88	1.08	0.97	1.14	1.02	0.92	1.15	1.05	1.21	1.08
PM (2)	1.26	1.42	1.33	1.50	1.38	1.32	1.51	1.43	1.58	1.46
CM (1)	0.73	0.83	0.78	0.90	0.81	0.79	0.91	0.85	0.98	0.88
CM(2)	1.09	1.25	1.18	1.33	1.21	1.15	1.31	1.23	1.41	1.27
Mean (B)	0.89	1.05	0.97	1.12		0.95	1.12	1.04	1.19	
L.S.D at5%	A= 0.015		B= 0.008		AB= 0.021	A= 0.023		B= 0.007		AB=0.018
Volatile oil yield/feddan (L)										
Control	18.22	21.46	20.34	23.49	20.88	20.38	23.49	22.15	25.76	22
NPK 50 %	26.94	35.54	30.30	35.47	31.56	28.84	35.44	32.78	37.10	33.54
PM (1)	28.30	34.62	31.13	36.54	32.65	29.61	36.95	33.73	38.95	34.81
PM (2)	40.43	45.64	42.77	48.18	44.25	42.46	48.52	45.85	50.71	46.88
CM (1)	23.43	26.67	25.09	28.81	26	25.25	29.33	27.32	31.36	28.31
CM (2)	35.08	40.14	37.78	42.6	38.90	36.87	42.07	39.49	45.05	40.87
Mean (B)	28.73	33.68	31.23	35.85		30.57	35.96	33.55	38.15	
L.S.D at5%	A= 0.46		B= 0.26		AB= 0.65	A= 0.72		B= 0.21		AB= 0.53

Volatile oil constituents

The most important results obtained from gas chromatographic (GC/MS) analysis showed that fennel oil contains **(12)** various compounds. When compare the percentages of active compounds in volatile oil, It has been observed that Estragole - D-Limonene- L-Fenchone - Anethole contain the best percentages of volatile oil constituents compared to other compounds. The highest average was recorded for the Estragole compound (78.2) in PM (2) + MBS+AZ , followed by PM(1)+MBS+AZ , which recorded (77.53), followed by control, which was (77.2), while the highest average was for the compound D-Limonene (13.27) in treatment CM(2)+MBS+AZ, followed by treatment 50% of NPK , which recorded (12.70), the highest percentages were for the compound L-Fenchone (4.85) in treatment PM (2) + MBS+AZ , While the highest percentage of anethole (3.44) was in the control, Which indicates that the treatments used were positive in improving the proportions of some of the main chemical compounds of fennel oil. Also that the treatments used in this study have a clear effect on some of the main chemical constituents of fennel oil, and this is consistent with those reported that by **Mahfouz *et al.* (2007) and Masada *et al.* (2007),** who

concluded that the percentages of volatile oil components of the fennel plant were increased through fertilization. This is due to the positive factors of fertilization in this study and its effect in facilitating the important nutrients needed for the plant, and this result is consistent with findings of **Mahfouz *et al*. (2007),** who stated that organic and biological fertilizers causes an increase in the compounds found in the fennel volatile oil.

Table (6). Impact of organic and biofertilizers on volatile oil identification of fennel (*Foeniculum vulgare* Miller.) during 2022/2023 and 2023/2024 seasons

No	Component Name	R T	Treatments				
			Control	NPK 50%	CM(2)+ MPS+AZ	PM(1)+ MPS+AZ	PM(2)+ MPS+AZ
1	α-Pinene	6.316	0.96	0.98	1.4	1.13	1.03
2	β-Phellandrene	7.281	0.25	0.23	0.33	0.27	0.25
3	β-Myrcene	7.691	0.31	0.33	0.43	0.34	0.3
4	α-Phellandrene	8.078	----	---	0.21	---	---
5	p-Cymene	8.609	0.32	0.30	0.38	0.35	0.27
6	D-Limonene	8.725	11.9	12.7	13.27	11.89	11.38
7	Eucalyptol	8.811	0.45	0.47	0.59	0.51	0.54
8	trans-β-Ocimene	8.933	0.71	0.68	0.82	0.71	0.63
9	γ-Terpinene	9.533	0.39	0.42	0.5	0.48	0.31
10	L-Fenchone	10.382	4.08	4.00	4.4	4.85	4.38
11	Estragole	13.559	77.2	76.2	74.53	77.53	78.2
12	Anethole	15.852	3.44	3.40	3.15	1.94	2.7
Number of vehicles identified			11	11	12	11	11
Total percentage of identified compounds			100	100	100	100	99.99

Discussion

The obtained results in current study revealed that the efficiency of organic fertilizer to increase the productivity, yield, and ingredient materials of fennel (*Foeniculum vulgare* Miller.). The increase in these previous qualities can be due to the basic role of organic fertilizers in the biological and functional processes within the plant. Which were mentioned by many investigators such as **Franz. (1973),** 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. **Schachtschable (1979) and Bohn *et al.* (1985)** 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 minimizes the loss of nutrients by leaching **Saber (1997**) and it caused an increase in microbial activities in the root zone when supplied it to the soil. **Taiwo *et al.* (2002) and Mashali (1997)** demonstrated that incorporation of organic manure in the soil improves permeability of soil and release carbon dioxide and certain organic acids during decomposition. **Reynders and Vlassak (1982)** suggested that organic manures contain microorganism for example, *Azospirillum* and *Azotobacter* which are fix N and release phytohormones such as, GA, IAA and cytokinins that are led to promote the growth, dry matter and nutrient absorption. **Follet *et al.* (1981)** concluded the positive roles of organic fertilization as follow: improving most of the

soil properties and its ability to retain water, increasing total nitrogen, organic matter and humus in the soil, releasing essential nutrients faster through microbial decomposition and improving the presence of most microelements as they are more readily available in a suitable pH range.

On the other hand, the promoting effect of bio-fertilization treatments on growth, yield components and chemical constituents of fennel (*Foeniculum vulgare* Mill.) plants the many biological and physiological roles of these fertilizers have become clear and have been confirmed by many authors, such as **Paron *et al.* (1997) and Hussein (1990).** Bio-fertilization systems also can raise the quality of the soil, more the availability and uptake of nutrients in the soil and increase crop productivity. This biosystem's microorganisms fix nitrogen, dissolve phosphate and potassium from the soil, create chemicals that encourage plant growth, and shield the plant from diseases and biotic and abiotic stresses **(Mącik *et al.*, 2020; Viji *et al*., 2021; Shalaby *et al.* 2022).**

Conclusion

In this study, it was found that the combination of poultry manure at 10 m^3/fed. + cattle manure at 30 m^3/fed. + mixture of Seweiri bacteria with Azola (AZ) improve the plant growth, yield and volatile oil yield and component of fennel (*Foeniculum vulgare* Mill.) plants.

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تحسين إنتاجية نباتات الشمر باستخدام بعض المعاملات العضوية والمخصبات الحيوية

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الملخص العربي

تم إجراء هذا البحث بمزرعة خاصة بقرية الكويت بمحافظة الوادي الجديد الخارجة بمصر خلال الموسمين التجريبيين 2023/2022 و 2024/2023 لتحديد تأثير اثنين من الأسمدة العضوية (زرق الدواجن وروث الماشية) والمخصبات الحيوية (خليط من البكتريا ازوتوبكتر كروكيم وازوسبريليم براسيليانسي وباسلس بلوماكس) والازولا على الصفات الخضرية ومحصول الثمار ومحصول الزيت الطيار ومكوناته الكيميائية كمحاولة لتحسين إنتاجية وجودة محصول نبات الشمر. اظهرت النتائج عن زيادة معنوية في صفات نمو النبات (ارتفاع النبات، عدد الأفرع، الوزن الجاف للعشب، عدد النورات/نبات، محصول الثمار لكل نبات والفدان، كذلك إنتاج الزيوت الطيارة بنسبة عالية من زرق الدواجن (10 م^3/فدان) سجلت أعلى القيم لهذه المعايير المدروسة ، كما سجلت إضافة خليط بكتريا مع مستخلص الأزولا معًا فعاليته في زيادة الخصائص ضمن هذه الدراسة تأثرت جميع المعاملات بشكل معنوي عن معاملة الكنترول.

أدت معظم المعاملات مجتمعة إلى زيادة كبيرة في جميع القياسات في هذه الدراسة. وكانت نسبة عالية من زرق الدواجن (10 م^3/فدان) بالإضافة إلى تلقيح نباتات الشمر بخلطها مع خليط البكتيريا و مستخلص الأزولا هي أكثر المعاملات فعالية. كما تأثرت المكونات الرئيسية للزيت الطيار بمعاملات الأسمدة العضوية والحيوية. كما يتضح من نتائج هذه الدراسة أن نتائج التحليل الكروماتوجرافي الغازي لمكونات الزيت الطيار يحتوي على (12) مركباً. عند مقارنة النسب فيما يتعلق بالمركبات الكيميائية للزيت الطيار، نلاحظ أن مركبات الاستراجول، د- ليمونين، ل- فينشون، وأنيثول تحتوي على أعلى نسب من مركبات الزيت الطيار مقارنة بالمركبات الأخرى.

الكلمات الدالة:- زرق الدواجن، روث الماشية، الأسمدة الحيوية، أزولا، الشمر.