Research Journal of Agriculture and Biological Sciences, 5(4): 541-554, 2009

Comparative Study of Some Agricultural Treatments Effects on Plant Growth, Yield and Chemical Constituents of Some Fennel Varieties under Sinai Conditions

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Abstract: Two field trails were conducted during 2002 and 2003 seasons at the research farm of Desert Research Center**,** (El-Maghara – North Sinai Governorate). Two experiments have been done. The first was to study the effect of bio and organic fertilization separately or combined with the addition of chemical fertilization. The second, was to study the effect of irrigation levels (2,4 and 8L/hour) on growth, yield, some chemical compositions and both essential oil percentage and constituents of some fennel varieties (*Foeniculum vulgare* var. *vulgare* Mill. and *Foeniculum vulgare* var. *azoricum* Mill.) Twelve treatments were used; to investigate effect of fertilization and three treatments were used to investigate the effect of irrigation levels. The results showed that in most cases, local or bitter variety (*Foeniculum vulgare* var. *vulgare* Mill.) was superior to sweet or German one (*Foeniculum vulgare* var. *azoricum* Mill.). Generally high chemical fertilization level combined with both bio and organic fertilizers (Bio + Organic + 300kg/feddan ammonium sulphate + 300kg/feddan calcium super phosphate + 100kg/feddan potassium sulphate) increase plant growth, essential oil and chemical constituents. Using (8L/h) dripper or high irrigation rate, generally, gave the best results.

Key words: Fennel,fertilization,irrigation,plant growth,essential oil.

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill) is a member of the family Apiaceae. [1] The Florence fennel (*Foeniculum vulgare* var. *azoricum*) is a variety group with inflated leaf bases which form a bulb-like structure. [2]. The fennel plant is used in many of the culinary traditions of the world and widely used in the preparation of various dishes. [3,4, 5, 6] Fennel is also considered as a spice due to terpenic compounds isolated from its fruits volatile oil [7]. The essential oil of fennel is used to flavor different food preparations and in perfumery industries.[8, 9]

Fennel contains anethole, which can explain some of its medical effects such, to ease flatulence in infant, treat babies with colic or painful teething, relax the intestines and reduce bloating caused by digestive disorders, and many other medicinal uses.[1, 10, 11, 12, 13].

It is still widely used in traditional Arabian medicine as diuretic appetizer and digestive.[14]

It is will known that, sandy soils are poor in their contents of both organic mater and mineral nutrients. So, importance of adding organic, bio and chemical fertilizers can be explained. Those nutrients can be divided into major and minor nutrients which have an important role on plant growth. Also have great effects on yield, chemical constituents and plant active constituents. One of the limiting factors for deserts or sandy soil cultivation is water. Irrigation under desert conditions and water requirements can be considered in such circumstances as economic factor. So to magnifying the retail from desert or sandy soil cultivation both fertilizers quantities and water requirements must be calculated.

There is a global trend to cultivate safe food, free of pollution. So, reducing add chemicals in production of medicinal plants are in most cases agreed with the needs of international markets. Syrian Arab Republic is leader in production of anise, badian (star anise), fennel and coriander, followed by India. While Egypt comes in the eighth rank.[15] The cultivated area in Egypt is about 2000–3000 feddans according to the Ministry of Agriculture Fennel is one of the most important economic medicinal plants grown within the Mediterranean region, in Egypt it's export value amounts up to 10 million US $. Many trails have been done to improve the possibilities of growing fennel on newly reclaimed land within Egypt.[16] The main Egyptian market for fennel is USA, one of the main Egyptian markets for fennel is European markets.[17,18, 19, 20].

Very little information is available on the specific requirements of fennel fertilization on newly reclaimed land.

The aim of this work is to study effect of different fertilization resources i.e., conventional (chemical), bio and compost (organic) separately or mixed, and to investigate effect of irrigation levels on some growth

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characters and both essential oil production and some constituents as well as chemical composition of both local or bitter fennel and German or sweet Fennel plant (nitrogen, phosphorus, potassium and Carbohydrate contents).

MATERIALS AND METHODS

The present work was conducted in the Experimental Farm of The Desert Research Center (DRC), El-Maghara, at North Sinai Governorate during two seasons of 2002 and 2003. Fennel varieties seeds were obtained from Sekem Company and sown in a well-prepared soil. The experimental layout per replicate was 5 × 1 m^2 The experimental layout was 5×1m^2 for each replicate. The distances between lines were 100cm apart; while the distance between hills was 50cm.

The First Experiment (Fertilization): There are 3 resources for fertilization were used chemical (NPK), organic (compost) and Bio fertilizer. The fertilization treatments have been done as follows:

1. Without fertilization (control).
2. Chemical fertilization first level (C1) (calcium super phosphate (150kg/feddan) during land preparation, while ammonium sulphate (150kg/feddan) and potassium sulphate (50kg/feddan)
3. Chemical fertilization second level (C2) (calcium super phosphate (300kg/feddan) during land preparation, while ammonium sulphate (300kg/feddan) and potassium sulphate (100kg/feddan)
4. Organic fertilization (adding compost (O) (20m^3)) where added.
5. Bio fertilization (Bio)(a solution mixture of some bacterial strains) was added.
6. Bio and organic fertilization.
7. First level chemical fertilization combined with Bio fertilization.
8. First level chemical fertilization combined with Organic fertilization.
9. First level chemical fertilization combined with both Bio and Organic fertilizations.
10. Second level chemical fertilization combined with Bio fertilization.
11. Second level chemical fertilization combined with Organic fertilization.
12. Second level chemical fertilization combined with both Bio and Organic fertilizations.

The Second Experiment (Irrigation): Drip irrigation method was used in the study. Three treatments have been done as follow:

1. 2 liter/hour
2. 4 liter/hour
3. 8 liter/hour

Data were recorded on some growth characters (plant height, number of branches, number of umbels and fruits weight per plant). Nitrogen, phosphorus and potassium elements were determined in acid solution, prepared according to [21]. Nitrogen content was determined according to [22], potassium content.[23], phosphorus content.[24] and Carbohydrate content according to [25] . Oil percentage was determined according to the [26].

Essential oil constituents as well as Head Solid State (HSS) and Gas chromatography technique (GC) analyses of the crushed fruits to identify oil constituents as follows: A sample of 2g of fruits was crushed and replaced in the HSS vial, sealed in the presence of an inert gas (N_2), then vials were incubated at 80°C with fast shaking for about 60 min in the Dani-HSS. After 60 min, the headspace aroma was automatically injected into the column (HP-5 capillary 30m × 0.250mm × 0.5 µm film thickness) in the GC HP5890 Series Gas Chromatograph. The injection conditions were as follows: Nitrogen was used as the carrier gas with a flow rate of 1.8 ml/min. Air and hydrogen flow rates were 50 and 50 ml/min, respectively. Temperature program was as follows: Injection temperature at 39.50ºC was held for 5 min, and was the programmed to rise from 40° to 220ºC at rate of 5ºC/min. The maximum temperature was maintained for a further 10 min before cooling. A set of standard compounds representing different chemical groups with a stated purity of 99% by GLC, was obtained from Drugago Company (Holzmiden, Germany).

Complete randomized block design was used. The statistical analysis was carried out using CoStat software program.[27] L.S.D at 5% test was used to compare the average means of different treatments.

RESULTS AND DISCUSSIONS

First Experiment (Effect of Fertilization Resources) Plant Height (Cm): Data in Table (1) show significant differences in plant height (cm/plant) among different treatments. German variety was generally shorter (60.91 and 75.55cm) than the local one (81.42 and95.12cm) allover the studied treatments in both seasons. It is also shown that, in general, increasing fertilization rates led to increases in plant height in both seasons.

Number of Branches (Branches/plant): Concerning the number of branches (branches/plant), data in Table (1) record that, in general, the local variety

Table 1: Effect of fertilization on Plant height (cm) and Number of branches (Branch/Plant) of Fennel during 2002 and 2003 seasons

	Plant height (cm)						No of branches (branch/plant)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Control	66.44	43.33	54.89	67.33	55.00	61.17	4.44	3.06	3.75	4.70	3.70	4.20
Bio	74.78	49.33	62.06	80.78	60.78	70.78	5.29	3.49	4.39	7.33	4.00	5.67
O	78.00	51.89	64.95	91.00	64.11	77.56	5.51	3.67	4.59	7.44	4.15	5.80
Bio+O	81.22	52.44	66.83	93.67	65.89	79.78	5.74	3.71	4.73	7.67	6.78	7.23
Mean	75.11	49.25		83.20	61.45		5.25	3.48		6.79	4.66	
C1	81.11	53.44	67.28	98.22	66.89	82.56	5.76	3.78	4.77	7.67	6.44	7.06
C1+Bio	82.11	56.67	69.39	98.22	72.33	85.28	5.80	4.01	4.91	8.00	6.52	7.26
C1+O	82.22	61.78	72.00	98.78	77.22	88.00	5.81	4.37	5.09	8.11	6.78	7.45
C1+Bio+O	84.44	65.33	74.89	98.89	79.44	89.17	5.97	4.94	5.46	8.33	7.56	7.95
Mean	82.47	59.31		98.53	73.97		5.84	4.28		8.03	6.83	
C2	85.67	69.89	77.78	100.11	79.78	89.95	6.06	5.07	5.57	8.67	6.33	7.50
C2+Bio	86.67	71.67	79.17	102.11	91.11	96.61	6.13	4.62	5.38	8.67	7.07	7.87
C2+O	86.89	75.00	80.95	103.33	95.78	99.56	6.14	5.30	5.72	8.89	6.11	7.50
C2+Bio+O	87.44	80.11	83.78	109	98.22	103.61	6.18	5.69	5.94	9.11	7.74	8.43
Mean	86.67	74.17		103.64	91.22		6.13	5.17		8.84	6.81	
Mean V	81.42	60.91		95.12	75.55		5.74	4.31		7.88	6.10	
Mean F	62.18	70.89	80.42	72.32	86.25	97.43	4.36	5.06	5.65	5.72	7.43	7.82
LSD 5%	F	2.23		F	5.70		F	0.28		F	0.58	
	V	2.37		V	3.48		V	0.5		V	0.39	
	F x V	4.10		F x V	6.03		F x V	0.57		F x V	10	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

plants allover different fertilization treatments was more branching than the German variety. The best result (5.74 and 7.88 branches/plant) for the means of the first and second seasons respectively was obtained using the combined treatments of high chemical fertilization, organic and bio fertilization during the first and second seasons.

Number of Umbels (Umbels/plant): Taking number of umbels (umbels/plant) into consideration, data in Table (2) reveal significant differences among all treatments. Generally, it was noticed that local variety (*Foeniculum vulgare* var. *vulgare* Mill.) was superior in number of umbels/plant than the *Foeniculum vulgare* var. *azoricum* Mill. Moreover, it was found that increasing fertilization levels gave the highest values of the studied parameters in comparison with the control values.

Fruits Yield (gm/plant) and (kg/feddan): The data on fruits yield/plant as shown in Table (3) show significant differences in this parameter. It was noticed that the German variety show lower value of fruits yield/plant than the local variety. Furthermore, high fertilization level gave the best results in both seasons compared with other treatments. Similar trend was observed in case of fruits yield per feddan.

Essential Oil Percentage (%): Tables (4) demonstrate the essential oil of both varieties. It is generally noticed that, although the local variety exhibited higher values in oil percentage than the German one, but this increase was insignificant. Moreover, fertilization allover different treatments showed insignificant differences in both seasons.

Oil Yield of Fennel per Plant and per Feddan: Concerning oil yield/plant, data in table (5) show that, generally speaking, the local variety was superior to the German one. Also, increasing the fertilization level led to increases in oil yield/plant or feddan allover the two studied seasons. These results were in agreement with those obtained by

Essential Oil Constituents: Both control and the oil of superior treatments (C2+Bio+O and Dr3) in most

Table 2: Effect of fertilization on Number of Umbels (Umbel/plant) of Fennel during 2002 and 2003 seasons

	No of Umbels(Umbel/plant)					
	First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean
Control	15.93	11.56	13.75	19.00	16.44	17.72
C0+Bio	19.00	11.78	15.39	26.28	17.22	21.75
C0+O	21.56	14.89	18.23	26.68	18.56	22.62
C0+Bio+O	21.67	15.44	18.56	27.48	19.56	23.52
Mean	19.54	13.42		24.86	17.95	
C1	22.33	19.44	20.89	27.48	19.78	23.63
C1+Bio	22.33	20.78	21.56	28.67	22.00	25.34
C1+O	22.56	21.89	22.23	29.07	22.44	25.76
C1+Bio+O	22.67	24.22	23.45	29.87	25.00	27.44
Mean	22.47	21.58		28.77	22.31	
C2	25.22	23.44	24.33	31.06	26.00	28.53
C2+Bio	27.11	23.89	25.50	31.06	27.44	29.25
C2+O	28.11	24.44	26.28	31.86	30.78	31.32
C2+Bio+O	31.22	27.00	29.11	32.66	33.11	32.89
Mean	27.92	24.69		31.66	29.33	
Mean V	23.31	19.90	8.77	28.43	23.19	
Mean F	16.48	22.03	26.31	21.40	25.54	30.50
LSD 5%	F	0.62		F	0.44	
	V	0.82		V	0.37	
	F x V	1.07		F x V	0.62	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

Table 3: Effect of fertilization on Fruits yield per plant (gm/plant) and Per feddan (Kg/feddan) of Fennel during 2002 and 2003 seasons

	Fruits yield Per plant (gm/plant)						Fruits yield Per feddan(kg/feddan)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Control	24.26	17.65	20.96	24.32	25.11	24.72	407.57	296.52	352.04	408.58	421.85	415.21
C0+Bio	29.01	17.98	23.50	40.13	26.30	33.22	487.37	302.06	394.72	674.18	441.84	558.01
C0+O	32.91	22.74	27.83	40.74	28.33	34.54	552.89	382.03	467.46	684.43	475.94	580.19
C0+Bio+O	33.08	23.58	28.33	41.96	29.86	35.91	555.74	396.14	475.94	704.93	501.65	603.29
Mean	29.82	20.49		36.79	27.40		500.89	344.19		618.03	460.32	
C1	34.10	29.69	31.90	41.96	30.20	36.08	572.88	498.79	535.84	704.93	507.36	606.14
C1+Bio	34.44	31.73	33.09	43.78	33.59	38.69	578.59	533.06	555.83	735.5	564.31	649.91
C1+O	34.61	33.42	34.02	44.39	34.27	39.33	581.45	561.46	571.45	745.75	575.74	660.74
C1+Bio+O	36.48	36.99	36.74	45.61	38.17	41.89	612.86	621.43	617.15	766.25	641.26	703.75
Mean	34.91	32.96		43.94	34.06		586.45	553.69		738.11	572.17	
C2	37.33	37.16	37.25	47.43	39.70	43.57	627.14	624.29	625.72	796.82	666.96	731.89
C2+Bio	41.33	41.4	41.37	47.43	41.91	44.67	694.34	695.52	694.93	796.82	704.09	750.46
C2+O	37.33	42.93	40.13	48.65	47.00	47.83	627.14	721.22	674.18	817.32	789.6	803.46

Table 3: Continue

C2+Bio+O	41.23	47.68	44.46	49.86	50.56	50.21	692.66	801.02	746.84	837.65	849.41	843.53
Mean	34.68	31.91		43.02	35.42		582.55	536.13		722.76	595.00	
Mean V	33.13	31.91		43.02	35.42		582.55	536.13		722.76	595.00	
Mean F	25.15	33.93	40.80	32.09	39.00	46.57	422.54	570.07	685.42	539.18	655.14	782.33
LSD 5%	F	1.24		F	2.08		F	21.39		F	35.01	
	V	0.65		V	2.19		V	12.58		V	36.69	
	F x V	2.14		F x V	3.61		F x V	37.05		F x V	60.63	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

Table 4: Effect of fertilization on Essential oil percentage (%) of Fennel during 2001 and 2002 seasons

	Oil%					
	First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean
Control	1.19	0.87	1.03	1.20	1.23	1.22
C0+Bio	1.43	0.88	1.16	1.97	1.29	1.63
C0+O	1.63	1.12	1.38	2.00	1.39	1.70
C0+Bio+O	1.65	1.16	1.41	2.04	1.47	1.76
Mean	1.48	1.01		1.80	1.35	
C1	1.68	1.46	1.57	2.06	1.49	1.78
C1+Bio	1.68	1.56	1.62	2.15	1.65	1.90
C1+O	1.69	1.64	1.67	2.18	1.69	1.94
C1+Bio+O	1.72	1.82	1.77	2.24	1.88	2.06
Mean	1.69	1.62		2.16	1.68	
C2	1.83	1.76	1.80	2.80	1.95	2.38
C2+Bio	2.06	1.79	1.93	2.30	2.04	2.17
C2+O	2.11	1.84	1.98	2.39	2.31	2.35
C2+Bio+O	2.34	2.03	2.19	2.45	2.49	2.47
Mean	2.09	1.86		2.49	2.20	
Mean V	1.75	1.50		2.15	1.74	
Mean F	1.25	1.66	1.98	1.57	1.92	2.34
LSD 5%	F	0.69 (ns)		F	0.87 (ns)	
	V	0.36 (ns)		V	0.91 (ns)	
	F x V	1.19		F x V	1.50	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

T able 5 : Effect of fertilization on Oil yield of Fennel per plant and per feddan during 2002 and 2003 seasons

	Oil yield per plant (ml/plant)						Oil yield per feddan (L/ feddan)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Control	0.29	0.15	0.22	0.29	0.31	0.30	4.85	2.58	3.71	4.90	5.19	5.05
C0+Bio	0.41	0.16	0.29	0.79	0.34	0.56	6.97	2.66	4.81	13.28	5.70	9.49
C0+O	0.54	0.25	0.40	0.81	0.39	0.60	9.01	4.28	6.65	13.69	6.62	10.15
C0+Bio+O	0.55	0.27	0.41	0.86	0.44	0.65	9.17	4.60	6.88	14.38	7.37	10.88
Mean	0.45	0.21		0.69	0.37		7.50	3.53		11.56	6.22	

Table 5: Continue

C1	0.57	0.43	0.50	0.86	0.45	0.66	9.62	7.28	8.45	14.52	7.56	11.04
C1+Bio	0.58	0.49	0.54	0.94	0.55	0.75	9.72	8.32	9.02	15.81	9.31	12.56
C1+O	0.58	0.55	0.57	0.97	0.58	0.77	9.83	9.21	9.52	16.26	9.73	12.99
C1+Bio+O	0.63	0.67	0.65	1.02	0.72	0.87	10.54	11.31	10.93	17.16	12.06	14.61
Mean	0.59	0.54		0.95	0.58		9.93	9.03		15.94	9.66	
C2	0.68	0.65	0.67	1.33	0.77	1.05	11.48	10.99	11.23	22.31	13.01	17.66
C2+Bio	0.85	0.74	0.80	1.09	0.85	0.97	14.30	12.45	13.38	18.33	14.36	16.35
C2+O	0.79	0.79	0.79	1.16	1.09	1.12	13.23	13.27	13.38	19.53	18.24	18.89
C2+Bio+O	0.96	0.97	0.97	1.22	1.26	1.24	16.21	16.26	16.4	20.52	21.15	20.84
Mean	0.82	0.79		1.20	0.65		13.81	13.24		20.17	16.69	
Mean V	0.62	0.51		0.95	0.53		10.41	8.60		15.89	10.86	
Mean F	0.33	0.56	0.81	0.53	0.76	1.10	5.51	9.48	13.52	8.89	12.80	18.43
LSD 5%	F	0.03		F	0.05		F	1.91		F	2.7	
	V	0.02		V	0.03		V	1.17		V	1.65	
	F x V	0.04		F x V	0.06		F x V	2.02		F x V	2.85	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

studied parameters were taken to identify its contents of volatile oil constituents by GC. Components which were identified in volatile oil of different treatments were divided into three main groups namely, hydrocarbons, oxygenated and unidentified ones. All the recorded data were tabulated in Table (6). The pharmaceutical effects of the volatile oil are mainly due to its content of oxygenated compounds. These results were in agreement with those obtained by [10] The data show that the local varaity was higher in its content of oxygenated compounds in compare to the German one. Generally, the ranges of the main constituents of volatile oil of the C2+Bio+O treatment were T-Anethole (48.51 – 71.79%), Limonene (12.52 – 35.64%), (+)-Champhene (2.44 – 3.70%), Methyl Chavecol or Astragol (1.45 – 3.08%) and α -Pinene (0.92 – 1.4%) for local variety.

Nitrogen Content: Table (7) indicate that, nitrogen (%) of the studied varieties in most cases, there were no significant differences among fertilization treatments and varieties. However, there was significant difference between local and German fennel varieties only in the second season.

Phosphorus Content: Taking phosphorus percentage into consideration, results in Table (7) reveal no significant differences among fertilization treatments and the studied varieties. Speaking in general, the local variety was superior to the German one.

Potassium Content: Table (8) demonstrates potassium percentage in the studied varieties. No significant differences were observed on the data concerning potassium. Again the local (bitter) variety exhibited higher value than the sweet or German one. The recorded data showed a trend all over deferent treatments, potassium content increases are follow increasing fertilization level.

Carbohydrate Content: Carbohydrate content illustrated in Table (8) showed, in most cases, significant differences between the studied treatments and varieties. However, only one exception (insignificant difference) was noticed between second and third fertilization groups in the first season only. Generally increasing fertilization level led to increase carbohydrate content.

Second Experiment (Effect of Irrigation Levels):

Plant Height (cm): Data in Table (9) showed significant differences in plant height among different treatments. The results revealed that the local variety exhibited taller plants than the German variety. Also, it was clear that increasing irrigation level led to increase in plant height.

Number of Branches (branch/plant): In concern with number of branches/plant, data in Table (9) record that the highest number of branches/plant was resulted from the local variety using the third irrigation rate (7.96 and 7.63 branches/plant). Contrarily, low irrigation level led to decrease in the studied parameter. The German variety combined the low irrigation rate (2L/h) had the lowest number of branches (4.57 and 3.38 branches/plant).

No. Of Umbels (Umbel/plant): Speaking of number of umbels/plant, results in Table (10) demonstrate that, the local variety was superior in the studied parameter than

Table 6 : Chemical composition of Fennel essential oil fractionated by GC technique

	Foeniculum vulgare var. *vulgare* Mill.				*Foeniculum vulgare* var. *azoricum* Mill.			
	Controls		C2+Bio+O		Controls		C2+Bio+O	
	2002	2003	2002	2003	2002	2003	2002	2003
1) Hydrocarbons								
α-Pinene	1.25	1.10	1.40	1.31	1.16	0.92	1.22	1.01
Camphene	3.31	2.90	3.70	3.47	2.78	2.44	3.21	2.66
Fenchone	0.12	0.10	0.13	0.12	0.37	1.45	0.11	0.09
dipentene	0.91	0.80	1.02	0.96	0.96	0.77	0.89	0.73
D-Limonene	15.61	13.66	17.44	16.33	35.64	30.94	15.14	12.52
γ-Terpinene	0.12	0.10	0.13	0.12	0.37	1.45	0.11	0.09
Total Hydrocarbons	21.32	18.67	23.82	22.31	41.28	37.97	20.68	17.1
2) Oxygenated								
Estragole (Methyl chavicol)	2.76	2.42	3.08	2.89	1.64	1.45	2.68	2.21
T-Anethole (Anisole)	64.67	56.61	71.79	67.67	55.69	48.51	62.72	51.89
Anise aldhyde	0.67	0.64	0.95	0.81	0.54	0.42	0.67	0.56
Total Oxygenated	68.10	59.67	75.82	71.37	57.87	50.38	66.07	54.66
3) Unknown	10.58	21.66	0.36	6.32	0.85	11.65	13.25	28.24

Table 7: Effect of fertilization on Nitrogen and Phosphorus contents of Fennel during 2002 and 2003 seasons

	N%						P%					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
C0	0.48	0.58	0.53	0.49	0.70	0.60	0.141	0.098	0.120	0.151	0.129	0.140
C0+Bio	0.71	0.70	0.70	1.38	0.96	1.17	0.168	0.111	0.140	0.233	0.191	0.212
C0+O	0.94	0.8	0.87	1.44	0.98	1.21	0.176	0.117	0.147	0.237	0.283	0.26
C0+Bio+O	1.06	0.81	0.94	1.48	1.01	1.24	0.190	0.118	0.154	0.244	0.324	0.284
Mean	0.80	0.72		1.20	0.91		0.169	0.111		0.216	0.232	
C1	0.86	0.82	0.84	1.45	1.03	1.24	0.193	0.120	0.157	0.244	0.308	0.276
C1+Bio	0.90	0.83	0.86	1.62	1.05	1.33	0.185	0.128	0.157	0.258	0.311	0.285
C1+O	0.96	0.86	0.91	1.55	1.06	1.31	0.196	0.139	0.168	0.255	0.324	0.29
C1+Bio+O	1.02	0.87	0.94	1.80	1.09	1.45	0.197	0.161	0.179	0.276	0.361	0.319
Mean	0.93	0.85		1.60	1.06		0.193	0.137		0.258	0.326	
C2	0.94	0.89	0.92	1.80	1.12	1.46	0.183	0.147	0.165	0.276	0.302	0.289
C2+Bio	0.98	0.92	0.95	1.66	1.15	1.40	0.183	0.157	0.170	0.265	0.338	0.302
C2+O	1.12	0.95	1.04	1.91	1.17	1.54	0.185	0.169	0.177	0.283	0.292	0.288
C2+Bio+O	1.37	1.00	1.19	1.53	1.20	1.36	0.197	0.181	0.189	0.290	0.370	0.330
Mean	1.10	0.94		1.72	1.16		0.187	0.164		0.280	0.330	
Mean V	0.94	0.84		1.51	1.04		0.18	0.140		0.250	0.290	
Mean F	0.76	0.89	1.02	1.06	1.33	1.44	0.14	0.17	0.18	0.220	0.290	0.300
LSD 5%	F	0.28 (ns)		F	0.58 (ns)		F	0.28 (ns)		F	0.581 (ns)	
	V	0.5 (ns)		V	0.39		V	0.497 (ns)		V	0.394 (ns)	
	F x V	0.57		F x V	1		F x V	0.565		F x V	1.000	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

Table 8: Effect of fertilization on Potassium and Carbohydrate contents of Fennel during 2002 and 2003 seasons

	K%						Carbohydrates %					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
C0	0.52	0.32	0.42	0.55	0.36	0.46	9.12	5.55	7.34	9.64	9.43	9.54
C0+Bio	0.62	0.41	0.52	0.87	0.47	0.67	10.85	8.21	9.53	15.05	10.74	12.9
C0+O	0.65	0.43	0.54	0.88	0.70	0.79	11.32	12.16	11.74	15.28	11.29	13.29
C0+Bio+O	0.70	0.44	0.57	0.90	0.80	0.85	12.25	13.91	13.08	15.74	11.41	13.58
Mean	0.62	0.40		0.80	0.58		10.89	9.96		13.93	10.72	
C1	0.71	0.45	0.58	0.90	0.76	0.83	13.23	12.43	12.83	15.74	11.63	13.69
C1+Bio	0.68	0.47	0.58	0.96	0.77	0.87	13.38	11.91	12.65	16.65	12.33	14.49
C1+O	0.72	0.52	0.62	0.94	0.80	0.87	13.91	12.60	13.26	16.42	13.44	14.93
C1+Bio+O	0.73	0.6	0.67	1.02	0.89	0.96	15.51	12.69	14.10	17.79	15.59	16.69
Mean	0.71	0.51		0.96	0.81		14.01	12.41		16.65	13.25	
C2	0.68	0.54	0.61	1.02	0.75	0.89	13.00	11.78	12.39	17.79	14.22	16.01
C2+Bio	0.68	0.58	0.63	0.98	0.83	0.91	14.52	11.82	13.17	17.1	15.21	16.16
C2+O	0.69	0.63	0.66	1.05	0.72	0.89	12.54	11.93	12.24	18.24	16.32	17.28
C2+Bio+O	0.72	0.67	0.70	1.07	0.91	0.99	15.89	12.57	14.23	18.7	17.53	18.12
Mean	0.69	0.61		1.03	0.80		13.99	12.03		17.96	15.82	
Mean V	0.68	0.51		0.93	0.73		12.96	11.46		16.18	13.26	
Mean F	0.51	0.61	0.65	0.69	0.88	0.92	10.42	13.21	13.01	12.32	14.95	16.89
LSD 5%	F	0.28 (ns)		F	0.58 (ns)		F	0.28		F	0.58	
	V	0.50 (ns)		V	0.39 (ns)		V	0.50		V	0.39	
	F x V	0.57		F x V	1.00		F x V	0.57		F x V	1.00	

Bio = Bio-fertilization O = Organic fertilization C = Chemical fertilization V = varieties F = Fertilization

Table 9: Effect of Irrigation levels on Plant height (cm) and number of branches (branch/plant) of Fennel during 2002 and 2003 seasons

	Plant height(cm)						No of branches(branch/plant)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Dr1	85.22	54.67	69.95	87.56	53.89	70.73	6.64	4.57	5.69	6.64	3.38	5.01
Dr2	86.89	76.11	81.50	93.89	71.67	82.78	7.56	6.64	7.10	6.81	6.08	6.45
Dr3	94.44	80.44	87.44	107.89	96.78	102.34	7.96	7.63	7.80	7.63	6.21	6.92
Mean	88.85	70.41		96.45	74.11		7.39	6.28		7.03	5.22	
Mean V	88.85	70.41		96.45	74.11		7.39	6.28		7.03	5.22	
Mean Dr	69.94	81.50	87.44	70.72	82.78	102.33	5.69	7.10	7.80	5.01	6.45	6.92
LSD 5%	Dr	2.50		Dr	5.69		Dr	0.39		Dr	0.51	
	V	2.65		V	3.48		V	0.68		V	0.35	
	Dr x V	4.59		Dr x V	6.03		Dr x V	0.77		Dr x V	0.88	

Dr = Dripper V = varieties

the sweet or German variety. Furthermore, there were slight increases in number of umbels/plant due to the studied treatments.

Plant Fruits Yield and per Feddan: Taking fruits yield/plant into consideration, it was record that, results in Table (11) exhibited that local variety gave higher fruits yield/plant, especially in first season. Considering irrigation rate, the recorded data showed that increasing irrigation level led to a clear increase in fruits yield/plant. A harmony trend was observed in both fruits yield per plant or per feddan.

Table 10: Effect of Irrigation levels on Number of Umbels (Umbel/plant) of Fennel during 2002 and 2003 seasons

	No of Umbels(Umbel/plant)					
	First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean
Dr1	22.67	17.67	20.17	22.18	13.11	17.65
Dr2	26.78	24.22	25.5	23.79	25.00	24.39
Dr3	34.67	38.00	36.33	27.33	30.78	29.05
Mean	28.04	26.63		24.43	22.96	
Mean V	28.04	26.63		24.43	22.96	
Mean Dr	20.17	25.50	36.33	17.65	24.39	29.05
LSD 5%	Dr	0.78		Dr	0.41	
	C	1.07		C	0.34	
	Dr x V	1.36		Dr x V	0.57	

Dr = Dripper V = varieties

Table 11: Effect of Irrigation levels on Plant fruits yield (gm/plant) and fruits yield per feddan (kg/feddan) of Fennel during 2002 and 2003 seasons

	Fruits yield Per plant(gm/plant)						Fruits yield Per feddan(kg/feddan)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Dr1	34.61	26.98	30.79	33.87	20.02	26.95	581.48	453.21	517.34	569.01	336.34	452.68
Dr2	40.89	36.99	38.94	36.32	38.17	37.25	686.94	621.38	654.16	610.17	641.33	625.75
Dr3	52.94	58.03	55.48	41.74	47.00	44.37	889.32	974.83	932.07	701.15	789.55	745.35
Mean	42.81	40.66		37.31	35.06		719.24	683.14		626.78	589.08	
Mean V	42.81	40.66		37.31	35.06		719.24	683.14		626.78	589.08	
Mean Dr	30.79	38.94	55.48	26.95	37.25	44.37	517.34	654.16	932.07	452.68	625.75	745.35
LSD 5%	Dr	1.59		Dr	1.92		Dr	26.82		Dr	32.30	
	V	0.83		V	2.02		V	15.77		V	33.85	
	Dr x V	2.75		Dr x V	3.33		Dr x V	46.45		Dr x V	55.95	

Dr = Dripper V = varieties

Essential Oil Percentage (%): Taking essential oil percentage into consideration, Table (12) show that in there were no significant differences among irrigation treatments or varieties.

Oil Yield of Fennel per Plant or per Feddan: Table (13) illustrate the oil yield/plant or per feddan and showed that, there were no significant differences recorded between varieties for both seasons, while in case of irrigation levels there were significant differences in both seasons.

Essential Oil Constituents: Both control and the superior treatment (Dr3) in most studied parameters were taken to identify its content of volatile oil constituents by GC. Components which were identified in volatile oil of different treatments were divided into three main groups namely, hydrocarbons, oxygenated and unidentified ones. All the recorded data were tabulated in Table (14). The pharmaceutical effects of the volatile oil are mainly due to its content of oxygenated compounds. These results were in agreement with those obtained by [10]. The data showed that the local varity was higher in its content of oxygenated compounds in compare to the German one. Generally, the ranges of the main constituents of volatile oil of the C2+Bio+O treatment were T-Anethole (48.51 – 67.46%), Limonene (13.66 – 37.13%), (+)-Champhene (2.44 – 3.64%), Methyl Chavecol or Astragol (1.45 – 3.16%) and α -Pinene (0.92 – 1.38%) for local variety.

Nitrogen and Phosphorus Contents: Tables (15) conclude that, nitrogen (%) of the studied varieties. Significant differences were noticed among irrigation levels and the studied varieties. Also, the local variety and higher irrigation rate were superior. Increasing irrigation level led to increase nitrogen % in both seasons.

For phosphorus percentage Table (15) shows that, there was no significant difference between second and third irrigation levels. Only significant difference was

Table 12 : Effect of Irrigation levels on Essential oil percentage (%) of Fennel during 2002 and 2003 seasons

	Oil%						
	First season (2002)				Second season (2003)		
	Local	German	Mean		Local	German	Mean
Dr1	1.70	1.33	1.51	Dr1	1.67	0.98	1.32
Dr2	2.01	1.82	1.91	Dr2	1.79	1.88	1.83
Dr3	2.60	2.85	2.73	Dr3	2.05	2.31	2.18
Mean	2.11	2.00		Mean	1.83	1.72	
Mean V	2.11	2.00		Mean V	1.83	1.72	
Mean Dr	1.51	1.91	2.73	Mean Dr	1.32	1.83	2.18
LSD 5%	Dr	0.87 (ns)			Dr	0.79 (ns)	
	V	0.46 (ns)			V	0.83 (ns)	
	Dr x V	1.51 (ns)			Dr x V	1.38 (ns)	

Dr = Dripper V = varieties

Table 13: Effect of Irrigation levels on Oil yield per plant and per feddan of Fennel during 2002 and 2003 seasons

	Oil yield per plant (ml/plant)						Oil yield per Fed (L/fed)					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Dr1	0.59	0.36	0.47	0.56	0.20	0.38	9.90	6.01	7.95	9.48	3.31	6.39
Dr2	0.82	0.67	0.75	0.65	0.72	0.68	13.81	11.30	12.56	10.90	12.04	11.47
Dr3	1.38	1.66	1.52	0.86	1.09	0.97	23.15	27.81	25.48	14.39	18.25	16.32
Mean	0.93	0.90		0.69	0.67		15.62	15.04		11.59	11.20	
Mean V	0.93	0.9		0.69	0.67		15.62	15.04		11.59	11.20	
Mean Dr	0.47	0.75	1.52	0.38	0.68	0.97	7.95	12.56	25.48	6.39	11.47	16.32
LSD 5%	Dr	0.05		Dr	0.05		Dr	3.07		Dr	2.30	
	V	0.03 (ns)		V	0.03 (ns)		V	1.88 (ns)		V	1.40 (ns)	
	Dr x V	0.07		Dr x V	0.06		Dr x V	3.25		Dr x V	2.43	

Dr = Dripper V = varieties

Table 14: Chemical composition of Fennel essential oil fractionated by GC technique

	Foeniculum vulgare var. *vulgare* Mill.				*Foeniculum vulgare* var. *azoricum* Mill.			
	Controls		Dr3		Controls		Dr3	
α-Pinene	1.25	1.10	1.38	1.21	1.16	0.92	1.22	1.10
Camphene	3.31	2.90	3.64	3.19	2.78	2.44	2.92	2.93
Fenchone	0.12	0.10	0.13	0.11	0.37	1.45	0.39	1.74
dipentene	0.91	0.80	1.00	0.88	0.96	0.77	1.01	0.92
D-Limonene	15.61	13.66	17.17	15.03	35.64	30.94	36.35	37.13
γ-Terpinene	0.12	0.10	0.13	0.11	0.37	1.45	0.39	1.52
Total	21.32	18.67	23.45	20.53	41.28	37.97	42.27	45.35
Estragole (Methyl chavicol)	2.76	2.42	2.83	3.16	1.64	1.45	2.29	2.18
Anethole (Anisole)	64.67	56.61	67.46	67.46	55.69	48.51	54.48	51.89
p- anise aldhyde	0.67	0.64	0.73	0.81	0.47	0.42	0.59	0.56
Total	68.10	59.67	71.02	71.43	57.80	50.38	57.36	54.63
3) Unknown	10.58	21.66	5.53	8.04	0.92	11.65	0.36	0.02

Table 15: Effect of Irrigation levels on Nitrogen and Phosphorus contents of Fennel during 2002 and 2003 seasons

	N%						P%					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Dr1	0.83	0.65	0.74	0.81	0.36	0.59	0.310	0.190	0.250	0.200	0.130	0.170
Dr2	0.98	0.89	0.94	0.87	0.48	0.68	0.60	0.200	0.400	0.360	0.210	0.290
Dr3	1.27	1.39	1.33	1.00	0.66	0.83	0.740	0.2100	0.480	0.380	0.240	0.310
Mean	1.03	0.98		0.89	0.5		0.550	0.200		0.310	0.190	
Mean V	1.03	0.98		0.89	0.5		0.550	0.200		0.220	0.290	
Mean Dr	0.74	0.94	1.33	0.47	0.68	0.83	0.250	0.400	0.480	0.170	0.290	0.310
LSD 5%	Dr	0.06		Dr	0.05		Dr	0.080		Dr	0.050	
	V	0.03		V	0.03		V	0.050		V	0.030	
	Dr x V	0.08		Dr x V	0.06		Dr x V	0.080		Dr x V	0.060	

Dr = Dripper V = varieties

Table 16: Effect of Irrigation levels on Potassium and carbohydrate contents of Fennel during 2002 and 2003 seasons

	K%						Carbohydrates %					
	First season (2002)			Second season (2003)			First season (2002)			Second season (2003)		
	Local	German	Mean	Local	German	Mean	Local	German	Mean	Local	German	Mean
Dr1	0.75	0.55	0.65	0.71	0.34	0.87	16.42	12.36	14.39	13.00	12.70	12.85
Dr2	1.00	0.59	0.79	0.72	0.45	1.73	23.39	18.25	20.82	23.26	13.62	18.44
Dr3	1.06	0.68	0.87	0.79	0.61	1.86	31.59	24.25	27.92	34.32	15.65	24.99
Mean	0.74	0.60		0.74	0.47		23.80	18.29		23.53	13.99	
Mean V	0.74	0.60		0.74	0.47		23.80	18.29		23.53	13.99	
Mean Dr	0.65	0.79	0.87	0.52	0.59	0.70	14.39	21.9	27.92	12.85	18.44	24.99
LSD 5%	Dr	0.04		Dr	0.02		Dr	4.21		Dr	3.78	
	V	0.03		V	0.02		V	2.57		V	2.31	
	Dr x V	0.06		Dr x V	0.05		Dr x V	4.46		Dr x V	4.01	

Dr = Dripper V = varieties

noticed between first and second irrigation level during the both seasons. In case of varieties, there is no significant difference.

Potassium Content: Speaking of potassium content (%) in Table (16), it was noticed that it took the same trend as the nitrogen content. Again, the local variety had higher values than German one. Increasing irrigation level increased potassium content.

Carbohydrate Content: Concerning Carbohydrate content (%) Table (16) results reveal the same trend as nitrogen and potassium contents.

Discussions: The recorded data generally show that the first season was higher in most cases allover deferent parameters, this may be due to the clear differences which were observed in recorded meteorological data for the tow seasons (the second one was higher on wind speed, air temperature, evapo-transpiration and lower in rain fall). This may be led to some environmental stress on plant growth. *(Table E).* ***Fertilization from different sources had positive effects on plant growth, chemical constituents and yields.***[16, 18, 26, 28, 29 , 30, 31, 32, 33].

There was increase in all recorded parameters due to increasing fertilization (Bio, organic and chemical) rates. This increment may be due too lake of soil in both organic and mineral nutrients. (Tables B and C). Also the increase of N uptake and synergistic effect of the microorganisms (bio fertilizer) on the physiological

and metabolic activities of the plant.[34]. The stimulation effects of applying nitrogen on vegetative growth characters may be attributed to the well known functions of nitrogen in plant life, being a part of protein; it is an important constituent of protoplasm. Also, enzymes and the biological catalytic agents which speed up life processes.[35]. Using complete chemical fertilization increase plant growth may be attributed to nitrogen importance to consist the amino acids to form protein which participate in cell enlargement and cell division. While phosphorus has an important role in producing energy for all physiological processes as synthesis protein by formation the coenzyme adenine tripohsphate (ATP). Furthermore, potassium plays a direct or indirect role in plant metabolism.[36] The stimulatory effect of fertilization treatments specially combined ones (Bio +Organic +Chemical) on volatile oil percentage may be due to the positive role of complete fertilization on plant growth. The increment in nitrogen, phosphorus and potassium percentages may be due to complete chemical fertilization and both organic and bio, organic fertilization such compost (organic matter and mineral nutrition) and bio fertilization (both fixing nitrogen and dissolving phosphorus bacteria) (Bio fertilizer).[37]. Also the increment in N,P, K and Carbohydrate contents, may be due to enhancing the combined fertilization treatment (Bio +Organic +Chemical) absorption and / or translocation of those nutrients in the plants, which have great effect on yields.[38] Considering irrigation level effect on growth, oil and yields. The recorded data agreed with that who found increasing irrigation rate increase growth and other parameters. In general, water accessibility ensures higher biomass production, but at the same time causes decrease of biological active components content[39, 40, 41, 42, 43, 44, 45] .

Table (A): The chemical and physical properties of compost:

Weight of m^3 (kg)	Wet. (%)	pH	EC	Total N (%)	O.M. (%)	Total carbon (%)	Ash	C/N ratio	Total P (%)	Total K (%)
520	39.97	8.35	4.88	1.69	1.5	28.6	53	1:16	1.3	1.26

Table (B): Mechanical properties of the experimental soil:

Very coarse sand %	Coarse sand %	Medium sand %	Fine sand%	Very fine sand%	Silt and clay %	Soil texture
(2 : 1 mm)	(1 : 0.5 mm)	(0.5 : 0.25 mm)	(0.25 : 0.1 mm)	(0.1:0.063 mm)	(<0.063 mm)	Sand
1.27	5.9	15.3	61.28	12.82	3.43	

Table (C): Chemical properties of the experimental soil:

pH	E.C (m mhos/cm)	OM %	Soluble cations (meq./L.)				Soluble anions (meq./L.)			
			K^+	Na^+	Mg^{++}	Ca^{++}	$CO3^{--}$	HCO_3^-	Cl^-	SO_4^{--}
8.7	0.76	0.47	0.09	2.43	0.8	3.2	-	3	1.38	2.14

Table (D): Water analysis:

pH	E.C (m mhos/cm)	OM %	Soluble cations (meq./L.)				Soluble anions (meq./L.)			
			K^+	Na^+	Mg^{++}	Ca^{++}	$CO3^{--}$	HCO_3^-	Cl^-	SO_4^{--}
8.36	4.06	1.4	0.69	24.6	3.48	11.4	-	4.4	32.2	3.57

Table (E): Meteorological data:

Wind speed Km/h		Wind temp (C)		Humidity RH%		Sun intensity W/m^2		Rain fall mm/day		Et MM	
2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
7.94	8.28	17.95	24.08	73.77	75.47	0.22	0.22	3.59	1.18	4.05	2.73

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