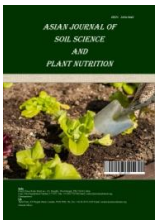

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Effect of Different Sources and Levels of Nitrogen Fertilizers with and without Organic and Bio-fertilizers on Growth and Yield Components of Fennel Plants (*Foeniculum vulgare* Mill.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors IAY, MEA, EHAN and SAI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MMEA managed the literature searches and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Two field experiments were conducted in a newly reclaimed land at a private farm in Village No 8, El-Minia Governorate, Egypt during two successive seasons (2017/2018) to evaluate the effect of integrated nitrogen fertilizer sources with organic and bio-fertilization on growth and yield components of the fennel plant. The experiment was arranged in a split- split-plot design. The organic treatments (0.0 and 5.0 t compost t/fed.) were arranged in main plots, nitrogen treatments (0.0, 10.0, 50.0 and 80.0 kg N/fed.) as urea or ammonium sulphate were allocated in subplots and bio-fertilizer treatments (without and with) were applied in sub-sub plots. The main effects of compost, nitrogen fertilization and bio-fertilizer showed that the maximum values of plant height, dry weight/plant, number of branches/plant, number of mumble/plant, number of umbellule's/umble

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and 1000-fruits weight were attained under 5 t/fed compost, 80 kg N/fed as ammonium sulphate with bio-fertilizer. The results of the interaction among treatments indicated that combined 5.0 t compost /fed with 50 kg N/fed as ammonium sulphate and using bio-fertilizer exhibited the highest values of growth and yield components of fennel. Meanwhile, we can save about 30 kg N/fed by treated fennel plants with organic and bio-fertilizers without any reduction in vegetative growth.

Keywords: Compost; mineral fertilizer; bio-fertilizer; growth and yield components.

1. INTRODUCTION

Fennel plant (*Foeniculum vulgare* Mill.) is one of the most important medicinal and aromatic plants. It is belonging to family Apiaceous. This plant has estrogenic activities and can be used as a carminative anti-inflammatory, diuretic, antimicrobial and galactagogue [1]. Mediterranean region is the original native of fennel and spread out to Europe and Latin America. Middle Egypt, especially, El-Minia and Assuit are the most Governorates concerned with growing fennel as a winter annual herb. Fennel fruits contain an essential oil (3-6% in mature fruit) which can be used as a constituent of cosmetic and pharmaceutical products. Fennel oil is also applied as a flavor in different foods preparation and plays an important role in confectionery due to the presence of fenchone [2]. Also, Lucinewton [3] mentioned that the essential oil of fennel fruits has antioxidant, antimicrobial and hepatoprotective activities.

Organic fertilizer is considered a good approach to sustainable agriculture, which requires great amounts of manure. The main role of manure is to create a balance between the interconnected systems of soil microorganisms and plants. Manure has many advantages in agriculture and has positive effects on soil aggregation, soil moisture-holding capacity and other physical properties [4]. Moreover, its application in a clay soil improves soil porosity and texture, which leads to marked reductions in waterlogged conditions by increasing the drainage process. Due to the shortage of manure in most areas, composting is a way to recycle waste materials from agricultural production and processing into a useful mature resource. Compost is a good organic fertilizer and soil amendment. Compost improves soil physical and biological properties, such as water retention capacity, soil reaction and microorganisms activity [5]. Seed germination, plant growth and crop yield increase due to the presence of plant hormones and micro- and macronutrients in the compost [6]. Also, compost can stimulate and improve plant physiological status and exert protective effects against diseases [7]. Ayyat [8] pointed out that fennel growth, yield and essential oil increase by manure application.

Mineral fertilizers contained one or more essential elements needed for supplying the plant growth and increase the quality and quantity of agricultural products [9]. In Egypt, several forms of nitrogen (N) fertilizers are used, e.g. urea and ammonium sulphate. Some fertilizers can cause acidic or basic effects on the soil reaction, while others have no effect on it [10]. Combination of inorganic fertilizers with compost may improve fennel productivity [8,11-12].

Bio-fertilizers are low-cost, eco-friendly and renewable sources for nutrients in the sustainable agricultural system. Bio-fertilizers are beneficial microorganisms with marked roles in improving root growth and nutrients, supplying, for instance, some biological materials such as auxin and gibberellins which finally enhance vegetative and reproductive growth of plants [13]. Dadkhah [14] and Pariari [15] reported that bio-fertilizer enhance the quality and quantity of fennel plants.

The main objective of this study is to investigate the most suitable treatments among chemical N levels and sources, compost level and bio-fertilizer for improving vegetative growth, and yield components of fennel plants under the field conditions of newly reclaimed land at El-Minia Governorate, Egypt.

2. MATERIALS AND METHODS

2.1 Field Experiment

Two field experiments were conducted at newly reclaimed land at a private farm at Village No. 8, El-Minia Governorate, Egypt during the two successive seasons of 2016/2017 and 2017/2018 to evaluate the effect of chemical N sources at different levels as well as the compost and bio-fertilizer on growth parameters and yield components of fennel plants. Seeds of fennel plants were received from the Medical and Aromatic Plant Section, ARC, Egypt. The

experimental plot size was 3 m x 3.5 m (10.5 m^2 = 1/400 fed) containing 3 raised beds (90 cm). The seeds cultivated in two rows in each raised bed and the sowing dates were 22 and 27 October for the two seasons, respectively. The plants were thinned to two plants/hill after 30 days from sowing. Phosphorus fertilizer as superphosphate (15.5% P_2O_5) was added at rate of 22 kg P_2O_5/fed as basal dressing before planting, and potassium was applied as potassium sulphate (48% K_2O) split into two equal doses, the first one month after the planting and the second one month after the first application. All recommended agricultural practices for fennel were done as recommended by the Ministry of Agriculture.

2.2 Soil and Compost Analyses

A surface soil sample (0-30 cm) was taken from the experimental site in the two seasons before sowing to determine some physical and chemical properties according to A.O.A.C [16]. The soil was sand with pH of 8.10-8.14, electric conductivity (EC) of 1.73-1.96 dS m^{-1}, soil organic matter (SOM) of 0.11-0.13%, total calcium carbonate of 5.12-6.20%, and soil available N, P and K of 2.21-2.63, 5.2-6.17, and 32.18-33.35 mg kg^{-1} in the chosen soil for both seasons.

Some chemical properties of the used compost (received from El-Neel for Solid Waste Utilization, New Minia City, Egypt) were listed in Table 1.

2.3 Experimental Design and Treatments

A split-split plot in complete randomized block design and four replicates was performed. The compost treatment (without and 5 t/fed compost) was applied in main plots, N sources (A) and levels (B) were arranged in sub-plots and the sub-sub-plots were occupied with bio-fertilizer (without and with bio-fertilizer) (C).

Nitrogen sources and levels were:

- Without nitrogen fertilization.
- 10 kg / fed as urea (46.5% N).
- 10 kg / fed as ammonium sulphate (20.5% N).
- 50 kg / fed as urea (46.5% N).
- 50 kg / fed as ammonium sulphate (20.5% N).
- 80 kg / fed as urea (46.5% N).
- 80 kg / fed as ammonium sulphate (20.5% N).

The N treatments were added in four equal doses, the first after one month from thinning and then after every 20 days. The compost treatment was added as basal dressing before planting, during the land preparation, while the bio-fertilizer, namely rhizobacteria, which mainly contain fixed N_2 Azotobacter bacteria was provided by Department of Microbiology; Soil, Water and Environment Institute, ARC, Egypt. The bio-fertilizer was applied twice into the soil beside the plants in a solution at the rate of 5 ml/ plant, the first dose was added 45 days after sowing, while the second dose was applied one month after the first application, and the plants were immediately irrigated.

2.4 Data Recorded

The plants were harvested in mid of April for the two seasons. Five plants were randomly taken from each plot to measure the following parameters:-

Growth parameters: plant height (cm), dry weight of herb/plant (g) and number of branches/plant.

Table 1. Some chemical properties of used compost

Properties	First season	Second season
Bulk density (g cm^{-3})	0.65	0.68
Moisture (%)	27	26
pH*	7.8	7.6
EC (dS m^{-1})*	2.2	2.5
Organic matter (%)	33	34
Organic carbon (%)	19.2	19.7
Total N (%)	1.2	1.1
Total P (%)	0.65	0.70
Total K (%)	1.0	1.2
C/N ratio	16:1	18:1

** in 1:10 compost-water suspension*

Yield components: number of umbles/plant, number of umbellules/umble and 1000- fruits weight (g).

2.5 Statistical Analysis

Data were statistically analyzed by least significant differences according to Snedecor and Cochran [17]. Differences among treatments were compared using the least significant difference (LSD) test at 5% level.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data in Tables 3, 4 and 5 showed the effects of compost, mineral N fertilizer and bio-fertilizer on some growth parameters of the fennel plant, namely plant height, dry weight plant^{-1} and number of branches plants^{-1}. As for the main effect of compost, the results clearly showed that the addition of compost to fennel plant had a positive effect on the studied growth parameters. Application of 5 t/fed compost increased plant height, dry weight plant^{-1} and number of branches plant^{-1} by 23.12, 20.85 and 15.89% compared to bio-fertilizer treatment, respectively in the first season. The corresponding increases in the second season were 13.69, 20.69 and 21.43% for the abovementioned parameters, respectively. The improved of fennel growth caused by compost application could have resulted from the beneficial effect of compost on physical and biological properties in the root zones. These results agree with those obtained by Taiwo [8,18-19].

Concerning the main effect of mineral N fertilizer, the presented data indicated that increasing N level up to 80 kg N/fed, whether as urea or ammonium sulphate fertilizers significantly increased all studied fennel growth parameters. Supplied fennel plants with 80 kg N/fed as urea or ammonium sulphate increased plant height, dry weight/plant and number of branches/plant by about 48.76 and 51.7, 104.13 and 107.24, and 47.06 and 52.94% as compared with nil N rate for both types of fertilizers applied in the first season, respectively. Similar trends were obtained in the second season. The promoted effect of N might be because N is the most important macronutrient for plants, where it encourages the merestmic activity, vegetative growth and accumulation of photosynthates. Similar results were obtained by [8,20-21]. It is worthy to observe that ammonium sulphate surpassed urea in its effect on growth parameters due to the acidic effect of ammonium sulphate on soil pH [11]. These results were in the same line as those obtained by [22] who stated that maximum growth parameters of fennel were obtained under ammonium sulphate fertilizer.

Concerning the main effects of bio-fertilizers, the results revealed that fennel plants supplied with bio-fertilizer significantly increased growth. The relative increase in plant height, dry weight plant

Table 2. Effects of organic (compost) and mineral N fertilizers and bio-fertilizer on plant height of fennel plant (cm)

Compost t/fed	N-fert. kg/fed	Bio-fertilizer			
		1 st season		2 nd season	
		-	+	-	+
0.0	0.0	70.2	75.6	72.3	75.5
	10 urea	90.6	93.2	95.8	98.3
	10 AS	91.9	96.6	97.9	100.1
	50 urea	110.2	117.1	115.8	118.7
	50AS	112.6	119.4	117	120.7
	80 urea	126.7	127.1	130.6	134.1
	80 AS	128.1	129.9	130.8	136.5
5.0	0.0	104.3	106.5	104.5	109.3
	10 urea	120.5	118.7	125.3	129.1
	10 AS	122.9	120.6	127.7	130.5
	50 urea	131.5	136.3	136.6	139.4
	50 AS	133.7	139.1	138.7	140.6
	80 urea	135.5	136.4	136.7	139.5
	80 AS	139.0	139.2	138.6	140.7
LSD at 0.05		1.83		3.02	

AS = ammonium sulphate

Table 3. Effects of compost, mineral N fertilizer and bio-fertilizer on dry weight (g) / plant of fennel

Compost t/fed	N-fert. kg/fed	Bio-fertilizer			
		1 st season		2nd season	
		-	+	-	+
0.0	0.0	13.6	15.8	15.7	16.9
	10 urea	26.2	28.6	28.6	29.1
	10 AS	27.1	29.0	29.3	29.9
	50 urea	32.8	34.6	34.6	35.6
	50 AS	33.5	53.7	35.1	36.2
	80 urea	37.8	37.3	34.6	39.3
	80 AS	83.2	38.9	40.3	40.8
5.0	0.0	23.2	24.7	24.7	25.6
	10 urea	36.1	36.9	37.1	38.9
	10 AS	36.9	37.4	37.9	39.6
	50 urea	39.3	40.5	40.8	41.7
	50 AS	39.9	40.6	41.3	41.8
	80 urea	40.3	41.8	41.5	42.5
	80 AS	41.2	41.8	42.3	42.7
LSD at 0.05		0.92		0.93	

AS = ammonium sulphate

Table 4. Effect of organic, mineral N and bio-fertilization on number of branches/plant of fennel plant

Compost t/fed	N-fert. kg/fed	Bio-fertilizer			
		1 st season		2nd season	
		-	+	-	+
0.0	0.0	7.5	7.8	7.2	7.5
	10 urea	8.1	8.9	7.8	8.6
	10 AS	8.5	9.2	8.2	9.1
	50 urea	10.3	10.8	10.1	10.5
	50 AS	10.5	11.2	10.2	11.2
	80 urea	11.6	11.9	11.3	11.6
	80 AS	11.9	12.2	11.7	11.9
5.0	0.0	9.0	9.5	9.1	9.7
	10 urea	11.3	12.4	11.1	11.9
	10 NA	11.7	12.9	11.4	11.7
	50 urea	12.4	13.6	12.1	12.6
	50 NA	12.7	13.6	12.5	12.6
	80 urea	13.0	14.2	12.8	12.9
	80 NA	13.6	14.2	13.3	12.9
LSD at 0.05		0.70		0.74	

AS = ammonium sulphate

and the number of branches/plant reached to 5.36, 3.9 and 6.42% as compared with no bio-fertilizer in the first season, respectively. The relative increase in the second season was 2.51, 3.47 and 3.80% for the abovementioned parameters, respectively.

The enhancement in fennel plants growth due to bio-fertilizer could be explained by the role of N_2-fixing bacteria as an increment of soil available N and production of phytohormones to improve nutrients uptake and protect the plants against pathogens through the production of antibacterial and antifungal substances. These results are in harmony with these obtained by [12,23-26].

The presented data clearly showed that fennel plants were positively and significantly affected by the three-way of interaction among the three factors (A x B x C), meanwhile fertilized fennel plants with 50 kg N/fed, whether urea or ammonium sulphate produced growth parameters equal to those obtained under 80 kg N/fed in the presence of 5 t /fed compost and

inoculated root zone with bio-fertilizers. In general, the values of fennel growth parameters which obtained when plants received 5 t compost/fed + 50 kg N /fed as ammonium sulphate + bio-fertilizers were equal to those when plants fertilized with 80 kg N/ fed. On the other hand, the plants under no compost, nitrogen and bio-fertilizers applications were exhibited the lowest fennel growth parameters.

3.2 Yield Components

The data of yield components of fennel, i.e., number of umbels/plant, number of umbellules / umbel and 1000-seed weight as affected by compost, mineral N fertilizer and bio-fertilizer application are given in Tables 5, 6 and 7. As for the main effect of compost, the obtained data showed that the addition of 5 t/fed compost increased yield components of fennel in both seasons. The increment percentage in the number of the umbles / plant, number of umbulates/umble and 1000- seed weight reached 18.60, 27.05 and 10.23% compared with no compost in the first season, respectively. The same trend was obtained in the second season with increases of 5.99, 19.78 and 14.13%, respectively. The positive effect of compost might be due to the role of compost in improving chemical and biological properties of soils, and in improving moisture-holding capacity which led to marked increases in plant growth. These findings were similar to those obtained by [25,27-28].

Concerning mineral N fertilization, the results indicated that the yield components of fennel were significantly increased with N level up to 80 kg/fed either in the form of urea or ammonium sulphate. Comparing with zero mineral N application supplied as urea or ammonium sulphate increased the abovementioned yield components by about 120.48-125.30, 62.99-67.76 and 87.69- 90.63%, respectively in the first season, while these increments in the second one were 100.0-104.28, 51.4- 55.14, and 82.42-87.88%, respectively. The beneficial effect of nitrogen on yield components might be attributed to the ability of applied nitrogen in producing better root and shoot growth, hence resulted in a higher number of umbles / plant, number of umpellers/ umble. These results agree with those obtained by [29-31]. The presented data clearly showed that ammonium sulphate fertilizer surpassed urea in its effect on fennel yield components, which mainly due to its acidic effect on soil pH. Similar results were obtained by [20].

Considering the effect of bio-fertilizer, the results showed that yield components of fennel were significantly affected by bio-fertilizer as compared with the control. The average values overall treatments for the number of umbles per plant were 32.8 and 33.5, the number of umbellules per umble were 50.1 and 51.2 and 1000-seed weight was 11.2 and 11.5 g in the first and second season, respectively. The increment of percentage for the abovementioned components

Table 5. Effects of compost, mineral N fertilizer and bio-fertilizer on number of umbels / plant of fennel plant

Compost t/fed	N-fert. kg/fed	Bio-fertilizer			
		1 st season		2 nd season	
		-	+	-	+
0.0	0.0	13.1	15.9	15.5	18.9
	10 urea	23.9	26.4	25.1	27.8
	10 AS	24.3	27.8	26.6	28.8
	50 urea	29.0	32.4	30.2	32.1
	50AS	29.3	32.8	30.9	32.9
	80 urea	34.4	36.5	35.4	36.8
	80 AS	35.1	37.4	36.2	37.5
5.0	0.0	17.0	20.4	18.9	21.5
	10 urea	31.8	35.3	33.8	36.2
	10 AS	32.3	35.9	34.4	36.9
	50 urea	35.0	38.3	36.3	39.2
	50 AS	35.9	39.0	37.2	40.2
	80 urea	36.8	38.4	38.0	39.3
	80 AS	37.8	39.2	39.1	40.2
LSD at 0.05		2.80		2.86	

AS = ammonium sulphate

Table 6. Effects of compost, mineral N fertilizer and bio-fertilizater on number of umbellules/ umbel

Compost t/fed	N fert. kg/fed	Bio-fertilizer			
		1 st season		2 nd season	
		-	+	-	+
0.0	0.0	23.1	27.9	27.1	32.1
	10 urea	35.9	39.3	37.8	41.3
	10 AS	36.6	41.4	40.1	42.9
	50 urea	43.5	48.3	45.5	48.0
	50 AS	44.1	49.2	45.9	49.1
	80 urea	51.3	54.3	53.0	54.9
	80 AS	53.4	56.0	54.6	55.8
5.0	0.0	38.7	44.3	43.4	45.3
	10 urea	47.6	53.1	50.4	54.0
	10 AS	48.2	53.9	51.2	55.4
	50 urea	52.8	57.6	54.0	58.5
	50 AS	53.9	58.7	55.7	60.2
	80 urea	54.9	57.8	57.1	58.7
	80 AS	56.6	58.8	58.7	60.5
LSD at 0.05		2.96		3.01	

AS= ammonium sulphate

Table 7. Effects of compost, mineral N fertilizer and bio-fertilization on 1000 – seed weight (g)

Compost t/fed	N fert. kg/fed	Bio-fertilizer			
		1 st season		2 nd season	
		-	+	-	+
0.0	0.0	6.87	7.01	6.95	7.16
	10 urea	8.27	8.54	8.61	8.85
	10 AS	8.63	8.83	8.79	8.89
	50 urea	10.29	10.50	10.40	10.61
	50 AS	11.92	12.13	10.92	11.25
	80 urea	13.15	13.41	13.51	13.63
	80 AS	13.46	13.67	13.90	14.21
5.0	0.0	7.19	7.51	7.82	8.11
	10 urea	9.45	9.83	10.02	10.31
	10 NA	9.72	9.95	10.23	10.52
	50 urea	12.85	13.60	13.66	13.92
	50 NA	13.10	13.81	13.98	14.35
	80 urea	13.50	13.62	13.70	13.95
	80 NA	13.56	13.85	13.99	14.34
LSD at 0.05		1.63		1.69	

AS = ammonium sulphate

were 10.44 and 7.03, 9.39 and 6.22 and 2.75 and 2.68% over control, respectively. The role of bio-fertilizer could have resulted from the better root proliferation, nutrients absorption, increasing of atmospheric N_2 by microbial inoculants. These results are in same line with those obtained by [12-13,32].

As for the interaction, the data clearly showed that fennel yield components were significantly affected by the interaction among the studied three factors (A x B x C). The combination effect of 50 kg N/fed as urea or ammonium sulphate with both 5 t/fed compost and bio-fertilizer on number of ambles/plant, number of umbellule's/ amble and 1000-seed weight were statistically equaled to those obtained under 80 kg N/ fed as urea or ammonium sulphate. In general, the treatment of 5 t compost/fed + 50 kg N/fed as ammonium sulphate + bio-fertilizer exhibited the highest yield component parameters, which were equaled or higher those obtained by 80 kg ammonium sulphate. On the other hand, the plants under zero organic, mineral and bio-

fertilizers recorded the lowest ones. The beneficial effect of mixed mineral nitrogen with organic and bio-fertilizer on fennel yield components was reported by many investigators [8,33].

4. CONCLUSION

From the abovementioned discussion, about 30kg N/fed as ammonium sulphate or urea could be saved when the fennel plant treated by 5t/fed compost and bio-fertilization in order to maximize growth and yield component parameters of fennel plant. Therefore, application of 50 kg N/fed as ammonium sulphate in the presence of 5t /fed is highly recommended as a good practice for the fertilization of fennel plants. Addition of compost and bio-fertilizer is a vital task to produce high growth and yield components of fennel plants grown on newly reclaimed lands.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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