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USING NANO-FERTILIZATION TO IMPROVE YIELD, VEGETATIVE GROWTH AND ESSENTIAL OIL CONTENTS OF FENNEL PLANTS

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ABSTRACT: Nutritional status, fruiting, yield and essential oil of fennel plants (*Foeniculum vulgare* L.) grown under clay loam soil conditions located at Beni Suwef governorate – Egypt in response to partial replacement of conventional NPK-mineral fertilizers by NPK-nano fertilizers at 25%, 50% and 75%, were investigated during 2017 and 2018 seasons. Increasing the replacement ratio of conventional NPK-mineral fertilizers by NPK-nano fertilizers from 25% to 75% was very effective in improving vegetative growth leaf mineral contents (N, P, K, Mg and Ca), and essential oil % rather than using 100% conventional NPK fertilizers. The gradual increasing the ratio of nano NPK fertilizers from 25% to 75% was remarkably enhancing oil yield/plant as well as oil yield/feddan. However, non-significant differences were observed between the two heights ratio 50% and 75% nano-fertilizers ratio.

Key words: Fennel plant, nano-fertilization, growth, yield, essential oil.

INTRODUCTION

Fennel plants (*Foeniculum vulgare* L.) belongs to family Umbelliferae. It is an annual plant that is cultivated for its economic, aromatic and medicinal value (**Kandil, 2002; Osman, 2009 and Ayub *et al.*, 2011**). Its fruit had a sweet taste and spicy odour that may be used in soups, sauces, pickles, confectioneries, perfumery, cosmetics, scenting soaps, pharmaceutical and phytotherapy industries **(Blumenthal *et al.*, 2000; Osman, 2009 and Valiki *et al.*, 2015).**

Medicinal plants production is mainly under condition of sustainable agriculture. In this system, management of environmental parameters is very critical (**Valiki *et al.*, 2015**). In Egypt, Fennel (*Foeniculum vulgare* L.) is an important economical export crop, used also in the local market in the food and pharmaceutical industries as an important spice. It ranks first crop in quantity of Egyptian exports of herbs and spices. The economical parts use of fennel is dry fruits, aromatic oil, green leaf bases.

Studies show that one of the most important uses of nano technology in agriculture is the using of nano fertilizers where it found to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation as well as reduces soil toxicity, Hence, nanotechnology has a high potential for sustainability agriculture, especially in developing countries (**Yang *et al.*, 2006; Yang *et al.*, 2007 and Valiki *et al.*, 2015**).

Nanotechnology can be used as an alternative technology in a wide scientific area. Nanotechnology has been described as relating to materials, systems and processes which operate at a scale of 100 nanometres or less (**Yang *et al.*, 2006 and Rameshiaiah *et al.*, 2015**).

Attempts have been made to synthesize nanofertilizer in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nanonutrients are more efficient than ordinary fertilizer. Nano-fertilizer technology is innovative and few reported literature is available in the scientific journals. However, some of the patented and reports strongly suggest that there is a scope for the formulation of nano-fertilizers. An enhanced production has been observed by foliar application of nano particles as fertilizer (**Tarafdar *et al.*, 2013**).

The main target of this study was examining the effect of partial replacement of nano-NPK fertilizers versus ordinary mineral fertilizers on some growth

traits, nutritional status of plants, yield and essential oil of the fennel plants.

MATERIALS AND METHODS

This study was carried out during two successive seasons (2017-2018 and 2018-2019,respectively) on fennel plants *(Foeniculum vulgare* L.), cultivated at the farm of the medical plants, Agriculture Research Center - Seds Research Station Beni Sueif Governorate-Egypt to explore the influence of partial replacement of mineral NPK fertilizers by nano – NPK fertilizers on the vegetative growth, nutritional status of plants, yield and essential oil of fennel plants.

Soil physical and chemical analysis: Mechanical, physical and chemical analysis of the farm soil were carried out at the start of the experiment according to the procedures of **Walsh & Beaton (1986)** and **Buurman *et al.*, (1996)** and the data as shown in Table (1).

Table 1. Physical and chemical analysis of the experimental farm soil

Physical Analysis
Sand % = 11.20; Silt % = 44.70; Clay % = 44.10; Soil Texture (Clay loam)
Chemical Analysis
Organic matter % = 1.52; CaCO3 % = 1.99; pH (1:2.5) = 7.69; E.C. (m mhose/cm) = 1.02; Total N%= 0.09; Available P (Olsen, ppm)= 3.02; Available K (ammonium acetate, ppm) = 398; Exch. Ca (mg / 100 g) = 25.92; Exch. Na (mg/100 g) = 1.98

Plant materials and Experimental work: Seeds of fennel plants were obtained from the Research Center of Medicinal and Aromatic Plant Section, Seeds Station Beni Sueif Governorate (Egypt). The seeds were sown on the end of September, in both seasons (2017 and 2018). The experimental unit (plot) was 3 × 3.4 meters and containing 4 rows, 60 cm apart. The seeds were cultivated in hills, 40 cm apart on east side of the rows. Each plot contained 32 hills, one month later from sowing date the plants were thinned to two plants per hill. Then, the plants were harvested on the end of April during 2018 and 2019 seasons.

Experimental design: Experiments were performed using a completely randomized block design (RCBD) and the statistical analyses were performed with SPSS program (SPSS Inc., Chicago, USA). Each treatment was replicated three times. The experimental unit (plot) was 3 × 3.4 meters and containing 4 rows, 60 cm apart.

This study included the following four treatments:

(1) 100% conventional mineral (N, P and K) fertilization (control).

(2) 75% conventional mineral (N, P and K) fertilization + 25% nano NPK fertilization.

(3) 50% conventional mineral (N, P and K) fertilization + 50% nano NPK fertilization.

(4) 25% conventional mineral (N, P and K) fertilization + 75% nano NPK fertilization.

Each treatment was replicated three times, one plot 3 X 3.4 meters per each plot. NPK fertilizer quantities were calculated according to the following fertilizer program (according to **Samuel, 2008**): 80 Nitrogen Units use as a form of ammonium nitrate (33.5 % N), 300 Kg Calcium Superphosphate/fed (15.5% P_2O_5), 48 Potassium Units used as a form of potassium sulphate (48 % K_2O), 20 Kg/fed Magnesium Sulfate. The amounts of conventional mineral NPK fertilizers were divided into three batches and added at one month interval, starting at November, 15th in both experimental seasons. All other agricultural practices were carried out as usual in the two growing seasons.

The uses of nano-fertilizers were divided into three batches applied at two methods: the first one includes 25% of the total amount of nano-fertilizers quantity (were divided into three batches and added as a foliar sprayed on the shoot system, one month interval, starting at November 30th), and the second nano-fertilizers part, includes 75% of the total quantity of nano-fertilizers (were added as a soil application with the traditional mineral NPK fertilizers). Triton B (at 0.05 g/liter) as a wetting agent was added to all spraying solutions, even control trees. Treatments were arranged in a complete randomized block design (RCBD).

Different measurements: The following vegetative growth, leaf mineral content, yield and essential oil % were determined at harvesting during the two experimental seasons.

1- Vegetative growth characters: at harvesting time (end of April during the two seasons), the plant height (cm), stem diameter measured at 10 cm above soil surface (cm), number of main branches/ plant, herb fresh weight/plant (g), and herb dry weight/plant (g) were determined.

2- Yield and yield component parameter: At harvesting time (end of April) the number of umbels/plant, number of umbellules/ umbel, weight of 100 fruits (g), fruit yield/plant (g), fruit yield / feddan (kg) were determined.

3- Essential oil determinations: Essential oil percentage of fruits, essential oil yield/plant (g) and essential oil yield / feddan (kg).

$$\text{Volatile oil \%} = \frac{\text{Volume oil in graduated}}{\text{Sample weight}} X\ 100$$

Essential oil percentage in the fruits of fennel was determined according to **Gad *et al.*, (1963)**. Satisfactory results were obtained by distillation of 25 g of fruits for three hours. Then the essential oil yield/plant and per feddan was calculated. Determination of oil yield/plant (ml.) was calculated as follows

$$\text{Plant oil yield (ml)} = \frac{\text{Oil \% x fruit yield/plant}}{100}$$

4- Leaves Mineral contents: The dried leaves were ground to a fine powder for determination of N, P and K elements. N, P and K elements were determined in the acid digested solution, which was prepared according to **Martin-Préval *et al.*, (1984)** using a mixture of hydrogen peroxide and Sulfuric acid (4 : 10) on 0.2 g of the dried samples.

Nitrogen was determined by the modified microkejldahl method described by **Martin-Préval *et al.*, (1984).**

Phosphorus was determined by using colorimetric method, described **by Walsh and Beaton (1986)** by measuring the optical density of phosphor-molibdo-vanadate complex by Spectro-photometrically at wave length 430 nm.

Potassium was flam-photometrically determined by using the method outlined by **Martin-Préval *et al.*, (1984)**.

Determination of calcium and magnesium: Calcium and Mg were determined according to the versinate titration method as described by **Barrows and Simpson (1962).**

Statistical design: The statistical analysis of the obtained data was carried out according to **Snedecor and Cochran (1990)** using New L.S.D. at 5% level.

RESULTS AND DISCUSSION

1- Vegetative growth

Data in Table 2 clearly showed the effect of partial replacement of conventional N, P and K fertilizers by those of Nano-fertilizers on vegetative growth parameters of Fennel plants (plants height (cm), stem diameter, number of branches per plant, plant fresh weight and plant dry weight) during 2018 and 2019 seasons. It is clear from the obtained data that all vegetative growth parameters were increasing gradually and significantly as a result of increasing the replacement percentage of Nano-N, P and K fertilizers. The maximum values of all vegetative parameters, were obtained from the plants received 75% from N, P and K as a form of Nano-fertilizers followed by those received 50% from N, P and K fertilizers as a form of Nano. However, the plants received 100% of N, P and K as a conventional fertilizers gave the lowest vegetative growth. Nano particles (1:100 nm) have extensive surface area and capable of holding abundance of nutrients and release it slowly and steadily such that it facilitates uptake of nutrients matching the crop requirement without any associated ill effects of customized fertilizer inputs (**Valiki *et al.*, 2015 and Elwany, 2019)**.

The obtained results concerning the stimulation of fennel plants vegetative growth as a result of replacement the conventional mineral fertilizers by those of Nano-Fertilizers during the present study are in harmony with those obtained by **Valiki *et al.*, 2015; Yang *et al.*, 2006; Yang *et al.*, 2007; Tarafdar *et al.*, 2013; Cieck and Nadaroglu, 2014; Roshdy and Refaai, 2016; Wassel and Mohamed, 2017** and **Elwany, 2019**.

Table 2. Effect of partial replacement of conventional minerals N, P and K fertilizers by Nano N,P and K fertilizers on vegetative growth parameters of fennel plants during 2018 and 2019 seasons

Treatments	Plant height (cm)		Stem diameter (cm)		Number of branches/ plant		Fresh weight per plant		Dry weight per plant	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
100% mineral (control)	99.2	97.6	1.12	1.14	1.34	1.51	98.1	100.3	29.3	28.9
75% mineral + 25% Nano	113.7	119.3	1.32	1.45	2.11	2.13	125.6	142.9	37.68	42.7
50% mineral + 50% Nano	145.5	157.3	1.54	1.59	3.10	3.18	167.3	198.5	56.6	59.7
25% mineral + 75% Nano	149.9	158.8	1.55	1.68	2.92	3.01	164.9	199.8	50.67	59.9
New LSD 5%	10.2	12.5	0.16	0.18	0.35	0.53	23.11	19.83	4.42	5.89

2- Effect on the yield and its components

It is evident from data in Table 3 that all Nano fertilizers treatments had a significant effect on yield and its components y during both seasons. During the two seasons, the maximum number of umbel/plant (25.1& 30.1), numbers of umbellules/ umbel (32.0 & 34.8), weigh of 1000 fruit (9.77 & 9.93 g), fruit yield/plant (45.11 & 53.18) and yield/ feddan (1352.8 & 1329.5 kg) were recorded with 75% as a form of Nano-fertilizers. These were followed by those received 50% Nano-fertilizers. However, the minimum yield as well as its components was obtained in the plant received 100% conventional mineral N, P and K fertilizers.

Nano-fertilizers may be causing an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application (**Zheng *et al.*, 2005; Yang *et al.*, 2006 and Yang *et al.*, 2007**).

Table 3. Effect of partial replacement of conventional minerals N, P and K fertilizers by Nano N, P and K fertilizers on the yield (kg)/feddan and its components of fennel plants during 2018 and 2019 seasons

Treatments	Number of umbellules/ plant		Number of umbellules/ umbel		Weight of 1000 fruits (g)		Fruit yield / plant (g)		Yield (kg) / fed.	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
100% mineral (control)	11.7	13.67	19.9	22.3	6.87	6.79	23.60	25.33	590.0	632.7
75% mineral + 25% Nano	19.7	22.1	27.8	29.1	8.12	8.43	39.92	41.44	998.0	1036.0
50% mineral + 50% Nano	23.5	28.4	32.2	33.9	9.56	9.98	49.91	50.98	1247.7	1274.5
25% mineral + 75% Nano	25.1	30.1	32.0	34.8	9.77	9.93	54.11	53.18	1352.8	1329.5
New LSD 5%	2.12	2.18	3.81	3.78	0.34	0.38	4.87	4.76	77.93	88.8

3- Effect on essential oil

The data in Table 4 showed significant influence of partial replacement of conventional N, P and K fertilizers by those of Nano-fertilizers on essential oil %, oil yield/plant and oil yield/feddan during both the seasons of study. It is evident from the pooled data (Table 4) that all NPK Nano-fertilizers treatments increased the essential oil%, Oil yield/plant and oil yield/feddan over the conventional fertilizers. This increment in the three parameters (essential oil%, Oil yield/plant and oil yield/feddan) was gradual and parallel with increasing NPK Nano-fertilizers ratio from 25% to 75%. However, the plant received the highest NPK Nano-fertilizers (75%) produced the higher values of essential oil%, oil yield/plant and oil yield/feddan. This was followed by those received 50% from NPK as a form of Nano-fertilizers. While, the lowest values of essential oil%, oil yield/plant and oil yield/feddan were obtained from the plants received 100 NPK as a form of conventional fertilizers.

The present findings on number of essential oil%, oil yield/plant and oil yield/feddan are in conformity with the results obtained by **Zheng *et al.*, (2005); Yang *et al*. (2007); Osman, (2009); Cicek and Nadarolgu (2014)** and **Ayub *et al.* (2015)**.

4- Effect on leaves mineral contents

The results pertaining to the effect of partial replacement of conventional N, P and K fertilizers by N, P and K Nano-fertilizers on leaves mineral contents are presented in Table 5. The perusal of data reveals that all treatments of Nano-fertilizers replacement exerted a significant effect on leaves N%, P%, K%, Mg% and Ca% during both experimental seasons. However, non-significant differences in leaves Ca% and Mg% between the two higher level of Nano fertilizers (%0% and 75%). Similar trend was observed during the two experimental seasons. The lowest leaves mineral contents were recorded in plants received 100 of N, P and K as form of conventional fertilizers.

The present findings of increased of Fennel leaves macro-nutrients contents with NPK-nanofertilizers application are in close conformity with those of **Ayub *et al.*, 2011; Ayub *et al.*, (2015); Cieck & Nadaroglu (2014) and Roshdy & Refaai (2016).**

Table 4. Effect of partial replacement of conventional minerals N, P and K fertilizers by Nano (N, P and K) fertilizers on essential oil %, oil yield / plant (g) and oil yield / feddan (kg) of fennel plants during 2018 and 2019 seasons

Treatments	Essential oil%		Oil yield / plant		Oil yield / feddan	
	2018	2019	2018	2019	2018	2019
100% mineral (control)	1.49	1.52	0.61	0.63	15.25	15.75
75% mineral + 25% Nano	1.89	1.97	1.02	1.01	25.50	25.25
50% mineral + 50% Nano	2.26	2.69	1.21	1.24	30.25	31.00
25% mineral + 75% Nano	2.67	2.79	1.35	1.37	33.75	34.25
New LSD 5%	0.39	0.42	0.29	0.27	4.81	3.12

Table 5. Effect of partial replacement of conventional minerals N, P and K fertilizers by Nano (N, P and K) fertilizers on leaves mineral contents of fennel plants during 2018 and 2019 seasons

Treatments	N %		P %		K %		Mg %		Ca %	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
100% mineral (control)	1.40	1.42	0.18	0.19	1.56	1.59	0.46	0.44	1.78	1.77
75% mineral + 25% Nano	1.57	1.58	0.27	0.28	1.68	1.72	0.55	0.56	1.89	1.88
50% mineral + 50% Nano	1.65	1.68	0.30	0.32	1.78	1.79	0.64	0.66	2.01	2.04
25% mineral + 75% Nano	1.73	1.75	0.32	0.34	1.80	1.81	0.72	0.73	2.11	2.09
New LSD 5%	0.068	0.070	0.013	0.011	0.10	0.12	0.06	0.05	0.11	0.09

CONCLUSION

In conclusion, for improve vegetative growth, nutritional status, yield and essential oil of fennel plant; it is necessary partial replacement at least 50% of conventional mineral-NPK fertilizers by nano-NPK fertilizers.

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