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# Growth and Productivity of Fennel (*Foeniculum vulgare,* Mill) Plants as Affected by Phosphorus Rate and Nano-Micronutrients Concentration

**Abdelkader, M. A. I. [1] ; Fatma R. Ibrahim[2] and E. E. Metwaly[3]**

**[1]Hoticulture Dept., (Floriculture) Faculty of Agriculture, Zagazig University, Egypt**

**[2]Vegetable and Floriculture Dept., (Floriculture) Faculty of Agriculture, Mansoura University, Mansoura, Egypt**

**[3]Vegetable and Floriculture Dept., (Vegetable)Faculty of Agriculture, Mansoura University, Mansoura, Egypt**



## ABSTRACT

The present study was carried out to evaluate the effect of different phosphorus fertilization rates at [0.0, 30 and 45 kg/feddan as $P_2O_5$, nano micronutrients concentrations (0.0, 250, 500 and 100 mg/l) as well as their combinations on growth and production of fennel (*Foeniculum vulgare*, L.). A field experiment was carried out at Experimental Farm (Ghazala Farm), Fac. Agric., Zagazig Univ., Egypt, during the two winter consecutive seasons of 2017/2018 and 2018/2019. Phosphorus fertilization as main plots and nano-micronutrients called "Magro NanoMix" which contained (Fe 6%, Zn 6%, B 2%, Mn 5%, Cu 1% and Mo 0.1%) as subplots were considered. The obtained results showed the importance of the nano-micronutrients on improving fennel growth, fruits and volatile oil yield compared to control. Fennel plants treated with phosphorus fertilizer or/and nano micronutrients instigated critical increments in vegetative growth (plant height and branch number/plant as well as dry weight of herb/plant), yield (number of inflorescence /plant, fruit yield/plant and /feddan), volatile oil production (volatile oil percentage and yield/plant and /feddan) and some chemical constituents (total phosphorus, total carbohydrates percentage and total chlorophyll content), as contrasted and un-treated plants. In general, 45 kg $P_2O_5$/feddan + 500 or 1000 mg/l of nano-micronutrients as foliar spray had significant effects in above mentioned parameters of fennel plant compared to the other combinations under Sharkia Governorate conditions.

**Keywords:**Fennel,phosphorus, nano-micronutrients, growth, yield components, volatile oil

## INTRODUCTION

(Ekiert, 2000) reported that the family *Apiaceae* includes many species which are well known as a source of many important herbal products. Fennel (*Foeniculum vulgare* Mill), which belongs to this family, is an annual aromatic and medicinal plant. Vegetative parts of fennel are used as a green salad whenever fruits have a burning sweet taste, spicy scent, pleasant and have pharmaceutical, food flavoring and perfumery used. Volatile oils in fennel fruits are about 1- 4%, which have anti-inflammatory action and disinfectant, primarily on the respiratory and digestive organs and have an anti-spasmodic influence on muscle of smooth (Stary and Jirasek, 1975). Ruberto *et al*. (2000) indicated that fennel has antimicrobial and antioxidant activities.

For plant growth and its development phosphorus considered as a one of the essential macronutrients to achieve this purpose (Harrison *et al*., 2002). Phosphorus is an important constitutive of bio-molecules such as ATP, phospholipids and nucleic acids in plant. Ordinarily, the soils are phosphorus imperfect in order to of problems of fixation, which turn out it less obtainable to the plants especially in clays soils. To overcome the phosphorus disability, different types of phosphate fertilizers are utilized to the soil (Gentili*et al*., 2006 and Rotaru and Sinclair, 2009).

Recent research on nano-particles in several plants has demonstrated for improved each of physiological activities, vegetative growth, protein level and yield indicating their potency use in crop betterment (Kole *et al.,* 2013). Furthermore, Azarpour *et al*. (2013) found that foliar spraying by nano iron fertilizers had significant influences at 1% probability level on cover yield of fresh flower of *Crocus sativus.* Also, Studies showed that the use of nano-fertilizers causes' enhancement in nutrients utilize efficiency (NUE), reduces the frequency of the application and reduces the possible negative effects related with over dosage. So, nanotechnology has a high prospect for obtaining sustainable agriculture, especially in developing regions (Naderi and Danesh-Shahraki, 2013).

The most important aim of this study is maximizing the fennel productivity by using different phosphorus fertilization rates combined with nano-micronutrients treatments. Besides, study the effect of using different phosphorus fertilization rates, nano-micronutrients and their combinations on growth parameters, yield and its components, volatile oil and chemical ingredients of *Foeniculum vulgare* plant under Sharkia Governorate conditions, Egypt.

## MATERIALS AND METHODS

The present work was carried out at the Experimental Farm, Faculty of Agriculture (Ghazala Farm, Fig. 1), Zagazig Univ., Egypt during the two consecutive winter seasons of 2017/2018 and 2018/2019. Seeds of fennel were gained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza and were sown on 10$^{th}$ October during the first and second seasons. Seeds were sown and then immediately irrigated. The mechanical and chemical properties of the experimental farm soil site are shown in Table 1 according to (Chapman and Pratt, 1971).

This experiment inclusive 12 treatments, in order to achieve the combinations between three phosphorus fertilization rates (0.0, 30 and 45kg $P_2O_5$ kg / feddan)as calcium superphosphate (15.5 % $P_2O_5$) and four nano-micronutrients concentrations (0.0, 250, 500 and 100 mg/l) and their combinations on growth parameters and productivity of fennel (*Foeniculum vulgare*, L.).Nano-micronutrients was added as a foliar application which commercially known as Magro NanoMix, which consists of the following minerals: Fe (6%) – Zn (6%) – B (2%) – Mn (5%) – Cu (1%) and Mo (0.1%) as well as it consists of citric acid (4%) which obtained from Modern Agricide Company (MAC).

The plot area was 10.8 m$^2$ (3.00 ×3.60 m) included six rows; each row was 60 cm apart and three meters in length. The seeds were sown in hills on one side of ridge and the distances between hills were 50 cm. After three weeks from sowing, seedlings were thinned to be two plants /hill. The treatments were arranged in a split plot design with 3 replicates, where the main plots were occupied by

phosphorus rates in randomly distributed, while the sub-plots were occupied by nano-micronutrients concentrations in randomly arranged.

Nitrogen and potassium fertilizers as ammonium sulphate (20.5 % N) at the rate of 150 kg/feddan and potassium sulphate (50% K2O) at 50 kg/feddan, respectively, were added to all of experimental plot units. Phosphorus fertilizer was added as soil application during soil arranging While, nitrogen and potassium fertilizers were divided into 3 equal portions and were added to the soil at 30, 60 and 90 days after sowing. Also, nano-micronutrients were added three times as foliar application at 30, 60and 90 days after sowing. All plants received the normal agricultural practices whenever they needed.

**Table 1. Experimental farm soil physical and chemical properties (average of two seasons)**

| **Mechanical analysis** | | | | | | | | | | **Soil texture** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Clay (%)** | | **Silt (%)** | | **Fine sand (%)** | | | **Coarse sand (%)** | | | **Sandy clay** | | |
| 43.49 | | 9.10 | | 13.52 | | | 33.89 | | | | | |
| Chemical analysis | | | | | | | | | | | | |
| pH | E C | Organic matter | Soluble cations (meq. / l) | | | | Soluble anions (meq. / l) | | | Available (ppm) | | |
| | m.mohs /cm | (%) | $Mg^{++}$ | $Ca^{++}$ | $K^{+}$ | $Na^{+}$ | $Cl^{-}$ | $HCO_3^{-}$ | $SO_4^{--}$ | N | P | K |
| 7.87 | 0.95 | 0.52 | 2.8 | 1.5 | 1.3 | 3.8 | 4.5 | 1.5 | 3.4 | 17.0 | 8.30 | 71.0 |

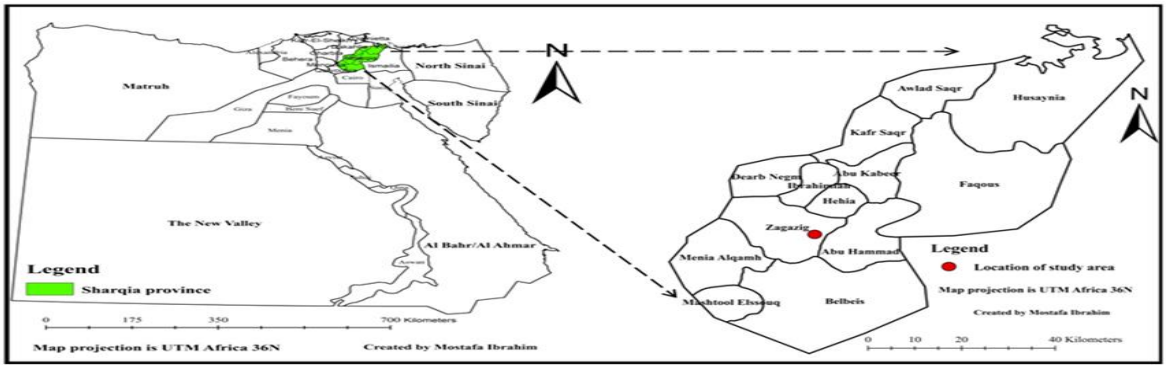


**Fig. 1. Study location in Zagazig County, SharkiaGovernorate, Egypt**

**Data recorded:**

Plant height (cm), branch number /plant and plant dry weight (g) were estimated, at harvesting stage. Number of inflorescence/ plant, fruit yield /plant (g) was established, and then fruit yield / feddan (kg) was studied.

For chemical analysis a sample of fennel dry fruits was possessed randomly of each treatment. Hydro distillation for 3 hr., was used to extract the volatile oil from fennel air dried fruits according to Guenther (1961). Then, volatile oil yield per plant (ml) and yield per feddan (l) was studied. Furthermore, total phosphorus (%) was estimated in fennel fruits according to the method qualified by Chapman and Pratt (1978).

Also, total carbohydrates percentage of fennel fruits was determined according to the methods substantive through AOAC (1990). Furthermore, chlorophyll a+ b content (mg/100g as fresh weight) in leaves of fennel was determined at 110 days after sowing according to Mazumder and Majumder (2003).

**Statistical Analysis**

After data were calculated then tabulated and subjected to analysis of variance using computer program of Statistix Version 9 (Analytical Software, 2008) which, was followed by the least significant differences (L.S.D) at the 5% level to explore the significancy among means of different treatments.

## RESULTS AND DISCUSSION

**Plant growth parameters:**

Plant height, branch number/ plant and dry weight of fennel plant were significantly increased by all phosphorus fertilization rates compared with control during the two tested seasons. Generally, those characteristics were gradually increased by increasing phosphorus rates up to the highest rate (Table 2). Moreover, the elevated values in this concern were achieved by usage of phosphorus fertilization at (45 kg $P_2O_5$ /feddan) compared with the other two rates. The superior effects of P fertilizer application on fennel growth parameters are due to, phosphorus is a part of molecular structure of vitally important compounds. In addition, it plays an essential role in DNA, RNA and photosynthesis and cell division as well as for meristim tissues (Marshner, 1995). These results are in harmony with those stated by Jalili and Majidi (2015) on *Satureia hortensis* L and Janaki*et al*. (2013) on *Thymus serphyllum*.

Table 2 shows that using of nano-micronutrients concentration produce significant increase in fennel plant height, branch number per plant and total dry weight per plant in comparison to control in both seasons. Furthermore, increasing nano - micronutrients concentrations gradually increased the abovementioned parameters. These results could be attributed to nano-fertilizers improve easiness of utilize of nutrient to the plants which promote formation of pigments, production of dry material, rate of photosynthesis and result get superior in the plant general growth (Hediat, 2012). In addition, El-Metwally *et al*. (2018) found that use of nano-fertilizers recorded the greatest of plant height, branch number /plant and dry weight of straw /plant of peanut compared to untreated plant.

The comparison of the combination effect between phosphorus rates and nano-micronutrients concentrations indicated that the most values of growth parameters of fennel plants were related to phosphorus fertilization at 45 kg $P_2O_5$ / feddan accompanied with nano-micronutrients at 1000 mg/l concentration (Table 2). These results agreed

with those reported by Hassani *et al*. (2015) on *Mentha piperita* and Al-Juthery *et al*. (2018) on wheat plants.

**Table 2. Effect of phosphorus fertilization rate, nano-micronutrients and their combinations on plant growth parameters of fennel plants during the two seasons of 2017/2018 and 2018/2019**

| Treatments | | Plant height (cm) | | Number of branches/plant | | Dry herb weight/plant (g) | |
|---|---|---|---|---|---|---|---|
| | | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| Phosphorus rates (kg/feddan) as $P_2O_5$ | | | | | | | |
| 0.0 | | 112.80 | 124.33 | 9.42 | 10.50 | 35.68 | 33.50 |
| 30 | | 133.72 | 144.67 | 12.50 | 12.92 | 43.17 | 44.22 |
| 45 | | 146.97 | 155.00 | 14.25 | 14.58 | 60.27 | 60.16 |
| LSD at 5% | | 1.40 | 4.49 | 0.60 | 0.52 | 1.03 | 2.93 |
| Foliar application with nano-micronutrients(mg/l) | | | | | | | |
| Without | | 119.80 | 130.89 | 10.56 | 11.33 | 38.74 | 37.72 |
| 250 | | 130.69 | 138.44 | 12.11 | 12.33 | 46.51 | 42.61 |
| 500 | | 133.91 | 145.67 | 12.67 | 12.89 | 48.83 | 49.47 |
| 1000 | | 140.24 | 150.33 | 12.89 | 14.11 | 51.42 | 54.06 |
| LSD at 5% | | 2.15 | 3.63 | 0.58 | 0.47 | 0.79 | 2.81 |
| Combination between phosphorus rates and nano-micronutrients levels | | | | | | | |
| 0.0 | Without | 99.80 | 107.67 | 8.33 | 9.00 | 27.89 | 27.65 |
| | 250 | 111.80 | 124.00 | 9.33 | 10.67 | 37.06 | 33.79 |
| | 500 | 117.13 | 130.33 | 9.67 | 10.67 | 38.35 | 33.72 |
| | 1000 | 122.47 | 135.33 | 10.33 | 11.67 | 39.42 | 38.86 |
| 30 | Without | 123.80 | 142.00 | 11.00 | 12.33 | 33.26 | 42.79 |
| | 250 | 133.13 | 136.67 | 12.67 | 11.67 | 44.68 | 38.69 |
| | 500 | 136.47 | 149.67 | 13.67 | 13.33 | 44.85 | 47.76 |
| | 1000 | 141.47 | 150.33 | 12.67 | 14.33 | 49.89 | 47.66 |
| 45 | Without | 135.80 | 143.00 | 12.33 | 12.67 | 55.07 | 42.72 |
| | 250 | 147.13 | 154.67 | 14.33 | 14.67 | 57.78 | 55.36 |
| | 500 | 148.13 | 157.00 | 14.67 | 14.67 | 63.30 | 66.92 |
| | 1000 | 156.80 | 165.33 | 15.67 | 16.33 | 64.97 | 75.66 |
| LSD at 5% | | 3.50 | 7.00 | 1.05 | 0.86 | 1.56 | 5.09 |

**Yield components:**

Number of florescence/plant as well as fruit yield of fennel per plant and significantly increased with phosphorus fertilization rates compared to untreated plants in both seasons (Table 3). The maximum increase in this concern was observed with phosphorus application at rate of 45 kg $P_2O_5$ per feddan compared to the other phosphorus rates during the two tested seasons under study. It is fully known that phosphorus is an fundamental element in productivity and vegetative growth and number of flower which can enhance by the used phosphorus applications (Abadi *et al*., 2015). These results agreed with those found by Ahmed*et al*. (2016) on *Ambrosia maritime* and Pal *et al*. (2016) on *Origanum vulgare*.

In the mean time, there was gradual increase in the abovementioned parameters with increasing nano-micronutrients concentrations (Table 3). From the abovementioned results it could be suggested that, the superiority in fennel fruit yield by nano-micronutrients application is directly owing to the enhancing effect on growth parameters of fennel plants, which resulted in increments in metabolites syntheses to fruits and this in turn increase total fruit yield. Amuamuha*et al*. (2012) reported that the influence of Nano-iron concentration was considerable on the flower yield at second harvest and on the pot marigold yield at the first one. Also, Pavithra *et al*. (2017) demonstrated that rice plants treated with nano ZnO showed improved in biomass, tiller number and yield.

Similarly, the data given in Table 3 suggest that, the best combination treatment for increasing number of florescence/plant, plant fruit yield and fruit yield per feddan was that of the treatment of 45 kg $P_2O_5$ per feddan combined with 1000 mg/l concentration of nano-micronutrients compared to the other combination ones, in most cases. Moreover, under each rate of phosphorus fertilization fennel yield and its components were increased through increasing nano-micronutrients concentrations.

**Table 3. Effect of phosphorus fertilization rate, nano-micronutrients and their combinations on yield components of fennel plants during the two seasons of 2017/2018 and 2018/2019**

| Treatments | | Number of florescence/plant | | Fruits yield / plant (g) | | Fruits yield / feddan (Kg) | |
|---|---|---|---|---|---|---|---|
| | | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| Phosphorus rates (kg/feddan) as $P_2O_5$ | | | | | | | |
| 0.0 | | 52.25 | 51.75 | 19.95 | 20.96 | 558.62 | 586.86 |
| 30 | | 62.33 | 61.08 | 21.05 | 23.05 | 589.54 | 645.42 |
| 45 | | 72.75 | 69.42 | 22.56 | 26.67 | 631.66 | 746.83 |
| LSD at 5% | | 1.71 | 1.48 | 0.49 | 0.58 | 13.69 | 16.37 |
| Foliar application with nano-micronutrients(mg/l) | | | | | | | |
| Without | | 56.67 | 55.89 | 19.70 | 22.29 | 551.66 | 624.15 |
| 250 | | 60.00 | 59.78 | 21.28 | 22.34 | 595.84 | 625.40 |
| 500 | | 66.22 | 61.67 | 22.19 | 24.10 | 621.20 | 674.86 |
| 1000 | | 66.89 | 65.67 | 21.59 | 25.51 | 604.40 | 714.40 |
| LSD at 5% | | 1.01 | 1.39 | 0.47 | 0.50 | 13.26 | 14.15 |
| Combination between phosphorus rates and nano-micronutrients levels | | | | | | | |
| 0.0 | Without | 47.67 | 47.67 | 18.76 | 19.28 | 525.37 | 539.84 |
| | 250 | 50.33 | 54.67 | 20.36 | 19.73 | 570.17 | 552.44 |
| | 500 | 56.67 | 50.33 | 21.40 | 21.68 | 599.11 | 607.04 |
| | 1000 | 54.33 | 54.33 | 19.28 | 23.15 | 539.84 | 648.11 |
| 30 | Without | 57.67 | 58.33 | 19.46 | 21.83 | 544.97 | 611.24 |
| | 250 | 60.33 | 56.33 | 21.06 | 21.75 | 589.77 | 608.91 |
| | 500 | 66.00 | 64.33 | 22.53 | 23.81 | 630.84 | 666.77 |
| | 1000 | 65.33 | 65.33 | 21.16 | 24.81 | 592.57 | 694.77 |
| 45 | Without | 64.67 | 61.67 | 20.88 | 25.76 | 584.64 | 721.37 |
| | 250 | 69.33 | 68.33 | 22.41 | 25.53 | 627.57 | 714.84 |
| | 500 | 76.00 | 70.33 | 22.63 | 26.81 | 633.64 | 750.77 |
| | 1000 | 81.00 | 77.33 | 24.31 | 28.58 | 680.77 | 800.33 |
| LSD at 5% | | 2.27 | 2.54 | 0.86 | 0.95 | 23.96 | 26.58 |

**Volatile oil production:**

Data in Table 4 illustrate that, the elevated rate of P fertilizer (45 kg $P_2O_5$/fed.) recorded the highest values of volatile oil percentage in fennel fruits as well as plant volatile oil yield (ml) and feddan volatile oil yield (l) compared to non-fertilized (control) and other rates under study during the two consecutive seasons. Likewise, the abovementioned parameters were showed gradually significant increase with increasing P fertilizer rates in the first and second seasons. Abadi *et al*. (2015) on black cumin and Sonmez (2018) on anise plant have been obtained similar results. However, Lambers *et al*. (2000) indicated that P fertilizer plays important roles in many physiological processes in the plant. These effects were observed with significant increase in fennel fruit yield and its components as well as volatile oil production under study.

The topmost increase in percentage of volatile oil as well as volatile oil per plant and per feddan of fennel were

observed with nano-micronutrients application at concentration of 1000 mg/l compared to other concentrations under study during both seasons (Table 4). In the mean time, there was gradual increase with increasing nano-micronutrients concentrations in the above mentioned parameters. These results coincided with those reported by Mohsenzadeh and Moosavian (2017) on rosemary, Rezaei-Chiyaneh *et al.* (2018) on black cumin and Sabet and Mortazaeinezhad (2018) on cumin plants.

The best combination treatment for volatile oil production of fennel was that of the treatment of phosphorus fertilizer at 45 kg P2O5 per feddan combined with nano-micronutrients of 1000 mg/l concentration compared to the other combination treatments in the two tested seasons (Table 4). Moreover, under each treatment of phosphorus fertilization rates fennel volatile oil parameters were increased with increasing nano-micronutrients concentrations. In the same trend, Hamed (2018) showed that application of 3/4 N dose followed by 1/2 N dose + foliar spray with nano-fertilizer significantly super passed full N dose in oil yield characters.

**Chemical constituents**:

The data given in Table 5 suggest that, all phosphorus fertilization treatments significantly increased fennel total phosphorus as well as total carbohydrates percentage in fruits and total chlorophyll content (a+b) in fennel leaves compared to control. Moreover, chemical constituents of fennel plant were gradually increased with increasing phosphorus rates. Furthermore, the maximum increase in this respect was obtained from the treatment of (45 kg P2O5 per feddan) compared with the other rates under study. Such enhancement was significant in the two seasons. These results are in line in both seasons. Phosphorus uptake caused an increase in net fixations of CO2 with increased photosynthesis rate and thereby more photosynthates to promote more plant yield (Badsra and Chaudhary, 2001). Similar results were also found by Hendawy *et al.* (2013) on lovage, Rahimi *et al.* (2013) on basil.

**Table 4. Effect of phosphorus fertilization rate, nano-micronutrients and their combinations son volatile oil production of fennel plants during the two seasons of 2017/2018 and 2018/2019**

| Treatments | | Volatile oil (%) | | Volatile oil yield/plant (ml) | | Volatile oil yield/feddan (l) | |
|---|---|---|---|---|---|---|---|
| | | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| Phosphorus rates (kg/feddan) as $P_2O_5$ | | | | | | | |
| 0.0 | | 3.308 | 3.282 | 0.660 | 0.688 | 18.493 | 19.281 |
| 30 | | 3.437 | 3.372 | 0.724 | 0.778 | 20.284 | 21.785 |
| 45 | | 3.532 | 3.477 | 0.797 | 0.929 | 22.329 | 26.008 |
| LSD at 5% | | 0.017 | 0.033 | 0.019 | 0.021 | 0.539 | 0.588 |
| Foliar application with nano-micronutrients(mg/l) | | | | | | | |
| Without | | 3.318 | 3.323 | 0.654 | 0.742 | 18.327 | 20.781 |
| 250 | | 3.488 | 3.361 | 0.742 | 0.753 | 20.793 | 21.082 |
| 500 | | 3.434 | 3.373 | 0.762 | 0.816 | 21.350 | 22.841 |
| 1000 | | 3.463 | 3.449 | 0.750 | 0.883 | 21.006 | 24.727 |
| LSD at 5% | | 0.012 | 0.033 | 0.017 | 0.019 | 0.481 | 0.545 |
| Combination between phosphorus rates and nano-micronutrients levels | | | | | | | |
| 0.0 | Without | 3.220 | 3.253 | 0.604 | 0.628 | 16.920 | 17.577 |
| | 250 | 3.440 | 3.290 | 0.700 | 0.649 | 19.617 | 18.187 |
| | 500 | 3.300 | 3.260 | 0.705 | 0.707 | 19.750 | 19.807 |
| | 1000 | 3.277 | 3.323 | 0.632 | 0.770 | 17.687 | 21.553 |
| 30 | Without | 3.300 | 3.373 | 0.642 | 0.737 | 17.983 | 20.633 |
| | 250 | 3.473 | 3.323 | 0.732 | 0.723 | 20.483 | 20.243 |
| | 500 | 3.467 | 3.367 | 0.781 | 0.802 | 21.870 | 22.463 |
| | 1000 | 3.510 | 3.423 | 0.743 | 0.850 | 20.800 | 23.800 |
| 45 | Without | 3.433 | 3.343 | 0.717 | 0.862 | 20.077 | 24.133 |
| | 250 | 3.550 | 3.470 | 0.795 | 0.887 | 22.280 | 24.817 |
| | 500 | 3.540 | 3.493 | 0.801 | 0.938 | 22.430 | 26.253 |
| | 1000 | 3.603 | 3.600 | 0.876 | 1.023 | 24.530 | 28.827 |
| LSD at 5% | | 0.025 | 0.059 | 0.032 | 0.036 | 0.893 | 0.999 |

**Table 5. Effect of phosphorus fertilization rate, nano-micronutrients and their combinations on some chemical constituents of fennel plants during the two seasons of 2017/2018 and 2018/2019**

| Treatments | | Total phosphorus (%) in fruits | | Total carbohydrates (%) in fruits | | Total chlorophyll (a+b) (%) mg/100 g fresh leaves weight | |
|---|---|---|---|---|---|---|---|
| | | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| Phosphorus rates (kg/feddan) as $P_2O_5$ | | | | | | | |
| 0.0 | | 0.332 | 0.365 | 14.54 | 15.31 | 28.31 | 32.50 |
| 30 | | 0.375 | 0.392 | 15.07 | 16.20 | 29.43 | 33.93 |
| 45 | | 0.442 | 0.432 | 15.77 | 17.09 | 33.14 | 36.77 |
| LSD at 5% | | 0.021 | 0.005 | 0.33 | 0.21 | 1.512 | 0.17 |
| Foliar application with nano-micronutrients(mg/l) | | | | | | | |
| Without | | 0.347 | 0.371 | 14.54 | 15.69 | 8.22 | 32.66 |
| 250 | | 0.384 | 0.393 | 15.04 | 16.23 | 30.48 | 33.60 |
| 500 | | 0.389 | 0.397 | 15.40 | 16.15 | 30.55 | 35.44 |
| 1000 | | 0.412 | 0.424 | 15.37 | 16.72 | 31.94 | 35.90 |
| LSD at 5% | | 0.021 | 0.009 | 0.31 | 0.24 | 0.66 | 0.50 |
| Combination between phosphorus rates and nano-micronutrients levels | | | | | | | |
| 0.0 | Without | 0.315 | 0.353 | 14.05 | 14.76 | 27.29 | 31.10 |
| | 250 | 0.336 | 0.363 | 14.14 | 15.62 | 28.19 | 31.82 |
| | 500 | 0.345 | 0.369 | 14.87 | 15.18 | 28.65 | 32.67 |
| | 1000 | 0.333 | 0.374 | 14.45 | 15.68 | 29.10 | 34.42 |
| 30 | Without | 0.354 | 0.371 | 14.62 | 15.75 | 27.59 | 32.64 |
| | 250 | 0.348 | 0.377 | 14.97 | 15.90 | 29.30 | 33.60 |
| | 500 | 0.365 | 0.389 | 15.75 | 16.43 | 30.28 | 35.17 |
| | 1000 | 0.433 | 0.429 | 14.97 | 16.72 | 30.56 | 34.30 |
| 45 | Without | 0.373 | 0.389 | 14.95 | 16.57 | 29.77 | 34.25 |
| | 250 | 0.468 | 0.437 | 15.85 | 17.16 | 33.93 | 35.38 |
| | 500 | 0.457 | 0.434 | 15.58 | 16.86 | 32.72 | 38.49 |
| | 1000 | 0.471 | 0.467 | 16.68 | 17.75 | 36.15 | 38.96 |
| LSD at 5% | | 0.038 | 0.015 | 0.56 | 0.42 | 1.79 | 0.77 |

Results under discussion presented in Table 5 indicate the influence of foliar spray with nano-micronutrients on total phosphorus and carbohydrates percentage and total chlorophyll a+b content (mg/100g as fresh weight).In addition, there was gradual increase in this connection with increasing nano-micronutrients concentrations. The highest values in this concern were achieved by the treatment of 1000 mg/l concentration compared to the other ones under study during both seasons. Furthermore, Al-Juthery and Saadoun (2018) indicated that nano-applied treatment of (Cu+ Zn+ Fe+ Mn) was significantly higher followed by the triple, di and single spray combinations, in total chlorophyll content of artichoke plant.

The results of the twice combination effect reveal that the fennel plants fertilized with the highest added rate of phosphorus (45 kg P2O5/fad.) and supplemented with the mixture of nano-micronutrients (at 1000 mg/l) gave the significant highest total phosphorus percentage as well as total carbohydrates percentage in fruits and total chlorophyll content in fennel leaves compared to control (Table 5). Generally, under every treatment of nano-micronutrients concentrations chemical constituents of fennel were increased through increasing of phosphorus rates.

## CONCLUSION

In general, greater fennel plant productivity was observed when phosphorus fertilizer with high rate was used. Foliar application of nano-micronutrients mixtures improved markedly plant growth parameters, yield and its components and volatile oil parameters of fennel plant. Furthermore, 45 kg $P_2O_5$/feddan + 500 or 1000 mg/l of nano-micronutrients as foliar spray had significant effects in above mentioned parameters of fennel plant when compared to the other combination treatments under conditions of Sharkia Governorate.

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## تأثيرمعدل الفسفوروتركيز العناصر الصغرى متناهية الصغرعلى نمو وإنتاجية نباتات الشمر

**محمد أحمد إبراهيم عبد القادر[1] ، فاطمة رشاد إبراهيم خليل سليمان[2] و السعيد السيد متولى[3]**

**[1]قسم البساتين ( زينه)- كلية الزراعة - جامعة الزقازيق- مصر**

**[2]قسم الخضر والزينة ( زينه)- كلية الزراعة - جامعة المنصورة– مصر**

**[3] قسم الخضر والزينة (خضر)- كلية الزراعة - جامعة المنصورة- مصر**

أجريت تجربتين حقليتين في المزرعة التجريبية (مزرعة غزالة) بكلية الزراعة، جامعة الزقازيق، مصر، لدراسة تأثيرمعدل التسميد الفوسفاتي (صفر، 30 و45 كجم فو$_2$أ$_5$/فدان)، وتركيزات مختلفة من العناصر الصغرى النانونية (صفر، 250 ، 500 و1000ملليجرام/ لتر) بالإضافة إلى معاملات التداخل بينهما على نمو وإنتاج نبات الشمر،خلال الموسمين الشتويين المتتاليين 2018/2017و2019/2018. وزعت مستويات التسميد الفوسفاتي في القطع الرئيسية وتركيزات العناصر الصغري متناهية الصغر المسماه بالماجرو نانو ميكس والتي تحتوى على (حديد 6% و زنك 6% و بورون 2% و منجنيز 5% و نحاس 1% وموليبدنيم 0.1%) في القطع تحت الرئيسية . أوضحت النتائج المتحصل عليها أهمية العناصر الصغرى متناهية الصغر في تحسين نمو ومحصول الثمار والزيت العطري لنباتات الشمر مقارنة بالكنترول. أدت معاملة نباتات الشمر بالتسميد الفوسفاتي و/أو العناصر الصغرى متناهية الصغر إلى زيادة معنوية في صفات النموالخضري (ارتفاع النبات، عدد الأفرع /النبات ،الوزن الجاف للعشب /نبات)، والمحصول (عدد النورات / نبات ومحصول الثمار للنبات وللفدان)، وإنتاج الزيت العطري (النسبة المئوية للزيت العطري وكل من محصول الزيت العطري للنبات وللفدان) وبعض المكونات الكيميائية (النسب المئوية للفسفور الكلي والكربوهيدرات الكلية بالثمار ومحتوى الكلوروفيل الكلي أ+ب)، وذلك مقارنةً بالنباتات الغير معاملة. عموماً ، أثر معدل الفوسفور 45 كجم فو$_2$أ$_5$/فدان + 500 أو 1000 ملليجرام من العناصر الصغرى متناهية الصغر رشا على الأوراق معنويا على صفات الشمر سالفة الذكر مقارنة بالتداخلات الأخرى تحت ظروف محافظة الشرقية.