Evaluation of adaptation of dill plants by adding phosphorous sources and mycorrhiza to improve growth, fruit yield and essential oil

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ABSTRACT
This experiment was conducted at Baluza Station belong to Desert Research Center newly reclaimed region located at North of Sinai, Egypt during two successive seasons of (2017/2018 and 2018/2019), to study the effect of phosphorous, mycorrhiza and their interaction to improving and adaptation on the productivity of dill (Anethum graveolens, L.) was investigated. Dill plants were treated with different sources of phosphorous (mono phosphate ammonium, dair phosphate ammonium, super phosphate calcium and rock phosphate) with or without mycorrhiza, the experimental design was split plot. Obtained results showed that, there was a significant increase in all growth, fruit yield and essential oil composition when using different source phosphorous fertilization where the best treatment was using rock phosphate, while when using the mycorrhiza application it led to a significant increase in all measurements. On the other hand, the interaction between different source phosphorous fertilization and mycorrhiza application led to a significant increase in all parameters such as growth, fruit yield, volatile oil composition and carvone; while β-phellandrene and d-limonene were reduced when using rock phosphate and mycorrhiza together.

Keywords: dill, Anethum graveolens, mycorrhiza, phosphorous fertilization.

1. Introduction
Dill (Anethum graveolens, L.) belongs to family Umbelliferae (Apiaceae), an annual herb plant that tolerates cold weather and low temperatures and is not affected by weather changes during growth periods (Radulescu et al., 2010). It is native to the Mediterranean region and used in ancient Egyptian and spread in most countries of the world, it is also a widespread herb in Algeria and Asia. Minor and Iran. China, Egypt, India, England and America are important dill producing countries (Callan et al., 2007). Fresh and dry dill leaves are used in making salads and are added to foods to impart flavor and aroma, and they are added to pickles and preserved meats. When adding dill fruit powder to food, it strengthens the stomach, body, and heart, and it is useful in calming the nerves, blood pressure, relieving chest pain, and is useful in increasing the production of milk and urine. It is also considered a repellant for gases, intestinal swelling, and a headache remedy (Hellal et al., 2011).

Dill fruits contain volatile oil, estimated at 2.2-4%, the fruits contain 53-63% (carvone, limonene, phellandrene and apiole). Oil is used in manufacturing medicines that stimulate the stomach, remove indigestion, flatulence, expel gases, and eliminate gastric and intestinal spasms internally, due to the presence of dihydrocarvone, α-pinene, and β-pinene components in the essential oil of dill. The oil is also used as an insecticide to eliminate some insects due to the presence of the apiole compound extracted from the oil (Dhima et al., 2010).

As a result of the increased use of chemical fertilizers in recent years, it led to pollution in soil, water and air, and its impact on human health was reflected everywhere as well as a result of high soil alkalinity in many soils in the arid and semi-arid regions and so-called arid lands. Where it was found that 75% of the added phosphorus is not able to most growing plants to benefit from it due to its
transformation into insoluble forms, and these combined factors increase the cost of agricultural production) and given that the mycorrhiza fungus, as previously mentioned, is characterized by good growth in soils with difficult conditions and has an important role in causing it. A way to increase absorption from distant are as about root respectively. Ghorchiani et al., (2018) on maize, Rezakhani et al., (2019) on Triticum aestivum L. and Leila, et al., (2020) on Sorghum bicolor, L. plants.

Mycorrhiza fungus is very important in protecting the environment from pollution by reducing the amount of phosphate fertilization by half, and phosphate rock can also be used instead of the expensive, polluting, expensive phosphate fertilizer. As it is known that the phosphorous leakage into waterways leads to contamination, as well as increases the growth of algae and weeds in waterways, and this leads to impeding the use of these waterways. Also, the mycorrhiza helps to take advantage of the slow-moving element of phosphorus by means of reducing the degree of The acidity in the soil is in addition to the process of sorting the phosphatase enzyme and chelation of the element, which leads to easy entry into the plant, and this is very useful under alkaline soil conditions as phosphorous is not facilitated for absorption by the plant (Sylvia and Williams, 1992; Toro et al., 1997).

In general, phosphate fertilization mixed with the mycorrhiza led to improvement and increase in growth in dill plants, and thus an increase in the number of inflorescences per plant as a result of an increase in the rate of building carbohydrates and nutrients inside, which led to an increase in the amount of fruits on the plant, which led to an increase in fruit production in Acre increased production (Wafaa and Rania, 2016) on Ricinus communis, var. red Arish.

The importance and aim of the study is that phosphate rock is one of the natural elements available in the Egyptian environment (Wafaa and Rania, 2016). Therefore, the possibility of using it directly as a cheap natural phosphorous source reduces the cost of production, on the other hand it contributes to reducing environmental pollution with chemical fertilizer. The use of Mycorrhizae facilitates the dissolution of phosphorus, and thus the plant benefits from it in the way it is suitable for it, in addition to that it reduces the consumption of phosphorous fertilizers by 50%, which allows the production of plants safely, which contributes to reducing production costs and thus an increase in the economic return. Through to study the effect of phosphorous fertilization and mycorrhiza application and their interaction on improving productivity and adaptation of dill (Anethum graveolens, L.) plant under reclaimed regions (North of Sinai) conditions.

2. Materials and Methods
Field experiment was conducted during two successive seasons of (2017/2018 and 2018/2019) in newly reclaimed arid land in the Agricultural Experimental Station of the Desert Research Center at Baluza region (31°30″N, 32°36′0″E), North Sinai Governorate, Egypt to study the effect of phosphorous fertilization and mycorrhiza application and their interaction on improving productivity and adaptation of dill (Anethum graveolens, L.) plant.

2.1. Plant material and procedure
The experiment was designed in a split plot design with three replications. The main plots were consisted of five source of phosphorous fertilization as follows “control (without phosphorous), mono phosphate ammonium, dai-phosphate ammonium, super phosphate calcium, rock phosphate “. The sub-plots included mycorrhiza application as follows “with and without mycorrhiza “. Compost manure was added to the sandy soil before sowing at the rate of 10 m³ per feddan. The seeds of dill obtained from the Medicinal and Aromatic Plants Research Department, Horticulture Institute, Agricultural Research Center, Dokki, Egypt. Sowing was done in the first week of October for both seasons under drip irrigation system in rows 75 cm apart and 50 cm between hills. After five weeks the plants were thinned at one plants per hill (11200 plants/feddan). All agricultural practices were performed as usual.

The soil, samples were analyzed at the laboratories of Desert Research Center and Soils, Water and Environment Research Institute, according to (Page et al., 1984). The soil mechanical” particle size distribution sand, silt and clay 90.5 and 50% , Texture class sand, EC dSm⁻¹ 1.37 and PH 8.20” and the soil chemical soluble ions (meq/l) included cations” Ca²⁺ 1.8 , Mg²⁺2.1 , Na⁺1.5 and K⁺0.09“ and Anions “HCO⁻³ 3.5 , SO₄⁻0.84 , Cl⁻ 1.51“available nutrients (ppm) include N 60 , P3.65 and K 144.
2.2. Fertilizer application

Different source phosphorous fertilization the recommended phosphate fertilizer was applied (32 unit of $P_2O_5$) mono phosphate ammonium (MAP, 61% $P_2O_5$), dai-phosphate ammonium (DAP, 46 % $P_2O_5$), super phosphate calcium (SPC, 15.5 % $P_2O_5$), rock phosphate (RP, 28% $P_2O_5$). The various fertilizer sources add during preparing for planting the soil.

The Mycorrhiza were obtained from Microbiology Laboratory, Faculty of Agriculture, Ain Shams University, Egypt, as (1L/1 kg seeds). Mycorrhiza was mixed with the seeds as soak for one hour

The treatments were conducted as follows
1. Control + without mycorrhiza
2. Mono phosphate ammonium (MAP, 61 % $P_2O_5$) + without mycorrhiza
3. Dai-phosphate ammonium (DAP, 46 % $P_2O_5$) + without mycorrhiza
4. Super phosphate calcium (SPC, 15.5 % $P_2O_5$) + without mycorrhiza
5. Rock phosphate (RP, 28% $P_2O_5$) + without mycorrhiza
6. Control + mycorrhiza
7. Mono phosphate ammonium (MAP, 61 % $P_2O_5$) + mycorrhiza
8. Dai-phosphate ammonium (DAP, 46 % $P_2O_5$) + mycorrhiza
9. Super phosphate calcium (SPC, 15.5 % $P_2O_5$) + mycorrhiza
10. Rock phosphate (RP, 28% $P_2O_5$) + mycorrhiza

2.3. Harvesting

The end of the experiment plants were harvested at first week of May in both seasons. During two seasons the following data were recorded at the end of the experiment.

2.4. Data recorded:
1. Vegetative growth and fruit yield parameters:
   A. Plant height (cm)
   B. Number of umbels per plant
   C. Fruit yield (g/ plant)
   D. Fruit yield (kg/feddan).

2- Active constituent’s parameters
   A. Essential oil percentage was determined in the air dried fruits by hydro-distillation for 3 hours using a Clevenger type apparatus according to Abd El-Azim, et al., (2017 and 2016) on Foeniculum vulgare, Mill.
   B. Determination of volatile oil yield (ml/plant) as follows: oil percentage x fruit dry weight per plant /100
   C. Determination of essential oil yield (L/feddan) as follows: oil yield per plant x number of plants/feddan.
   D. Determination of essential oil components: The essential oil samples of second season were analyzed Spectrometry instrument (G.L.C analysis) at the Laboratory of Medicinal and Aromatic Plants Research Department, Horticulture Institute, Agricultural Research Center, Dokki, Egypt.

2.5. Statistical analysis

L.S.D. test at 0.05 was used to compare the average means of treatments according to Snedecor and Cochran (1980) by using computer program of StatistixVersion 9 (Analytical software, 2008).

3. Results
3.1. Vegetative growth and fruit yield parameters
   A. Plant height (cm)

Regarding to different sources phosphorous fertilization, there was a significant effect on plant height of Anethum graveolens, L. at both seasons. All treatments separately or mixed with mycorrhiza application increased plant height compared to untreated control in two growing seasons. Data in Table (1) reveal that plant height of Anethum graveolens, L. was significantly affected with mycorrhiza
application the two seasons. It was found that mycorrhiza surpassed compared to the control treatment, plant height ranged from 116.60 cm to 118.96 cm during the first and second seasons, respectively.

However, it was found that inoculating *Anethum graveolens*, L. seeds with mycorrhiza + rock phosphate followed by mycorrhiza + super phosphate calcium registered the tallest plants, hence plant height increased by 111.73 cm and 113.48 cm versus those obtained by the control treatment in two successive seasons respectively, Table (1).

Concerning the effect of interaction between different sources of phosphorous fertilization and mycorrhiza application, data in Table (1) indicated a significant on the plant height of *Anethum graveolens*, L. in both seasons. Moreover, the most effective treatments were obtained by treating the plants with mycorrhiza + rock phosphate followed by mycorrhiza + super phosphate calcium in comparison with the other combination treatments in both seasons, plant height ranged from 121.83 cm to 125.43 cm in the first and second seasons, respectively; by application mycorrhiza + rock phosphate treatments.

**B- Number of umbels / plant**

Illustrated data in Table (1) pointed out that number of branches per plant of *Anethum graveolens*, L. had significantly affected by different source phosphorous fertilization in both seasons. However, it is obvious that rock phosphate surpassed all treatments concerning number of branches ranged 20.50 and 21.00 in the first and second seasons, respectively.

Regarding to mycorrhiza application, the data reveal that, all of them significantly augmented number of branches of *Anethum graveolens*, L. in both seasons. However, the maximum values of number of branches was observed when adding mycorrhiza + rock phosphate which increased it 18.33 and 18.33 over control plants in the first and second seasons, respectively.

The interaction between some different source phosphorous fertilization and mycorrhiza application on number of branches per plant had significant effect in two successive seasons. It is obvious that using rock phosphate plus inoculating with mycorrhiza gave the highest values from number of branches ranged from 24.00 to 24.67 in the first and second seasons, respectively compared with those obtained by the combination treatments for both seasons, Table (1).

**C- Fruit yield (g/plant)**

Data in Table (1) show that, fruit yield was significantly affected by the different sources of phosphorous fertilization in two seasons. It is obvious that rock phosphate heaviest from all treatments ranged 39.55 g and 40.33 g in the first and second seasons, respectively.

Fruit yield was significantly affected by inoculation treatments with or without mycorrhiza at both seasons. From the obtained results, it is noticed that all of them led to a significant increase in fruit yield in comparison with the control treatment in the first and second seasons. Inoculating the plants with mycorrhiza gave better fruit yield which increased it by 36.99 gm and by 38.57 gm over the control plants in both seasons, respectively, as clearly shown in Table (1).

The interaction between different source phosphorous fertilization and mycorrhiza application on fruit yield had significant effect in two successive seasons. It is obvious that rock phosphate plus inoculating the plants with mycorrhiza gave the highest values of fruit yield which increased it by 44.23 g and 45.00 g in comparison with those obtained by other combination treatments in two experimental seasons, as clearly shown in Table (1).

**D- Fruit yield (kg/feddan)**

The obtained data in Table (1) reveal that fruit yield had significantly affected by different source phosphorous fertilization in two experimental seasons. It is obvious that rock phosphate surpassed other source phosphorous fertilization concerning ranged from 442.96 kg to 451.73 kg in the first and second seasons, respectively.

Regarding to mycorrhiza application, it is appear that it was significant effect on fruit yield for both seasons. From the obtained results, it could be noticed that all plants application with mycorrhiza led to a significant increase in fruit yield as compared to untreated control in two growing seasons.

However, it was founded that inoculating *Anethum graveolens*, L. plants with mycorrhiza application the best plant registered the increased the fruit yield by 414.33 kg/ feddan and 432.02 kg.
over than those obtained by control in two successive seasons respectively, as clearly shown in Table (1).

### Table 1: Effect of different source phosphorous fertilization and mycorrhiza application on growth and fruit yield.

| Mycorrhiza Phosphate source | First season | No. of umbels |
|-----------------------------|--------------|---------------|
| Control                     | 82.03^I      | 10.33^F       |
| MAP (61 % P2O5)             | 98.43^G      | 17.33^CD      |
| DAP (46 % P2O5)             | 102.07^F     | 19.00^C       |
| SPC (15.5 % P2O5)           | 107.57^E     | 21.00^B       |
| RP (28% P2O5)               | 111.37^D     | 24.00^A       |
| Mean                        | 111.73^A     | 12.67^B       |

**Second season**

| Mycorrhiza Phosphate source | First season | No. of umbels |
|-----------------------------|--------------|---------------|
| Control                     | 85.03^I      | 10.67^GH      |
| MAP (61 % P2O5)             | 99.60^G      | 17.67^D       |
| DAP (46 % P2O5)             | 103.10^F     | 19.33^C       |
| SPC (15.5 % P2O5)           | 108.77^E     | 23.33^B       |
| RP (28% P2O5)               | 112.48^D     | 27.00^A       |
| Mean                        | 113.48^A     | 13.46^B       |

| Mycorrhiza Phosphate source | Fruit weights (g/plant) | Fruit (kg/feadden) |
|-----------------------------|-------------------------|-------------------|
| Control                     | 18.67^H                 | 209.07^H          |
| MAP (61 % P2O5)             | 21.30^G                 | 238.56^G          |
| DAP (46 % P2O5)             | 25.50^F                 | 285.60^F          |
| SPC (15.5 % P2O5)           | 30.73^E                 | 344.21^E          |
| RP (28% P2O5)               | 34.87^D                 | 390.51^D          |
| Mean                        | 36.99^A                 | 414.33^A          |

**Second season**

| Mycorrhiza Phosphate source | Fruit weights (g/plant) | Fruit (kg/feadden) |
|-----------------------------|-------------------------|-------------------|
| Control                     | 21.17^I                 | 237.07^I          |
| MAP (61 % P2O5)             | 23.83^H                 | 266.93^H          |
| DAP (46 % P2O5)             | 27.47^G                 | 307.63^G          |
| SPC (15.5 % P2O5)           | 31.70^F                 | 355.04^F          |
| RP (28% P2O5)               | 35.67^E                 | 399.47^E          |
| Mean                        | 38.57^A                 | 432.02^A          |

Averages that share the same alphabet do not differ from each other significantly according to Duncan's test at the 5% level.

(MAP, 61 % P2O5) Mono phosphate ammonium, (DAP, 46 % P2O5) Dai-phosphate ammonium, (SPC, 15.5 % P2O5) Super phosphate calcium and (RP, 28% P2O5) Rock phosphate.

Concerning the effect of the interaction, between different source phosphorous fertilization and mycorrhiza, data in Table (1) pointed out that it was significant on the fruit yield in both seasons. Moreover, the most effective treatments were obtained due to supplying the plants rock phosphate, followed by super phosphate calcium plus mycorrhiza application in comparison with other combination treatments in two consecutive seasons. Treatment rock phosphate plus mycorrhiza gave the best value of fruit yield with a range from 495.41 kg to 504.00 kg in both seasons, respectively.
The positive effect of the different sources of phosphorous and mycorrhiza application on enhancing fruit yield per feddan (kg) was studied by many authors such as Rezakhani et al. (2019) on *Triticum aestivum*, L., Kayina, and Reedy, (2012) on *Cassia angustifolia*, Vahl and Adav et al., (2011) on *Acorus calamus* L.

3.2. Active constituent’s parameters

A. Essential oil percentage

Data presented in Table (2) show that oil percentage of *Anethum graveolens*, L. had significantly was affected by the different sources phosphorous fertilization in both seasons. Moreover, Rock phosphate was the best treatment compared with the other treatments on with the values of 3.77 % and 3.85 % for both seasons, respectively. Oil percentage was significantly affected by inoculating treatments with mycorrhiza in both seasons. All results had a significant increase in oil percentage compared with the untreated plants in the first and second seasons. Inoculating plants with mycorrhiza application gave higher oil percentage which an increased by 3.69 % and 3.75 % versus the control plants in both seasons, respectively (Table 2).

The interaction between the different sources of phosphorous fertilization and Mycorrhiza application on oil percentage had significant effect during the first and second seasons. Rock phosphate treatment with inoculating the plants with mycorrhiza gave the highest values of oil percentage with the values of 4.03 % and 4.15% versus the other combination treatments in both seasons (Table 2).

B. Volatile oil content (ml/plant)

Data in Table (2) show that volatile oil content (ml/plant) was significantly affected by the different sources phosphorous fertilization in both seasons revealing that rock phosphate surpassed the other sources of phosphorous fertilization concerning fruit index which ranged from 1.50 ml to 1.54 ml in the two growing seasons, respectively. In regard to mycorrhiza application, data reveal that all treatments significantly augmented volatile oil content in both seasons. however, the maximum values of volatile oil was observed when adding mycorrhiza which increased by 1.38 ml and by 1.41 ml over untreated plants in the first and second seasons, respectively.

### Table 2: Effect of different source of phosphorous fertilization and mycorrhiza on essential oil contents.

| Phosphate source | Mycorrhiza |  |  |  |  |  |  |  |  |
|------------------|-----------|---|---|---|---|---|---|---|---|
|                  | With      | Without | Mean | With | Without | Mean | With | Without | Mean |
| **Volatile oil (%)** |  |  |  |  |  |  |  |  |  |
| Control          | 3.21<sup>E</sup> | 2.63<sup>G</sup> | 2.92<sup>E</sup> | 0.794<sup>F</sup> | 0.490<sup>H</sup> | 0.640<sup>E</sup> | 8.887<sup>F</sup> | 5.514<sup>H</sup> | 7.200<sup>E</sup> |
| MAP (61 % P<sub>2</sub>O<sub>5</sub>) | 3.57<sup>D</sup> | 3.10<sup>F</sup> | 3.34<sup>D</sup> | 1.275<sup>D</sup> | 0.660<sup>G</sup> | 0.970<sup>D</sup> | 14.274<sup>D</sup> | 7.390<sup>G</sup> | 10.830<sup>D</sup> |
| DAP (46 % P<sub>2</sub>O<sub>5</sub>) | 3.74<sup>C</sup> | 3.31<sup>E</sup> | 3.53<sup>C</sup> | 1.452<sup>C</sup> | 0.850<sup>F</sup> | 1.150<sup>C</sup> | 16.257<sup>C</sup> | 9.460<sup>F</sup> | 12.850<sup>C</sup> |
| SPC (15.5 % P<sub>2</sub>O<sub>5</sub>) | 3.88<sup>B</sup> | 3.45<sup>D</sup> | 3.66<sup>B</sup> | 1.611<sup>B</sup> | 1.060<sup>E</sup> | 1.340<sup>B</sup> | 18.048<sup>B</sup> | 11.865<sup>E</sup> | 14.960<sup>B</sup> |
| RP (28 % P<sub>2</sub>O<sub>5</sub>) | 4.03<sup>A</sup> | 3.52<sup>D</sup> | 3.77<sup>A</sup> | 1.781<sup>A</sup> | 1.227<sup>D</sup> | 1.500<sup>A</sup> | 19.946<sup>A</sup> | 13.743<sup>D</sup> | 16.850<sup>A</sup> |
| **Mean**         | 3.69<sup>A</sup> | 3.20<sup>B</sup> | 3.80<sup>A</sup> | 1.850<sup>A</sup> | 0.860<sup>B</sup> | 1.540<sup>B</sup> | 15.480<sup>A</sup> | 9.590<sup>B</sup> |

**First season**

| **Oil content (ml/plant)** |  |  |  |  |  |  |  |  |
|---------------------------|---|---|---|---|---|---|---|
| Control                   | 3.24<sup>H</sup> | 2.97<sup>I</sup> | 3.10<sup>E</sup> | 0.799<sup>F</sup> | 0.553<sup>H</sup> | 0.680<sup>E</sup> | 8.950<sup>F</sup> | 6.200<sup>H</sup> | 7.570<sup>E</sup> |
| MAP (61 % P<sub>2</sub>O<sub>5</sub>) | 3.68<sup>D</sup> | 3.17<sup>H</sup> | 3.43<sup>D</sup> | 1.315<sup>B</sup> | 0.676<sup>G</sup> | 1.000<sup>D</sup> | 14.730<sup>D</sup> | 7.570<sup>G</sup> | 11.150<sup>D</sup> |
| DAP (46 % P<sub>2</sub>O<sub>5</sub>) | 3.78<sup>C</sup> | 3.35<sup>G</sup> | 3.57<sup>C</sup> | 1.467<sup>C</sup> | 0.855<sup>F</sup> | 1.160<sup>C</sup> | 16.430<sup>C</sup> | 9.580<sup>F</sup> | 13.000<sup>C</sup> |
| SPC (15.5 % P<sub>2</sub>O<sub>5</sub>) | 3.89<sup>B</sup> | 3.45<sup>F</sup> | 3.68<sup>B</sup> | 1.618<sup>B</sup> | 1.060<sup>E</sup> | 1.340<sup>B</sup> | 18.120<sup>B</sup> | 11.880<sup>E</sup> | 14.100<sup>B</sup> |
| RP (28 % P<sub>2</sub>O<sub>5</sub>) | 4.15<sup>A</sup> | 3.55<sup>E</sup> | 3.85<sup>A</sup> | 1.836<sup>A</sup> | 1.238<sup>D</sup> | 1.540<sup>A</sup> | 20.560<sup>A</sup> | 13.860<sup>D</sup> | 17.210<sup>A</sup> |
| **Mean**                 | 3.75<sup>A</sup> | 3.30<sup>B</sup> | 3.90<sup>A</sup> | 1.900<sup>A</sup> | 0.880<sup>B</sup> | 1.570<sup>B</sup> | 16.760<sup>A</sup> | 9.820<sup>B</sup> |

**Second season**

Averages that share the same alphabet do not differ from each other significantly according to Duncan's test at the 5% level.

(MAP, 61 % P<sub>2</sub>O<sub>5</sub>) Mono phosphate ammonium, (DAP, 46 % P<sub>2</sub>O<sub>5</sub>) Dai-phosphate ammonium, (SPC, 15.5 % P<sub>2</sub>O<sub>5</sub>) Super phosphate calcium and (RP, 28 % P<sub>2</sub>O<sub>5</sub>) Rock phosphate.
Interaction between different source phosphorous fertilization and mycorrhiza application on volatile oil content was insignificant in both seasons. The maximum values of volatile oil content was observed when adding rock phosphate plus mycorrhiza which increased it by 1.78 ml and by 1.84 ml over untreated plants in the first and second seasons, respectively.

C. Volatile oil content (L/ feddan)

Data in Table (3) reveal that volatile oil content was significantly affected by the different sources of phosphorous fertilization in the first and second season, respectively. It was obvious that rock phosphate surpassed the other sources of phosphorous fertilization concerning volatile oil content which ranged from 16.85 to 17.21 L during second seasons.

Concerning mycorrhiza application, data in Table (3) show that the influence of them on volatile oil content was significant in both seasons from the obtained results, it is noticed that the highest number of volatile oil content per feddan /L was attributed to inoculating *Anethum graveolens*, L plants with mycorrhiza which reached 15.48 and 15.76 L/feddan compared with control for both seasons, respectively.

As for , the interaction effect between the different sources of phosphorous fertilization and mycorrhiza application on volatile oil content per feddan (l) was significant in second season only. The most effective treatments were obtained from treating rock phosphate treatments with mycorrhiza application with an amount of 19.95 L and 20.56 L compared to the other combination treatments, as clearly shown in Table (3).

D. Essential oil components by using G.L.C. analysis

Data showed in Table (3) and figures (1, 2 and 3) the oil analysis, five main components were obtained, which are carvone, β-phellandrene, d-limonene, apiol and myristicin.

Carvone is the main compound in dill oil with 40: 60%. The increase was noticeable when treating plants with different sources of phosphorous fertilization only, where the ratio ranged between 35.911 % and 52.038 %. There was also an increase in Carvone compound when treating plants with Mycorrhiza only, with a range from 0.724 % to 52.547%.

While the interaction between the different sources of phosphorous fertilization and mycorrhiza application resulted in an increase in all sources of phosphate fertilization with the addition of mycorrhiza. However, the most significant value for carvone was obtained when using rock phosphate with mycorrhiza application with 60.263% compared with the other combination treatments, Table (3).

Table 3: Effect of different source phosphorous fertilization and mycorrhiza application on the main components (%) of fruit volatile oil.

|                | Carvone | β-phellandrene | D-limonene | Apiol  | Myristicin |
|----------------|---------|----------------|------------|--------|------------|
| Control        | 0.724   | 47.373         | 27.494     | 9.462  | 14.946     |
| MAP (61 % P2O5) without Mycorrhiza | 35.911 | 47.373         | 2.843      | 0.425  | 13.448     |
| DAP (46 % P2O5) with Mycorrhiza | 50.364 | 1.630          | 3.621      | 29.457 | 14.927     |
| SPC (15.5 % P2O5) | 50.849 | 2.473          | 0.724      | 33.787 | 12.166     |
| RP (28% P2O5)   | 52.038  | 2.378          | 30.096     | 15.489 | -          |
| Control        | 52.547  | 2.723          | 32.284     | 12.445 | -          |
| MAP (61 % P2O5) with Mycorrhiza | 53.461 | 2.744          | 27.494     | 16.120 | 0.181      |
| DAP (46 % P2O5) with Mycorrhiza | 56.209 | 1.930          | 28.503     | 13.358 | -          |
| SPC (15.5 % P2O5) | 56.416 | 2.767          | 30.437     | 10.380 | -          |
| RP (28% P2O5)   | 60.263  | 2.507          | 9.462      | 27.768 | -          |

(MAP, 61 % P₂O₅) Mono phosphate ammonium, (DAP, 46 % P₂O₅) Diammonium phosphate, (SPC, 15.5 % P₂O₅) Super phosphate calcium and (RP, 28% P₂O₅) Rock phosphate.

The second and third compounds β-phellandrene and d-limonene had an inverse relationship between the presence of the two compounds and the increase or decrease of the Carvone compound in the plant, the highest value of β-phellandrene 47.373% and 27.494 % d-limonene in the control plants.
while the lowest value was found when rock phosphate with mycorrhiza application with 2.507 % and 9.462 % respectively.

Apiol compound was present in all treatments, where the highest value was recorded with DAP without Mycorrhiza 29.457%, while the lowest value was recorded with MAP without Mycorrhiza 0.425%.

Myristicin was present in Control, MAP, DAP, SPC without Mycorrhiza, and MAP with Mycorrhiza treatments, 14.946 %, 13.448 %, 14.927 %, 12.166 % and 0.181 % respectively. While it was absent from other treatments.

Fig. 1: Effect of different source phosphorous fertilization on the main components of fruit volatile oil
Fig. 2: Effect of different source phosphorous fertilization with mycorrhiza application on the main components of fruit volatile oil

Fig. 3: Effect of control and mycorrhiza on the main components of fruit volatile oil.

4. Discussion

In this study, the effect of phosphorous fertilization and application of fungi and their interaction in improving productivity and adaptability of dill plants (Anethum graveolens, L.) under North Sinai conditions were studied.

Data in Tables (1 and 2) that the treatment of phosphate rock is superior to the rest of the various phosphate fertilizers, as the effect of using phosphate rock has a significant effect on Growth and fruit yield parameters and Active constituent's parameters where the increase ranges in "plant height (cm)
116.60 and 118.96 cm, number umbels per plant 20.50 and 21.00, fruit yield per plant (g) 39.55 and 40.33 g and fruit yield per feddan (kg) 442.96 and 451.73 kg in both season, respectively. On the other hand, there was an increase in the rate of essential oils 3.77 and 3.85 % and the yield of volatile essential oil per plant (ml) 1.50 and 1.54 ml and yield of volatile essential oil per feddan (liter) 16.85 and 17.21 L in both season of dill plants, respectively.

This increase may be due to the role that phosphorous plays in building the nuclear proteins needed for growth and its direct role in the physiological processes that do not take place without it, which is the analysis of carbohydrates resulting from the process of light news to release the energy needed for vital interactions within cells and help in the growth and formation of biological membranes within cells, mitochondria And chloroplastsides and the plasma membrane

These results are similar to those found by Fouda, on Vicia faba L., Kostic et al. (2017) on wheat, Sarmadian (2018) on wheat and Edossa, et al., (2016) on Vicia faba L.

The results in tables (1 and 2) also showed the effect of pollination of soil with the mycorrhiza fungus to a significant increase in the rate of fruit production and oil yield of the dill plant. Per acre

Where the increase in the first season was “plant height (cm) 111.73 cm, number of umbels per plant 18.33, fruit yield per plant (g) 36.99 g, fruit yield per feddan (kg) 414.33 kg. On the other hand, there was an increase in the percentage of essential oil 3.69 %, yield of volatile essential oil per plant (ml) 1.38 ml and yield of volatile essential oil per feddan (liter) 15.48L.

While in the second season it was: “plant height (cm) 113.48 cm, number of umbels per plant 18.73, fruit yield per plant (g) 38.57 g, fruit yield per feddan (kg)) 432.02 kg. Furthermore, there was an increase in the percentage of essential oil 3.75 %, yield of volatile essential oil per plant (ml) 1.41 ml and yield of volatile essential oil per acre (liter) 15.76 L in dill plants.

The results showed the effect of using Mycorrhiza fungus, which led to a significant increase when using mixed with all sources of phosphorous compared to using phosphorous sources alone to improve plant growth and increase production by increasing the surface absorption of the roots, which led to facilitating the absorption of elements into the soil solution. Where mushrooms act as a biological fertilizer that supplies the plant with mineral elements such as phosphorous, zinc, and copper, as well as providing 20% of the plant’s needs for irrigation as the plant’s capacity improves on the absorption of water from the soil. This is reflected in the apparent increase in production, the increase in the number of inflorescences on the plant, and then the increase in the weight of fruits per plant and per acre.

On the other hand, the results showed the effect of using different sources of phosphate fertilization and applying Mycorrhiza to the best treatment when using phosphate rock mixed with Mycorrhiza, where there was a significant effect. Moreover, mycelium has the best ability to dissolve insoluble phosphorous making it easier for phosphorous and other nutrients to be absorbed by the dill plant.

These results are similar to those found by Wafaa and Rania (2016) on Ricinus communis, var. red Arish, Osorio, and Habte, 2013 on Leucaena leucocephala and Estrada et al., (2013) on maize

As indicated by the interaction between the different sources of phosphate fertilization and mixing the mycorrhizal fungus, there was a significant increase with all fertilizers, and the best treatment was when using phosphate rock, with the addition of Mycorrhizae, where the effect was significant. This was reflected in an increase in parameters of growth and fruit yield such as “plant height (cm)121.83 and 125.43 cm, number of umbels per plant 24.00 and 24.67, fruit yield per plant (g) 44.23 and 45.00 g, fruit yield per feddan (kg) 495.41 and 504.00 kg” and active ingredient parameters such as “percentage of essential oil 4.027 and 4.150 %, yield of essential oil included volatile oil yield per plant (ml) 1.781 and 1.836 ml, volatile essential oil yield per feddan (liter) 19.95 and 20.56 L in first and second season, respectively, of dill plants.

This is due to the fact that phosphorous from microscopic dissolution of phosphate rock has an important role in forming the ATP energy compounds that contribute to the formation of Coenzymes. And phospholipids and in the activity of plant biological processes, which led to an increase in the growth and fruit yield parameters and Active constituent's parameters, as previously mentioned.

These results are similar to those found by Hammam (2002) on Cassia acutifolia, Delile , , Abo–Baker, and Gehan, (2011): on Hibiscus sabdariffa and Hassan, (2005) on some medicinal and aromatic plants
5. Conclusion
Results indicate that the dual application of phosphate rocks and fungal roots would be a suitable alternative to phosphate fertilization as an important practice to increase phosphorus uptake from soil via dill when using different sources of phosphate fertilization and thus reduce chemical phosphate application. Fertilizers in sustainable farming systems in perspective. Thus, the plants benefit from it in the way that works for it, in addition to that it reduces the consumption of phosphorous fertilizers by 50%, which allows the production of plants safely which contributes to reducing production costs and thus an increase in the economic return.

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