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Study The Effect of Different Phosphorus Fertilization Resources on The Growth and Productivity of German-Chamomile (*Matricaria chamomilla* L.) Plant under Sand Soil Conditions

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ABSTRACT

This research was conducted at Sekem farm in the desert back of Minya Governorate, Egypt, during the two consecutive seasons of 2019/2020 and 2020/2021. The work aimed to study the effect of different phosphorus fertilization resources on the growth, yield, and essential oil content of chamomile (*Matricaria chamomilla* L.). The treatments included six phosphorus fertilization resources, like the following: F1: control 48 kg P_2O_5 (single super phosphate 16% P_2O_5), F2: 48 kg P_2O_5 (phosphoric acid 85% P_2O_5), F3:48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5), F4: 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5), F5:48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate), and F6: 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5). Results showed that applying 48 kg mono ammonium phosphate (MAP 12% N: 61% P_2O_5) produced the highest plant growth parameters, oil content, N, P, and K in plant tissues. Also, this treatment increased the concentrations of chamazulene to 41.68 % and bisabolol oxide-B to 13.61%. In comparison, as traditional phosphorus fertilizer, single super phosphate gave the lowest values in the two tested seasons.

Keywords: *Matricaria chamomilla* L., phosphorus fertilization, yield, chamazulene.

1. Introduction

Medicinal and aromatic plants are of fundamental economic importance because of local and foreign markets' continuous and increasing demand for their products (Khalid, 2006; Hamed, 2018; Abd El-Aleem *et al*., 2021; Toaima, 2022). Chamomile is a common name for several daisy-like plants of the family Asteraceae (Presibella *et al*., 2006). The vital kind of chamomile is German chamomile (*Matricaria chamomilla* L.). Its native region is southern and eastern Europe, where it spreads. The economic segment: inflorescences being dried and essential oil. Egyptian chamomile is in great demand for foreign markets. Fayoum, Beni Suef, Minya, and Assiut are the most productive areas. The average productivity per feddan is about 500-600 kg of entire inflorescences and gives about 3-8 kg volatile oil in the season. The inflorescences contain volatile oil ranging between 0.70 - 0.77%, extracted by steam distillation. The resulting oil is distinguished by its blue color because of its chamazulene presence, which has a 38.6 - 41.8% ratio. Chamazulene determines the quality of the produced oil. Also, the oil contains other substances such as bisabolol oxide B, bisabolol, farnesene, germacrene, and bisabolol oxide A (Das, 2014). Chamomile is used to treat indigestion cases, irritable bowel syndrome, general tonic, antipyretic, soothing nerves, and treat insomnia, encouraging stomach and bile secretions. Treating skin infections and wounds, making anti-fever medications, anti-colic and convulsions, gain on flavor in drinks, dental pain, mouth and gum ulceration, gout treatment, anti-inflammatory, anti-allergic, anti-cramping, eye fatigue and fatigue, manufacture of cosmetics, soaps, and perfumes (Sheibanivaziri, 1997; Abla *et al*., 2004; Omidbeigi, 2005; Salmon and Abou-zied, 2006; Letchamo *et al*., 2006; Ahmadian *et al*., 2011).

Phosphorus is a moving component within the plant that is a slow movement in the soil, and it is one of the fundamental nutrients in plant nutrition. It comes second after nitrogen in terms of its quantity

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in plant tissues. Microorganisms transform organic phosphorous into inorganic phosphorous. The degree of phosphorous utilization of a plant varies according to several factors. The most important factors are:- the type of clay metal, fixed in clay and sandy lands with a higher calcium content than light and pH in the soil where the highest validity level is to benefit from it at pH 6.5-7. The CO_2 gas released from the decomposition of organic matter plays a significant role in increasing the susceptibility of phosphorus to benefit. The essential functions of phosphorus are included in the composition of the nucleus protein, which is a necessary component of respiration processes. It has a role in transforming carbohydrates inside the plant, such as converting starch into sugar. It has a role in representing fats and accelerates the fruit ripening processes. Abla *et al.,* (2004) reported that phosphorus had a pronounced effect on carbohydrates, soluble sugars, mineral contents, and the percentage of oil production from chamomile flowers compared with the control.

The problem is that calcium superphosphate quickly becomes a non-absorbable form in the soil after a short addition period. The symptoms of P element deficiency appear especially with lower temperatures and the entry of plants into the flowering stage (Saharkhiz and Omidbaigi, 2008). The most commonly used fertilizer phosphorus sources are phosphoric acid and mono ammonium phosphate (MAP). These phosphorus fertilizer sources are highly water-soluble (>80 %) and thus dissolve quickly in soil to release plant-available phosphate and ammonium. Now MAP and phosphoric acid are widely used as sources of P fertilizer. They are popular in most European counters due to their high P nutrient content and excellent physical properties (Rosen *et al*., 2014).

This research aims to study the effect of the different phosphorous sources that are more readily available for absorption on the growth, yield, and active ingredients of the chamomile plant instead of the traditional forms such as calcium superphosphate. Also, to increase the productivity of chamomile plants under conditions of reclaimed lands, most of which are exposed to frost waves for long periods that affect productivity in Egyptian desert lands (sandy soils).

2. Materials and Methods

The field experiment was conducted at Sekem farm in the desert back of Minya Governorate, Egypt, during the two consecutive seasons of 2019/2020 and 2020/2021. The aim was to study the effect of different phosphorus fertilizers on the growth, flower yield components, and volatile oil production of chamomile (*Matricaria chamomilla*) plants.

Chamomile seeds were obtained from the National Research Centre, Medicinal and Aromatic Plants Department, Dokky, Giza, Egypt. Seeds were sown on 25th and 30th September during the 1st and 2nd seasons, respectively. The sowing was directly in the reclaimed sandy soil plains. 15 cm between the lines and 7 cm between the plants using a seed planting machine at a rate of 1 kg seed per feddan. The seeds index 0.1 g (100-120 plant / m^2).

Plants were irrigated by central spraying at a rate of 20-25 m^3 per feddan until germination is complete, then 20 m^3 per day after day. 90 kg of nitrogen was added as ammonia sulfate + 100 kg of potassium sulfate per feddan. It was added injection in the irrigation system throughout the season + 5 tons of compost / feddan, added to all treatments during soil preparation for cultivation (Sharafzadeh *et al*., 2011; Naderidarbaghshahi *et al*., 2011; Osman *et al*., 2013). The physical and chemical properties of the soil are shown in Table (1). The analyses were conducted according to Chapman and Pratt (1978). Also, the chemical properties of irrigation water and compost manure are shown in Tables (2 and 3).

Table 1: The mechanical and chemical analyses of the experimental soil area

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture
0-30	86.00	5.00	9.00	Sandy

pH	E.C. (ds/m)	O.M. (%)	Soluble anions (meq/l^{-1})				Soluble cations (meq/l^{-1})			
			CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
7.90	1.80	0.5	-	1.00	10.00	7.00	6.00	8.00	8.60	1.40

Table 2: The chemical analysis of irrigation water

pH	E.C. (ppm)	Soluble anions (meq/l^{-1})				Soluble cations (meq/l^{-1})			
		CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
7.32	747.15	-	4.26	8.59	7.44	11.45	5.64	7.31	0.69

Table 3: The chemical analysis of used compost manure

Bulk density kg/m^3	Moisture content (%)	pH	EC (ds/m)	O.M. (%)	Ash (%)	C/N ratio (%)	N (%)	P (%)	K (%)
639	25	7.91	5.53	25.97	74.03	10.91	1.38	0.49	0.59

The treatments included six different phosphorus fertilization resources, like the following:

F1: Control 48 kg P_2O_5/feddan (single super phosphate 16% P_2O_5), divided into two batches (30 kg when preparing the soil for sowing, then 18 kg when flowering begins).
F2: 48 kg P_2O_5/feddan (phosphoric acid 85% P_2O_5), distributed over 24 weeks from the cultivation date.
F3: 48 kg P_2O_5/feddan (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5), distributed over 24 weeks from the start of cultivation.
F4: 48 kg P_2O_5/feddan (mono ammonium phosphate MAP 12% N:61% P_2O_5), distributed over 24 weeks from cultivation.
F5: 48 kg P_2O_5/feddan (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate), distributed over 24 weeks from cultivation.
F6: 48 kg P_2O_5/feddan (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5), distributed over 24 weeks from cultivation.

Harvesting was conducted three times during the growing season, on 5th January, 20th February, and 15th April, and samples were dried in the shade (Kandeel, 1982; Essa, 1999). The recorded data included:

2.1. Vegetative growth parameters

Plant fresh weight (g/m^2), plant dry weight (g/m^2), fresh weight of flower heads (g/m^2), and dry weight of flower heads (g/m^2).

2.2. Chemical constituents

2.2.1. Essential oil percentage: was determined during both seasons and extracted from the air-dried flower heads by hydrodistillation using a Clevenger apparatus (British Pharmacopoeia, 1963).

2.2.2. Essential oil yield/m^2 (ml): This was calculated as follows: oil percentage × flower heads dry weight per m^2/100.

2.2.3. Essential oil composition

GC-MS analysis of essential oils was performed by Gas Chromatography-Mass Spectrometry instrument at the Laboratory of Medicinal and Aromatic Plants, National Research Center, Egypt, with the following specifications. Device: a TRACE GC Ultra Gas Chromatographs (THERMO Scien-tific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system had a TR-5MS column (30 m x 0.32 mm i.d., 0.25 μm film thickness). Analyses were conducted using helium as carrier gas at a flow rate of 1.3 ml/min at a split ratio of 1:10 and the following temperature program: 80°C for 1 min; rising at 4°C/min to 300°C and held for 1min. The injector and detector were held at 220 and 200°C, respectively. Diluted samples (1:10 hexane, v/v) of 1 μL of the mixtures were continuously injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Identification of the compounds depended on comparing the retention times with those of authentic samples. Comparing their linear retention

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indices relative to the series of n-hydrocarbons and on computer matching against commercial and libraries mass spectra built up from pure substances, components of known oils, and MS literature data (Bunzen *et al*., 1969; Hoftman, 1967; Massada, 1976; Jennings and Shibamoto, 1980; National Committee for Clinical Laboratory Standards, 2002; Adams, 2007; Babushok *et al*., 2011).

2.2.4. Mineral elements content

Nitrogen, phosphorus, and potassium percentages were determined according to Koch and Mc-Meekin (1924), Troug and Mayer (1939), and Brown and Lilleland (1946), respectively.

The randomized complete block design was used with three replicates (six treatments). According to Snedecor and Cochran (1968), the statistical analysis was carried out, and L.S.D. test at 5 % was used to compare the means.

3. Results and Discussion

3.1. Vegetative characters

3.1.1. Fresh and dry weights of plant (g/m^2)

Data in Table (4) presented fresh and dry weights of plants (g/m^2). Results showed that all treatments increased the fresh and dry weights of *Matricaria chamomilla* plants compared with the control treatment. This increment is significant in both seasons. Compared with other fertilization treatments, the best results were obtained with F4 48 kg P_2O_5/feddan (mono ammonium phosphate). This treatment gave the heaviest fresh and dry weights of plants in the 1st and 2nd seasons, respectively which recorded 1510 and 1515 g/m^2. Also, the same treatment produced the highest value for dry weights of the plant (g/m^2), which recorded 345.33 and 350.66 g/m^2. It was followed by F6 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 +16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N: 61% P_2O_5). Meanwhile, fertilization with control treatment F1 48 kg P_2O_5 (single super phosphate 16% P_2O_5) produced the lowest fresh and dry weights in the first and second seasons, respectively.

Table 4: Effect of different phosphorus fertilization resources on the plant fresh and dry weights (g/m^2) during 2019/2020 and 2020/2021seasons

Treatments	Plant fresh weight (g/m^2)			Plant dry weight (g/m^2)		
	1st season	2nd season	Mean	1st season	2nd season	Mean
F1	1350.00	1365.00	1357.50	275.33	276.67	276.00
F2	1410.00	1400.00	1405.00	289.33	288.67	289.00
F3	1380.00	1375.00	1377.50	295.67	293.33	294.5.0
F4	1510.00	1515.00	1500.50	345.33	350.66	348.00
F5	1375.00	1370.00	1372.50	312.33	310.33	311.30
F6	1485.00	1490.00	1440.00	322.33	325.67	324.00
Mean	1418.00	1419.00	1409.00	306.72	307.56	307.13
LSD at 5%	1st season =2.51 2nd season =2.13			1st season =13.87 2nd season =11.34		

F1= control 48 kg P_2O_5 (single super phosphate 16% P_2O_5).
F2= 48 kg P_2O_5 (phosphoric acid 85% P_2O_5) .
F3= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5).
F4= 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5),
F5= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate).
F6= 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5).

These results coincided with those obtained by several authors such as Ragab *et al.,* (2015) on potatoes who found that the addition of phosphorus as MAP resulted in vigor plant growth expressed as plant height, number of leaves/plant, shoots/plant, fresh and dry weight, leaf area, leaf area index, relative growth rate and net assimilation rate if compared with triple superphosphate and diammonium phosphate (DAP). Maurya (1989) and Farahani *et al.,* (2009) found that the application of phosphorous fertilizer increased the vegetative yield of coriander. Also, these results are similar to the findings of Bharose *et al.,* (2001) on Toria, Naderidarbaghshahi, *et al.,* (2011) on German chamomile (*Matricaria chamomilla* L.), Saharkhiz and Omidbaigi (2008) on feverfew, Sharafzadeh *et al.,* (2011) on sweet basil and Nassar *et al.,* (2004) on chamomile. They obtained the best results in higher levels of phosphorus.

These results may be due to increased available P concentrations in the plant's root zone. Because mono ammonium phosphate high-efficiency source of phosphorus as phosphate (PO_4^-) promotes rapid absorption by plants. It also has an acidifying effect on the favoring soiling solubility of phosphorus and micro-nutrients, fully soluble and fast dissolving. Although the amount of soil P concentration seems to be sufficient, the application of F4 48 kg P_2O_5 (mono ammonium phosphate), which produces the high available P-containing fertilizers in the soil, can increase the plant nutrient concentrations (Nell *et al.,* 2009; Rahimi *et al.,* 2013; Khalid 2012; Khalid, 2015; Kumar *et al.,* 2015).

3.1.2. Fresh and dry weights of flower heads (g/m^2)

Data presented in Table (5) indicated the main effect of fertilization on fresh and dry weights of flower heads (g/m^2). The highest values of these parameters were obtained when the plants were treated with F4 48 kg P_2O_5 (mono ammonium phosphate) compared to other fertilization treatments resulting in significant differences in most cases. The heaviest fresh weights of flower heads recorded 675 and 670 g/m^2 in the first and second seasons. It was followed by F6 48 kg P_2O_5 (16 kg P2O5 single super phosphate 16% P_2O_5 +16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5) gave the lower values of fresh weights. Conversely, fertilization with control treatment F1 48 kg P_2O_5 (single super phosphate 16% P_2O_5) produced the lowest values of fresh weights of flower heads which recorded 675 and 670 g/m^2 in the first and second seasons, respectively. Concerning the effect of fertilization on the dry weight of flower heads, a significant increase was observed when the treatment of F4 was applied to plants in both seasons; they were 132.33 and 134.66 g/m^2 in the first and second seasons, respectively. It was followed by F6 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 +16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5) which recorded 131.33 and 130.33 g/m^2 in the first and second seasons, respectively. Meanwhile, control treatment F1 (48 kg P_2O_5 as single super phosphate 16% P_2O_5) produced the lowest dry weights of flower heads, which were 115.33 and 116.33 g/m^2 in the first and second seasons, respectively. The differences between treatments and control were significant when the experiment was repeated in both seasons.

Table 5: Effect of different phosphorus fertilization resources on the fresh and dry weights of flower heads (g/m^2) during 2019/2020 and 2020/2021seasons

Treatments	**Fresh weight of flower heads (g/m^2)**			**Dry weight of flower heads (g/m^2)**		
	1st season	**2nd season**	**Mean**	**1st season**	**2nd season**	**Mean**
F1	570.00	580.00	575.00	115.33	116.33	115.83
F2	610.00	600.00	605.00	129.33	130.33	129.83
F3	645.00	635.00	640.00	124.66	127.66	126.16
F4	675.00	670.00	672.50	132.33	134.66	133.50
F5	650.00	655.00	652.50	125.33	123.66	124.50
F6	670.00	665.00	662.50	131.33	130.33	130.83
Mean	636.67	634.17	634.58	126.39	127.16	126.78
LSD at 5%	1st season =4.36 2nd season =3.03			1st season =3.51 2nd season =3.33		

F1= control 48 kg P_2O_5 (single super phosphate 16% P_2O_5).
F2= 48 kg P_2O_5 (phosphoric acid 85% P_2O_5) .
F3= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5).
F4= 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5),
F5= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate).
F6= 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5).

Our results agree with those obtained by Maurya (1989) and Farahani *et al.,* (2009) findings that the application of phosphorous fertilizer increased the vegetative yield of coriander. Also, these results are similar to the findings of Bharose *et al.,* (2001) on toria, Naderidarbaghshahi *et al.,* (2011) on German chamomile, Saharkhiz and Omidbaigi (2008) on feverfew and Sharafzadeh *et al.,* (2011) on sweet basil also Nassar *et al.,* (2004) on chamomile obtained the best results in higher levels of phosphorus. Generally, it could be concluded that fresh and dry weights of flower heads (g/m^2) recorded their maximum values when phosphorus was added as a MAP source. The opposite was true for single super phosphate treatment. The highest chamomile yield was obtained by using MAP. It may be due to enhanced development of meristematic tissue or the increment of the following attributes: the number of flower heads, photosynthetic activity, mobilization of photosynthates, and chlorophyll biosynthesis photosynthetic of CO_2 fixation, cell division, and carbohydrates metabolism. Also, it could be concluded that the superiority of MAP may be attributed to its higher water solubility and pH value, and higher nitrogen content. These results agree with Hill *et al.,* (2011) and Rosen *et al.,* (2014).

3.2. Chemical constituents

3.2.1. Essential oil percentage

Data in Table (6) showed a progressive increase in the volatile oil percentage of the chamomile plant during both seasons. The differences between fertilization treatments were significant. The highest oil percentage (%) in flower heads was produced when the plants were treated with F4 (48 kg P_2O_5 mono ammonium phosphate) compared with other fertilization treatments; these estimates were 0.77 and 0.75% in the first and second seasons, respectively. It was followed by F6 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5) + 16 kg P_2O_5 phosphoric acid 85% P2O5 + 16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5) which gave the following higher values of oil percentage (%) which were recorded 0.75 and 0.74% in the first and second season, respectively. In contrast, control treatment F148 kg P_2O_5 (single super phosphate 16% P_2O_5) produced the lowest oil percentage (%) in flower heads during both seasons.

Table 6: Effect of different phosphorus fertilization resources on essential oil percentage in flower heads and oil yield per m^2 during 2019/2020 and 2020/2021seasons

Treatments	Essential oil percentage (%) in flower heads			Oil yield per (ml/m^2) in flower heads		
	1st season	2nd season	Mean	1st season	2nd season	Mean
F1	0.70	0.72	0.71	0.81	0.84	0.83
F2	0.73	0.74	0.74	0.94	0.96	0.95
F3	0.73	0.73	0.73	0.91	0.93	0.92
F4	0.77	0.75	0.76	1.02	1.01	1.02
F5	0.73	0.75	0.74	0.91	0.93	0.92
F6	0.75	0.74	0.75	0.98	0.96	0.97
Mean	0.74	0.73	0.74	0.94	0.93	0.94
LSD at 5%	1st season = 0.01 2nd season = 0.01			1st season = 0.43 2nd season = 0.30		

F1= control 48 kg P_2O_5 (single super phosphate 16% P_2O_5).
F2= 48 kg P_2O_5 (phosphoric acid 85% P_2O_5) .
F3= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5).
F4= 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5),
F5= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate).
F6= 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5).

Effect of different phosphorus fertilizers on essential oil percentage may be due to their distinct effect on enzyme activity and metabolism necessary for oil production. According to Jeshni *et al.,* (2015), P fertilization increased the essential oil concentration of chamomile. Khalid (1996) and Economakis (2002) showed that P significantly increased the essential oil content of Apiaceae and *Origanum dictamnus* plants. P enhanced essential oil extracted from bitter fennel (*Foeniculum vulgare* Mill.) (Tank *et al.,* 2007; Osman 2009). P had a significant effect on the essential oil content isolated from sweet fennel cultivars growing in arid regions in Egypt (Zaki *et al.,* 2010; 2011). Also, it increased the essential oil content of basil (Ramezani *et al*., 2009), fennel (*Foeniculum vulgare*) (Kapoor *et al*., 2004), and cumin (Tuncturk and Tuncturk, 2006). Furthermore, a lack of effect the phosphorous application on oil percentage was reported for other plants, including *Salvia officinalis* (Nell *et al*., 2009; Rioba *et al*., 2015).

3.2.2. Essential oil yield (ml/m^2)

Data of the volatile oil yield productivity are shown in table (6). The results showed that the best effect in this respect was obtained by fertilized chamomile plant with F4 showed its superiority for increasing the oil yield per (ml/m^2) as it gave 1.02 and 1.01 ml/m^2 followed descendingly by using the treatment F6, which recorded 0.98 and 0.96 ml/m^2 in the first and second seasons, respectively. Conversely, the minor oil yield per plant (ml/m^2) was obtained by treating the plants with F1, recorded at 0.81 and 0.84 ml/m^2. This may be due to this treatment gave less plant growth, reflecting less oil yield per plant. The increment of oil yield per plant may be due to the beneficial effects of these fertilizers on the synthesis of carbohydrates in plant tissues, consequently used for oil production. The obtained results follow those Al-Humaid (2004) reported on fennel plants and Khalid (2015) on coriander. They stated that the application of phosphorous caused a pronounced increment in essential oil yield.

3.2.3. Essential oil constituents

Six main constituents were identified in the essential oil extracted from chamomile flowers head, accounting for 79.15 - 86.31% of total components (Table 7). The main constituents of chamomile flowers' essential oil as detected by GC/MS were chamazulene, bisabolol oxide B, and α-bisabolol, which increased by F4 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5) treatment compared with the control treatment F1 48 kg P_2O_5 (single super phosphate 16% P_2O_5). Also, the chemical classes of chamomile essential oil were changed in all treatments compared with the control. It could be concluded that the superiority of F4 may be attributed to its high effect on enzymes activity and accelerate plant metabolism.

The previous investigations concerning the response of chamomile yield and its components to the various phosphorus sources were confirmed (Sheibanivaziri, 1997; Rosen and McNearney, 2003; Hill *et al*., 2011; Rosen *et al*., 2014; Nikolova *et al*., 1999). They showed that P fertilization increased the essential oil concentration of chamomile, and it is a necessary element. Thus, the essential oil was increased by applied MAP as expected in the present study. Phosphorus also has various cellular functions in plants, including signaling and transmembrane metabolic flux. The results were in line with those obtained by Marschner (1999) and Nilbe *et al.,* (2005), who observed increasing biomass of chamomile. Therefore, secondary metabolism (essential oil) is modulated by these mechanisms.

Table 7: Effect of different phosphorus fertilization resources on the main constituents of essential oil during 2019/2020 and 2020/2021 seasons

Treatments	Germacrene D	α-Farnesene	Bisabolol Oxide B	α-Bisabolol	Chamazulene	Bisabolol oxide A	Total identified
F1	4.75	6.47	12.85	12.76	41.52	6.76	82.10
F2	4.54	7.32	12.73	10.83	41.66	6.35	79.15
F3	4.43	7.61	13.52	11.51	40.88	6.72	81.83
F4	4.91	7.55	13.61	11.65	41.68	7.85	86.31
F5	4.88	6.92	12.60	10.89	41.44	6.89	83.56
F6	4.74	7.32	12.89	11.32	41.35	7.71	80.48

F1= control 48 kg P_2O_5 (single super phosphate 16% P_2O_5).
F2= 48 kg P_2O_5 (phosphoric acid 85% P_2O_5) .
F3= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5).
F4= 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5),
F5= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate).
F6= 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5).

3.2.4. Mineral elements content (NPK)

Data presented in Table (8) showed that fertilized chamomile plants with F4 48 kg P_2O_5 (mono ammonium phosphate) treatment showed its superiority for increasing nitrogen, phosphorus, and potassium percentages in their tissues. It was followed descendingly by using F6 compared with the other phosphorus fertilizers. The positive effect of F4 48 kg P_2O_5 (mono ammonium phosphate) on mineral composition could be attributed to the high available P-containing fertilizers in the soil, increasing the plant nutrient concentrations. It may be due to it's translocation from the root to the above-ground parts and more absorption and accumulation of N, P, and K. The obtained results for the effect of P on the percentages of the mineral are in harmony with those mentioned by (Massoud, 2006; El-Sayed *et al*., 2011; Abdel-Razzak *et al*., 2013; Rosen *et al*., 2014).

Table 8: Effect of different phosphorus fertilization resources on nitrogen, phosphorus and potassium (%) during 2019/2020 and 2020/2021 seasons

Treatments	N			P			K		
	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean
F1	1.81	1.83	1.82	0.35	0.34	0.35	2.11	2.13	2.12
F2	2.31	2.29	2.30	0.43	0.44	0.44	2.29	2.27	2.28
F3	2.22	2.20	2.21	0.41	0.41	0.41	2.24	2.25	2.25
F4	2.35	2.36	2.36	0.47	0.48	0.48	2.31	2.33	2.32
F5	2.11	2.12	2.12	0.42	0.43	0.43	2.14	2.16	2.15
F6	2.25	2.25	2.25	0.43	0.44	0.44	2.15	2.17	2.16
LSD at 5%	1st season = 0.08 2nd season = 0.09			1st season = 0.02 2nd season = 0.02			1st season = 0.06 2nd season = 0.07		

F1= control 48 kg P_2O_5 (single super phosphate 16% P_2O_5).
F2= 48 kg P_2O_5 (phosphoric acid 85% P_2O_5) .
F3= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 + 24 kg P_2O_5 phosphoric acid 85% P_2O_5).
F4= 48 kg P_2O_5 (mono ammonium phosphate MAP 12% N:61% P_2O_5),
F5= 48 kg P_2O_5 (24 kg P_2O_5 single super phosphate 16% P_2O_5 +24 kg P_2O_5 mono ammonium phosphate).
F6= 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5).

Finally, it could be concluded that the highest plant growth vigor was obtained from using F4 (MAP) followed by F6 48 kg P_2O_5 (16 kg P_2O_5 single super phosphate 16% P_2O_5 + 16 kg P_2O_5 phosphoric acid 85% P_2O_5 +16 kg P_2O_5 mono ammonium phosphate MAP 12% N:61% P_2O_5). The increase in dry weights of flowers head may be attributed to the rise in fresh plant weight, leading to more active photosynthesis and, in turn, more carbohydrate accumulation. The higher values of essential oil in flower heads may be due to the improvement effect of F4 (MAP) and the treated plants by F6 on fresh weight of flower heads and the advancement effect on essential oil in flower heads or oil yield per ml/m^2. The advantages of MAP as a phosphorus source on the productivity of chamomile plants might be attributed to one or more of the following. The higher nitrogen content (12 %), the higher phosphorus content (61%), water solubility (370 g/l), and its pH value (4.0 to 4.5), compared by 5 ppm max Nitrate (NO_3) and 85% P_2O_5, 548 g/100 ml (20°C), solubility and 2.14 pH value for phosphoric acid and pH value 1.5 (20°C,10 g/l). Because of properties variation within MAP, phosphoric acid, and single super phosphate, results clearly showed that the differences were significant concerning most plant growth parameters. The obtained results are in good accordance with those reported by Balemi and Schenk (2009), and Rosen *et al.,* (2014).

4. Conclusion

The experimental results showed that applying F4 48 kg P_2O_5/feddan (mono ammonium phosphate) produced the highest plant growth characteristics, oil content, N, P, and K in plant tissues. Also, this treatment increased the concentrations of chamazulene to (41.68 %) and bisabolol oxide B to (13.61%). In comparison, super-phosphate as phosphorus fertilizer gave the lowest values in the two tested seasons.

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