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Effect of Some Potassium Fertilization Treatments on Growth, Productivity and Chemical Composition of Safflower Plant

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ABSTRACT

The present study was conducted at El-Kasasin Research Station belonging to Ismailia Governorate Agriculture Research Center in the Department of Medicinal and Aromatic plants during two consecutive seasons of 2020/2021 and 2021/2022. This experiment included 9 treatments, which studied the Effect of mineral potassium fertilization as potassium sulfate (0, 50, and 75 kg/feddan), organic potassium fertilization as potassium humate (0. 2 and 4 kg/ feddan), and their combination treatments on the growth, fixed oil, and active ingredients of safflower. Data showed the effect of potassium sulfate on the growth parameters of safflower, where all treatments gave the highest significant increase compared to control during two seasons, where the treatment with 75 kg/fed. K sulfate produced the highest values in these characters compared to control plants, which record the lowest values under study. Regarding the effect of potassium humate, the data received from the treatment of plants led to a significant increase in all growth parameters under study compared to the other treatments. while the treatment 4 kg/fed. of K humate recorded gave the highest values in this study. In addition, the received data indicate that the interaction between potassium humate and potassium sulfate had a significant effect on the growth characteristics (growth traits, seed yield, petals yield, fixed oil yield and carthamine content) under study, where the treatment recorded of 4 kg/fed. as of K humate and treated with 75kg/fed. as K sulfate produced the highest values of growth and productivity compared to the control and other treatments.

Keywords: Safflower (*Carthamus tinctorius*, L.), potassium sulfate**,** potassium humate, carthamine.

1. Introduction

Safflower (*Carthamus tinctorius* L.) belongs to Asteraceae, which is considered one of the important serious of medicinal and food oils. It is one of the plants with multiple benefits and uses. It is a salinity-tolerant and drought-resistant plant (Weiss, 2000) and it grows well in dry or semi-arid areas the plant has strong roots. It is deep and diffused, capable of penetrating the soil to facilitate the movement of water and air in it, and the plant also endures long periods of drought, by absorbing water from the ground up to a depth of four meters. Water is largely a source of plant production, especially in arid and semi-arid areas.

However, safflower bears moderate and high levels of salinity, as it tolerates salinity more than wheat and barley is similar in its tolerance to salinity, and therefore it is planted in saline lands. Safflower oil is utilized medicinally to treat high blood pressure, rheumatism, arthritis, and infertility, in addition to utilizing its seeds to produce food oils. The seeds contain 35-40% oil and it is known as sweet oil (Koutroubas *et al.* 2004).

As the global production of safflower seeds is about 600 thousand tons annually in 60 countries, led by India, America, and Mexico, followed by Ethiopia, Kazakhstan, China, Argentina and Australia (Dordas *et al.,* 2008) and is characterized by safflower oil It contains a high percentage of unsaturated fatty acids, which is why it is considered of great value because it contains omega-6 and antioxidants (Nogala *et al.,* 2010) which are important in treating diseases and lowering cholesterol in the blood.

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Also, utilized in the production of cosmetics, and in dyes, lubricants, and bio-oil. It is also considered similar to olive oil, Lina et al., 2010 and thus is suitable for frying, various scientific studies have revealed that using safflower oil daily, contributes to reducing body fat percentage and increasing muscle weight, and it also helps to improve blood sugar and protein formation (Taha and Bertrand, 2018). The remains of the seeds after extracting the oil from them are used to feed poultry and livestock because they contain a high protein content.

Potassium is mobile within the plant, little mobile in the soil. It is directly related to building protein, as it helps in absorbing nitrogen from the soil, and its deficiency causes the accumulation and non-transformation of amino acids into protein. It also reduces the transpiration processes of the plant and thus increases its resistance to drought (Wakeel and Ishfaq 2022).

Previous studies on the effect of element K showed that safflower requires potassium in high quantities in the early stages of growth. Potassium is an essential element, as the use of potassium at a high rate led to an increase in the yield of seeds, flowers and the fixed oil in the plant (Mirzapour *et al.,* 2003). The consumption of adequate potassium fertilizers led to an increase in the moisture content of the plant, as this element plays a prominent role in activating many vital processes, photosynthesis and protein synthesis (Shabala, 2003). The results showed that when potassium phosphate was used at a rate of (0, 75 and 150 kg/fed.) the high levels of potassium increased the K contents of safflower, and potassium had positive effects on the calcium contents in plants. Moreover, the increased potassium level leads to decreased sodium content and sodium absorption. Increasing the relative humidity of the leaves improved the permeability of the cytoplasm membrane and gave the highest content of fixed oil in the seeds as a result of an increase in the rate of vegetative growth and seed yield. (Vafaie *et al.,* 2013).

On the other hand, results showed that when potassium sulfate was used at a rate of (0, 30, 60 units of potassium) the high levels of potassium with a fixed dose of nitrogen and phosphate gave a higher percentage of dry matter and increased alertness, thus increasing the yield of seeds and the active substance (Malik *et al.,* 2016). This study was also conducted to investigate the effect of humic acid on the oil yield and active substances in the safflower plant, where the use of a high rate of humic acid led to an increase in both the increase in the oil yield and thus the production of the oil and its active components of glycosides and flavonoids, and the increase of carthamine pigment in flowers. (Kashams *et al.,* 2018). Consequences showed that the use of humic acid at a rate (0, 300, and 600 kg/ha) led to an increase in the oil content of safflower seeds by 25.80% and protein by 24.30% (Babak and Siamak 2016).

The main objective of this study is to grow safflower in a new area as well as determine the most appropriate rate and the best form for potassium fertilization with a comparison between the organic and mineral forms of potassium in order to obtain the highest productivity of the fixed oil and the active substances of safflower plant.

2. Materials and Methods

The present study was conducted at El-Kasasin Research Station belonging to Ismailia Governorate Agriculture Research Center in the Department of Medicinal and Aromatic plants during two consecutive seasons of 2020/2021 and 2021/2022. This experiment included 9 treatments, which studied the effect of mineral potassium fertilization as potassium sulfate (0, 50 and 75 kg/feddan), organic potassium fertilization as potassium humate (0, 2 and 4 kg/ feddan) and their combination treatments on the growth, fixed oil, and active ingredient of safflower.

Where two rates of potassium were used in the mineral form as potassium sulfate (48%, K) at a rate of control (without potassium fertilization addition),50 and 75 kg / feddan, while two rates of potassium in the organic form were as potassium humate (18%, K) at the rates of 2 and 4 kg / feddan, in addition to the control treatment.

This experiment included two main factors the first one was potassium sulfate and the second one was potassium humate. The nine treatments were arranged in a factorial experimental design with three replicates.

Potassium sulfate levels were applied by dividing the amount of fertilizer into two parts that were added to the soil after 45 and 75 days of planting. The seeds were sown in rows, the distance between the rows is 60 cm, and the space in the plants is 40 cm between them. Seeds of safflower were obtained from the Research Centre of Medicinal and Aromatic Plants, Dokky, Giza, and sown on the 15th and

18th of October during the first and second seasons, respectively. 21 days after planting, (full germination) the seedlings were thinned out to be a single plant/hill, feddan containing 17500 plants. The physical and chemical properties of the experimental farm soil are shown in Table (1).

Table (1): The soil's physical and chemical properties in El-Kasasin Research Station.

Physical analyses				Mechanical analyses			
Saturation (capacity) (%)	**Field capacity (%)**	**Wilting coefficient (point) (%)**	**Available water (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Soil texture**
25	11	6	5	87.13	7.24	5.63	Sandy

Chemical properties

Salt analysis		Cations (meq/l)				Anions (meq/l)				Available elements (mg/kg)			Organic matter
EC dS_m^{-1}	**pH**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**Cl^{-}**	**CO_3^{2-}**	**HCO_3**	**SO_4^{2-}**	**N**	**P**	**K**	**(OM) (%)**
1.6	7.08	5.7	2.6	7	0.8	7.6	0	2.8	5.7	7.1	2.1	13.4	0.01

At the harvesting stage data recorded:

- Plant growth included: Plant height (cm), branch number /plant and fresh and dry weights/plant (g) and fruit weights (g).

- Production parameters included: Seed and dry petals yield /plant (g) were determined, and then seed and dry petals yield (kg/ feddan) was calculated for safflower plants.

- Oil production included: Seed fixed oil of safflower was extracted using petroleum ether in a soxhlet system HT apparatus according to the methods of A.O.C.S. (1998). Oil percentage and yield per plant (ml) and feddan (l) were calculated. Fixed oil chemical constituents by Gas-liquid chromatography (G.L.C.) according to Ichihara (2010).

- Chemical composition: A sample of dry petals of safflower and seeds was randomly taken from each treatment for chemical analysis, Total carbohydrate percentage according to Chaphlin and Kennedy (1994), nitrogen (%) was determined in seeds according to the methods described by Horneck and Miller (1998) and was multiplied by 6.25 to calculate protein (%) for safflower, Moreover, carthamin percentage was assessed according to the method described by Harborne (1973) then carthamin content/plant petals (mg/100g) was calculated through multiply carthamin percentage by dry petals yield per safflower plant.

Statistical analysis:

Data of the present work were statically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (L.S.D) at the 5% level by using the computer program Statistic version9, Analytical Software (2008). Means monitored by the similar letter did not significant vary at ≤ 0.05 fitting to Duncan's multiple range tests according to Gomez and Gomez, (1984).

3. Results and Discussion

3.1. Plant growth

3.1.1. Plant height (cm)

Data illustrated potassium sulfate in plant hight (cm) Table 2 it revealed that all treatments gave the highest significant increase in the plant height. The treatment 75 kg/ fed. of K sulfate was given the highest value of plant height were 153.56 cm and 157.28 cm in during two seasons, respectively, compared with other treatments in the both seasons.

Regarding the main effect of potassium humate, data in Table (2) show that treating plants with potassium humate resulted in a significant increase in plant height compared to control treatments. The effect of potassium humate where the highest value in the plant height was recorded the maximum values (146.11 cm) when at adding 4 kg/ fed. of K sulfate, in the first season. While the same treatment in the second season was recorded, 149.48 cm compared to the control treatment (129.33 cm and 132.40cm) in the first and second seasons, respectively.

Also, data in Table (2) indicate that the interaction between potassium humat and potassium sulfate had a significant effect on the plant height (cm) in the first season, the highest plant height (cm) was recorded 167.00 cm compared with control treatment 110.33 cm. As for the second season, the highest plant height (cm) was recorded 171.78 cm compared with the control plant 114.54 cm. This result was obtained from the treatment when the plants are applied to 4 kg/fed. of of K humate and treated with 75kg/fed. of K sulfate.

3.1.2. Branch number /plant

Results in Table (2) designate that, the effect of potassium sulfate on the safflower plant, potassium sulfate had a significant effect on a number of branches. In the first season, the highest values of the number of branches 10.89 were recorded when plants were applicate with 75 kg/ fed. K sulfate competed to control plant 4.56. As for the second season, the highest values of the number of branches 12.67 compare to the control plant 6.00. This result was obtained because of adding 75 kg/ fed. of K sulfate.

In general, the main effect of potassium humate was that all plant growth parameters, and the number of branches were enhanced significantly by applying 4 kg/ fed. (Table, 2).

The highest value was recorded in 4 kg/ fed., where the number of branches was recorded at 8.67 and 10.22 compared to the untreated plants at 6.44 and 8.44 in the first and second seasons, respectively.

In relation to the main effect of the interaction between potassium humate and potassium sulfate, data in Table (2) show that the application of plants with the of K humate and K sulfate resulted in a significant increase in all plant growth parameters compared with the control treatments.

The effect of the interaction between of K humate and K sulfate where the highest value was recorded in the number of branches at 4 kg/fed. of K humate and treated with 75kg/fed. K sulfate, which was 12.33 and 14.33 branches compared to the control treatment, which gave 4.00 and 5.33branch per plant in the first and second seasons, respectively.

3.1.3 Fresh and dry weights per plant (g)

Data explained the potassium sulfate in the fresh and dry weights (g) per plant Table, 2 revealed that all treatments significantly increased the fresh and dry weights (g) per plant. The treatment is 75 kg/ fed. of K sulfate was given the highest value of fresh and dry weights per plant 466.63 g and 190.73 g in the first season, respectively; combined with other treatments and control plants. However, the treatment is 75kg/fed. of K sulfate was recorded as the maximum value of fresh and dry weights per plant at 484.44 g and 249.60 g in the second season, respectively.

On the topic of the main effect of potassium humate, data in Table (2) illustrate that treating plants with potassium humate resulted in a significant increase in the dry weight per plant compared to the control treatment. The effect of potassium humate where the highest value in the fresh and dry weights per plant was recorded when using 4 kg/ fed. of K humate, In the first season, the increase in fresh and dry weight of safflower was recorded at 391.21 g and 408.11 g, while it was recorded in the second season at 164.92 g and 197.03 g, respectively, compared to the other treatments and the control

Information in Table (2) indicate that the interaction between potassium humate and Potassium sulfate had a significant effect on the fresh and dry weights (g) per plant In the first season, the highest fresh weight per plant was recorded at 572.30 g and 593.55 g, compared with control treatment 224.07 g and 235.33 g; during both seasons, respectively. As for the dry weight per plant, the highest values were recorded 216.77 g and 276.33 g, compared with the control plant 118.93 g and 133.10 g during two seasons, respectively. This result is obtained from the treatment when the plants are applied to 4 kg/fed. of K humate and treated with 75kg/fed. of K sulfate.

3.1.4. Fruit weights (g)

Data in Table, 2 show that fruit weights (g) increased in a gradual and significant trend as the potassium sulfate increased up to 75 kg/ fed. K sulfate per plant which gave the highest values of these characteristics. On the other hand, the fruit weights (g) recorded 143.50 g and 149.72 g g in the first and second seasons, respectively.

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Data recorded in Table (2) designate that fruit weights (g) were significantly increased when treating plants with potassium humate compared with the control treatment. The highest values in the fruit weights were recorded at 119.62 g and 127.46 g in the first and second seasons; respectively, these results were obtained when applied plants with 4 kg/ fed. humate for both seasons.

The united effect between potassium humate and potassium sulfate, Table (2) showed that the highest values of fruit weights (g) were obtained when plants were applied at 4 kg/fed. of K humate and treated with 75kg/fed. K sulfate. So, the highest values of fruit weights were 166.73 g and 175.29 g in both seasons, respectively.

The increase in both plant height (cm), branch number/plant fresh and dry weights (g) and fruit weights (g) when using rates of potassium fertilizer, whether mineral or organic, is attributed to the role of these fertilizers in improving the growth medium of the plant and securing its requirements Food, which allowed an increase in vegetative growth capable of providing the needs of flower buds, and seeds formed so that the plant reached the highest production of fruits, compared to the control.

The above-mentioned results agreed with those obtained Steingrobe and Claassen, (2000); Abbadi, *et al.,* (2008); Cakmak (2005); Hafsi *et al.,* (2014); Pal *et al.,* (2016); Khatab (2016);El-Gamal (2015) and Ali I *et al.,* (2019)

Table 2: Effect of potassium sulfate and potassium humate treatments as well as their combinations on plant growth of safflower plant during the two successive seasons of 2020/2021 and 2021/2022.

K humate / K sulfate	Control	2 kg/fed.	4 kg/fed.	Mean	Control	2 KG/fed.	4 kg/fed.	Mean
	First season (2020/2021)				Second season (2021/2022)			
	Plant height (cm)							
Control	114.54^{e}	126.66^{d}	131.40^{cd}	124.20^{C}	110.33^{f}	125.33^{e}	128.33^{de}	121.33^{C}
50kg/ fed.	134.59^{c}	136.13^{c}	145.25^{b}	138.65^{B}	132.67^{cd}	136.67^{c}	143.00^{b}	137.44^{B}
75kg/fed.	148.06^{b}	152.00^{b}	171.78^{a}	157.28^{A}	145.00^{b}	148.67^{b}	167.00^{a}	153.56^{A}
Mean	132.40^{C}	138.26^{B}	149.48^{A}		129.33^{C}	136.89^{B}	146.11^{A}	
	Branches number/plant							
Control	4.00^{f}	4.00^{f}	5.67^{e}	4.56^{C}	5.33^{d}	5.33^{d}	7.33^{c}	6.00^{C}
50kg/ fed.	6.00^{e}	7.33^{d}	8.00^{d}	7.11^{B}	8.33^{c}	8.67^{c}	9.00^{c}	8.67^{B}
75kg/fed.	9.33^{c}	11.00^{b}	12.33^{a}	10.89^{A}	11.33^{b}	12.33^{b}	14.33^{a}	12.67^{A}
Mean	6.44^{C}	7.44^{B}	8.67^{A}		8.44^{B}	8.67^{B}	10.22^{A}	
	Fresh weight (g)							
Control	224.07^{g}	257.37^{f}	266.15^{ef}	249.19^{C}	235.33^{f}	270.41^{e}	278.00^{e}	261.25^{C}
50Kg/ fed.	289.73^{ef}	310.60^{de}	335.17^{d}	311.83^{B}	302.07^{e}	321.89^{de}	352.79^{cd}	325.58^{B}
75kg/fed.	383.70^{c}	443.90^{b}	572.30^{a}	466.63^{A}	402.89^{c}	456.88^{b}	593.55^{a}	484.44^{A}
Mean	299.17^{C}	337.29^{B}	391.21^{A}		313.43^{C}	349.73^{B}	408.11^{A}	
	Dry weight (g)							
Control	118.93^{i}	124.43^{h}	132.00^{g}	125.12^{C}	133.10^{h}	137.00^{g}	140.33^{g}	136.81^{C}
50kg/ fed.	136.17^{f}	140.77^{e}	146.00^{d}	140.98^{B}	148.83^{f}	158.33^{e}	174.43^{d}	160.53^{B}
75kg/fed.	154.00^{c}	201.43^{b}	216.77^{a}	190.73^{A}	202.20^{c}	270.27^{b}	276.33^{a}	249.60^{A}
Mean	136.37^{C}	155.54^{B}	164.92^{A}		161.38^{C}	188.53^{B}	197.03^{A}	
	Fruit weights (g)							
Control	51.13^{h}	74.03^{g}	82.30^{fg}	69.16^{C}	54.22^{h}	76.96^{g}	88.81^{f}	73.33^{C}
50kg/ fed.	90.80^{ef}	97.60^{e}	109.83^{d}	99.41^{B}	95.29^{ef}	101.00^{e}	118.29^{d}	104.86^{B}
75kg/fed.	123.80^{c}	139.97^{b}	166.73^{a}	143.50^{A}	130.26^{c}	143.63^{b}	175.29^{a}	149.72^{A}
Mean	88.58^{C}	103.87^{B}	119.62^{A}		93.26^{C}	107.20^{B}	127.46^{A}	

3.2. Production parameters

3.2.1. Dry petals yield /plant (g) and (feddan /kg)

Data explained the potassium sulfate in the dry petals yield /plant (g) and (feddan /kg) Table,3 revealed that all treatments significantly increased the dry petals yield /plant (g) and (feddan /kg). The treatment is 75 kg/ fed. K sulfate was given the highest value of dry petals yield /plant (g) and (feddan /kg) 2.633 g and 46.079 kg in the first season, respectively; combined with other treatments and control plants. However, the treatment is 75kg/fed. K sulfate was recorded as the maximum value of fresh and dry weights per plant at 2.716 g and 47.528 kg in the second season, respectively.

Concerning, the main effect of potassium humate, data in Table (3) showed that treating plants with potassium humate resulted in a significant increase in the dry petals yield /plant (g) and (feddan /kg) compared to control treatment. The effect of potassium humate where the highest value in the dry petals yield /plant (g) and (feddan /kg) was recorded when using 4 kg/ fed. of K humate, In the first season, the increase in fresh and dry weight of safflower was recorded at 3.732 g and 65.306 kg, while it was recorded in the second season at 3.850 g and 67.369 g, respectively, compared to the other treatments and the control

Information in Table (3) point to, the interaction between Potassium humate and Potassium sulfate had a significant effect on the dry petals yield /plant (g) and (feddan /kg). In the first season, the highest dry petals yield /plant (g) and (feddan /kg) was recorded 4.339 g and 4.433 kg, compared with control treatment 0.523 g and 0.530 kg; respectively. As for, the second season dry petals yield /plant (g) and (feddan /kg), the highest values were recorded at 4.433 g and 77.572 kg, compared with the control plant 0.530 g and 9.275 kg; respectively. This result is obtained from the treatment when the plants are applied to 4 kg/fed. Of K humate and treated with 75kg/fed. K sulfate.

Table 3: Effect of potassium sulfate and potassium humate treatments as well as their combinations production parameters of safflower plant during the two successive seasons of 2020/2021 and 2021/2022.

K humate / K sulfate	Control	2 kg/fed.	4 kg/fed.	Mean	Control	2 kg/fed.	4 kg/fed.	Mean
	First season (2020/2021)				**Second season (2021/2022)**			
	Dry petals yield/plant (g)							
Control	0.523^{h}	1.100^{g}	1.280^{g}	0.968^{C}	0.530^{i}	1.1383^{h}	1.323^{g}	0.997^{C}
50kg/ fed.	1.623^{f}	2.017^{e}	2.280^{d}	1.973^{B}	1.679^{f}	2.1230^{e}	2.393^{d}	2.065^{B}
75kg/fed.	3.160^{c}	3.696^{b}	4.339^{a}	3.732^{A}	3.228^{c}	3.889 ^{b}	4.433^{a}	3.850^{A}
Mean	1.769^{C}	2.271^{B}	2.633^{A}		1.812^{C}	2.3833^{B}	2.716^{A}	
	Dry petals yield/fed (kg)							
Control	9.158^{h}	19.250^{g}	22.400^{g}	16.936^{C}	9.275^{i}	19.921^{h}	23.129^{g}	17.442^{C}
50kg/ fed.	28.408^{f}	35.292^{e}	39.900^{d}	34.533^{B}	29.382^{f}	37.153^{e}	41.883^{d}	36.139^{B}
75kg/fed.	55.300^{c}	64.680^{b}	75.938^{a}	65.306^{A}	56.484^{c}	68.052^{b}	77.572^{a}	67.369^{A}
Mean	30.956^{C}	39.741^{B}	46.079^{A}		31.714^{C}	41.708^{B}	47.528^{A}	
	Seed yield /plant (g)							
Control	7.31^{i}	11.22^{h}	15.15^{g}	11.23^{C}	9.36^{i}	11.56^{h}	17.24^{g}	12.72^{C}
50kg/ fed.	19.28^{f}	21.69^{e}	24.82^{d}	21.93^{B}	21.48^{f}	25.83^{e}	30.10^{d}	25.80^{B}
75kg/fed.	27.49^{c}	31.04^{b}	34.58^{a}	31.04^{A}	32.59^{c}	36.95^{b}	39.48^{a}	36.34^{A}
Mean	18.01^{C}	21.32^{B}	24.85^{A}		21.14^{C}	24.78^{B}	28.94^{A}	
	Seed yield/fed (kg)							
Control	127.96^{i}	196.40^{h}	265.13^{g}	196.50^{C}	163.78^{i}	202.27 ^{h}	301.73^{g}	222.59^{C}
50kg/ fed.	337.45^{f}	379.51^{e}	434.32^{d}	383.76^{B}	375.82^{f}	452.03^{e}	526.75^{d}	451.53^{B}
75kg/fed.	481.05^{c}	543.26^{b}	605.13^{a}	543.15^{A}	570.28^{c}	646.61^{b}	690.98^{a}	635.96^{A}
Mean	315.49^{C}	373.06^{B}	434.86^{A}		369.96^{C}	433.63^{B}	506.49^{A}	

3.2.2. Seed yield /plant (g) and feddan (kg)

Data illustrated the potassium sulfate in the seed yield /plant (g) and feddan (kg) Table (3) revealed that all treatments gave the highest significant increase in seed yield /plant (g) and feddan (kg). The treatment is 75 kg/ fed. K sulfate was given the highest value of seed yield /plant (g) and feddan (kg) at 24.85 g and 434.86 kg during the first season, respectively, otherwise, seed yield /plant (g) and feddan (kg) gave the highest values in the second season, which recorded 28.94 g and 506.49 kg, respectively combined with other treatments and control plants.

Regarding the main effect of potassium humate, data in Table (3) show that treating plants with of K humate resulted in a significant increase in the seed yield /plant (g) and feddan (kg) compared to the control treatment.

Effect of potassium humate where the highest value in the seed yield /plant (g) was recorded at the treatment 4 kg/ fed. of K humate, which was 31.04 and 36.34 g, during two seasons, respectively. In addition, an increase in the weight of seed yield / feddan (kg) was observed, where it was recorded at 543.15 kg and 635.96 kg in the first and second seasons respectively.

Data in Table (3) indicate that the interaction between potassium humate and potassium sulfate had a significant effect on the seed yield /plant (g) and feddan (kg). In the first season, the highest seed yield /plant (g) and feddan (kg) was recorded34.58 g and 605.13 kg compared with control plants 7.31 g and 127.96, respectively. As for the second season, the highest seed yield /plant (g) and feddan (kg) 39.48 g and 690.98 kg compared with the control plant 9.36 g and 163.78 kg, respectively; This result is obtained from the treatment when the plants are applied to 4 kg/fed. Of K humate and treated with 75kg/fed. K sulfate.

The reason for the increase in the proportion of the basic nutrients nitrogen, phosphorous, and, potassium in the plant is due to the effect of adding potassium fertilizer, which is due to the organic fertilizer (potassium humate) containing these elements and its positive role in transferring nutrients from the membranes to the cell.

Potassium fertilizer also stimulates root growth because it contains auxins and Gibberellins stimulate the processes of cell division and elongation and thus increase the rates of absorption of water, nutrients, and elements from the soil, which is reflected in an increase in the total production of the plant.

This is consistent with what he found by Steingrobe and Claassen, (2000); Abbadi *et al.,* (2008); Cakmak (2005); Hafsi *et al.,* (2014); Pal *et al.,* (2016); Khatab (2016); El-Gamal (2015) and Ali *et al.,* (2019).

3.3. Oil production

3.3.1. Seed fixed oil percentage

The data of fixed oil percentage in both seasons are shown in Table (4) the fixed oil percentage was significantly increased with potassium sulfate application. The highest values of fixed oil percentage were related to the treatment of 75 kg/ fed. of K sulfate. On the other hand, the highest value was recorded in 75 kg/ fed. of K sulfate, where fixed oil percentage was recorded at 27.93 % and 27.79 % in both seasons, respectively.

Fixed oil percentage as affected by potassium humate treatments were reported in Table (4), was found that treating plants with of K humate resulted in a significant increase compared with the control plants for the first and second seasons.

Otherwise, in the first season, the maximum oil percentage was 31.77 % while, in the second season the highest value of oil percentage was 34.53 % these results are recorded when applying the vitamins at 4 kg/ fed. of K humate. These results were obtained when applied plants with 4 kg/ fed. humate for both seasons.

Data in Table (4) there are significant differences in the oil percentage as a result of the difference in interaction treatments between potassium humate and potassium sulfate where the highest significant difference was recorded in the first and second seasons when applying the treatment 4 kg/fed. Of K humate and treated with 75Kg/fed. of K sulfate. The oil percentage was recorded at 35.15 % and 34.53 % compared to the control treatment 17.06 % and 17.32 %, respectively.

3.3.2. Oil yield per plant (ml) and feddan (l)

With reference to, the results in (Table, 4) show that increasing potassium sulfate produced an increase in oil yield per plant (ml) and feddan (l). These increments were significant in most cases for the two seasons. In the first season, the highest average of oil yield per plant (ml) and feddan (l) was recorded at 7.37 ml and 129.00 kg respectively. While in the second season the highest average oil yield per plant (ml) and feddan (l) were recorded at 8.50 ml and 148.75 l. This result was recorded when treating plants with 75 kg/ fed. of K sulfate

Regarding oil yield per plant (ml) and feddan (l) in seeds data in Table (4) show that all potassium humate treatments exhibited a stimulatory effect on oil yield per plant (ml) and feddan (l) accumulation in seeds compared with the control treatment. The differences between the treatments and the control were significant for both seasons. The uppermost values oil yield per plant (ml) were 9.95 ml and 11.44 ml in the first and second seasons; respectively. While the highest values of oil content per feddan were 174.05 kg and 148.75 kg in the first and second seasons; respectively. These results were obtained when applied plants with 4 kg/ fed. of K humate for both seasons.

in connection with, Data in Table (4) indicating that interaction treatments had a significant increase in oil yield per plant (ml) and feddan (l) in seeds of safflower plants compared with the control treatment. The highest values of oil yield per plant (ml) were 12.16 ml and 13.64 ml in the first and second seasons; respectively. Even though, the highest values of oil yield per feddan (l) were 212.71 l and 238.70 l in the first and second seasons; respectively. These results were produced from plants with added 4 kg/fed. of K humate and treated with 75kg/fed. of K sulfate.

Table 4: Effect of potassium sulfate and potassium humate treatments as well as their combinations on oil production parameters of safflower plant during the two successive seasons of 2020/2021 and 2021/2022.

K humate / K sulfate	Control	2 kg/fed.	4 kg/fed.	Mean	Control	2 kg/fed.	4 kg/fed.	Mean
	First season (2020/2021)				Second season (2021/2022)			
	Seed fixed oil percentage							
Control	17.06h	19.62g	21.977f	19.55C	17.32i	19.79h	22.12g	19.75C
50kg/ fed.	23.12f	25.24e	26.677d	25.01B	23.25f	25.44e	26.72d	25.14B
75kg/fed.	28.44c	31.74b	35.15a	31.77A	28.65c	30.69b	34.53a	31.29A
Mean	22.87C	25.534B	27.93A		23.08C	25.31B	27.79A	
	Oil yield per plant (ml)							
Control	1.27i	2.21h	3.33g	2.27C	1.63i	2.30h	3.82g	2.581C
50kg/ fed.	4.46f	5.48e	6.63d	5.52B	4.10f	6.58e	8.04d	6.54B
75kg/fed.	7.82c	9.87b	12.16a	9.95A	9.34c	11.35b	13.64a	11.44A
Mean	4.52C	5.86B	7.37A		5.32C	6.74B	8.500A	
	Oil yield per feddan (l)							
Control	22.21i	38.69h	58.34g	39.75 C	28.58i	40.16h	66.79g	45.17C
50kg/ fed.	78.09f	95.81e	115.95d	96.62B	87.41f	115.19e	140.77d	114.46B
75kg/fed.	136.81c	172.63b	212.71a	174.05A	163.41c	198.60b	238.70a	200.24A
Mean	79.04C	102.38B	129.00A		93.13C	117.98B	148.75A	

3.3.3. Fixed oil chemical constituents by G.L.C.

Data in G.L.C. analysis, it was found that the four fatty acids content in the fixed oil of safflower seeds are Palmitic acid, Stearic acid, Oleic acid, and Linoleic acid.

Figure 1, and 2 shows that Linoleic acid is the largest component of the fixed oil of safflower, as it scored 72%: 74%. While oleic acid was the second compound in the oil, it recorded 18%, while stearic acid recorded the lowest percentage in safflower oil at 2%.

Linoleic acid recorded the largest percentage of the fixed oil components 72%, followed by Oleic acid, the second compound, 18%, followed by Palmitic acid, which recorded 8% of the fixed oil components, while stearic acid was given 2%, and that was in the untreated plants (control).

On the other hand, the treatment showed 75 kg/ fed. potassium sulfate The presence of only three compounds in the fixed oil: Linoleic acid with a percentage of 74%, followed by Oleic acid, the second compound, 18%, and then Palmitic acid 8%, which recorded the smallest percentage in the fixed oil of safflower.

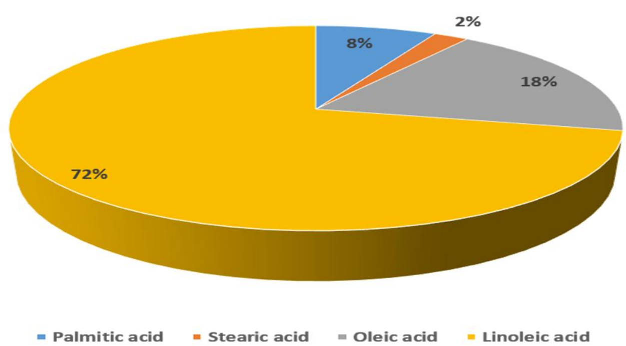

Fig. 1: Fixed oil constituents percentage of *Carthamus tinctorius*, L.to 75 kg/ fed. potassium sulfate treatment.

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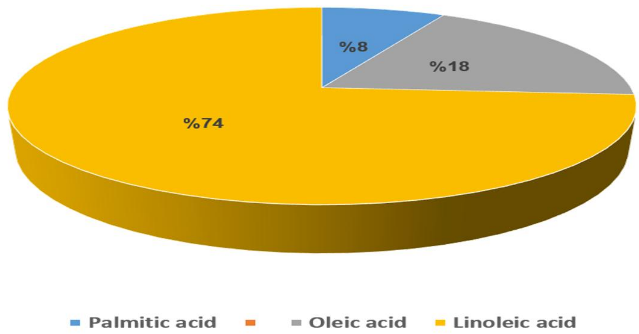

Fig. 2: Fixed oil constituents' percentage of *Carthamus tinctorius*, L.to control treatment.

The increase in seed and dry petals yield/plant (g) and feddan (kg) is due to the increase in cell division and cell expansion due to the accumulation of potassium sulfate, where potassium plays an important role in the transport and storage of metabolic products to the parts of the plant and also increases the content of chlorophyll in leaves nitrogen and its stimulation of plant photosynthesis, which helped to increase the division and elongation of leaf cells, thus increasing their area, which is reflected in an increase in the production of flowers and fruits, and thus this increase appears in the production of dry petals and seeds, including an increase in the percentage of oil (%) and oil yield/plant (g) and feddan (kg).

Similar results were recorded by Steingrobe and Claassen, (2000); Abbadi *et al.,* (2008); Cakmak (2005); Hafsi *et al.,* (2014); Pal *et al.,* (2016); Khatab (2016); El-Gamal (2015) and Ali *et al.,* (2019).

3.4. Chemical composition

3.4.1. Total carbohydrate percentage

Data in Table, 5 show that the total carbohydrate percentage increased in a gradual and significant trend as the potassium sulfate increased up to 75 kg/ fed. K sulfate per plant which gave the highest values of these characteristics. On the other hand, the total carbohydrate percentage recorded was 45.09 % and 44.91 % in the first and second seasons, respectively.

Records in Table (5) designate that the total carbohydrate percentage significantly increased when treating plants with potassium humate compared with the control treatment. the highest values in the total carbohydrate percentage were recorded at 56.08 % and 56.64 % in the first and second seasons; respectively, were obtained when applied plants with 4 kg/ fed. of K humate for both seasons.

The united effect between potassium humate and potassium sulfate, Table (2) showed that the highest values of total carbohydrate percentage were obtained when plants were applied at 4 kg/fed. of K humate and treated with 75kg/fed. K sulfate. So, the highest values of total carbohydrate percentage were 60.09 % and 61.20 % in both seasons, respectively.

3.4.2. Protein Percentage

With reference, the results in (Table, 5) show that increasing potassium sulfate rates produced an increase in protein percentage. These increments were significant in most cases for the two seasons. In the first season, the highest average protein percentage was recorded at 18.65 % while, in the second season the highest average protein percentage was recorded at 19.06 % This result was recorded as a result of treating plants with 75kg/fed. of K sulfate

Regarding protein percentage data in Table (5) show that all potassium humate treatments exhibited a stimulatory effect on protein percentage accumulation in seeds compared with the control treatment. The differences between the treatments and the control were significant for both seasons. The uppermost values protein percentages were 14.16 % and 19.06 % during the first and second seasons; respectively. These results were obtained when applied plants with 4 kg/ fed. of K humate for both seasons.

In connection with this, data in Table (5) indicate that interaction treatments had a significant increase in the protein percentage of safflower plants compared with the control treatment. The highest values of protein percentage23.05 % and 23.75 % during the first and second seasons; respectively.

These results were produced from plants with added 4 kg/fed. of K humate and treated with 75 kg/fed. of K sulfate.

Table 5. Effect of potassium sulfate and potassium humat treatments as well as their combination on the chemical composition of safflower plant during the two successive seasons of 2020/2021 and 2021/2022.

K humate / K sulfate	Control	2 kg/fed.	4 kg/fed.	Mean	Control	2 kg/fed.	4 kg/fed.	Mean
	First season (2020/2021)				Second season (2021/2022)			
	Total carbohydrates percentage							
Control	20.89^{h}	24.19^{g}	29.57^{f}	24.88^{C}	21.66^{i}	24.27^{h}	28.76	24.90^{C}
50kg/ fed.	30.96^{f}	36.10^{e}	45.59^{d}	37.55^{B}	31.34^{f}	36.25^{e}	44.78^{d}	37.46^{B}
75kg/fed.	51.78^{c}	56.37^{b}	60.09^{a}	56.08^{A}	51.20^{c}	57.52^{b}	61.20^{a}	56.64^{A}
Mean	34.54^{C}	38.89^{B}	45.089^{A}		34.73^{C}	39.35^{B}	44.91^{A}	
	Protein percentage							
Control	5.12^{h}	6.49^{g}	6.85^{fg}	6.15^{C}	5.46^{f}	6.55^{f}	6.91^{f}	6.31^{C}
50kg/ fed.	7.54^{f}	9.379^{e}	12.57^{d}	9.83^{B}	8.81^{e}	9.63^{e}	12.94^{d}	10.46^{B}
75kg/fed.	15.35^{c}	17.56^{b}	23.05^{a}	18.65^{A}	15.761^{c}	17.67^{b}	23.75^{a}	19.06^{A}
Mean	9.34^{C}	11.14^{B}	14.16^{A}		10.01^{C}	11.29^{B}	14.53^{A}	
	Carthamin content/plant petals (mg/100g)							
Control	0.032^{h}	0.045^{g}	0.055^{f}	0.044^{C}	0.039^{h}	0.0497^{g}	0.055^{f}	0.048^{C}
50kg/ fed.	0.057^{ef}	0.059^{de}	0.062^{cd}	0.059^{B}	0.058^{ef}	0.060^{de}	0.062^{cd}	0.060^{B}
75kg/fed.	0.064^{c}	0.067^{b}	0.072^{a}	0.068^{A}	0.065^{bc}	0.068^{b}	0.075^{a}	0.069^{A}
Mean	0.051^{C}	0.057^{B}	0.063^{A}		0.054^{C}	0.059^{B}	0.064^{A}	

3.4.2. Carthamin content/plant petals (mg/100g)

Data illustrated potassium sulfate in carthamin content Table 5 revealed that all treatments gave the highest significant increase in the carthamin content (mg/100g). The treatment is 75 kg/ fed. of K sulfate was given the highest value of carthamin content 0.063 mg/100g and 0.064 mg/100g during two seasons, respectively; combined with other treatments in both seasons.

Regarding the main effect of potassium humate, data in Table (5) show that treating plants with potassium humate resulted in a significant increase in the carthamin content (mg/100g) compared to control treatments. The effect of potassium humate where the highest value in the carthamin content (mg/100g) was recorded the maximum value of 0.068 mg/100g when adding 4 kg/ fed. of K humate, in the first season. While the same treatment in the second season was recorded, 0.069 mg/100g compared to the control treatment 0.044 mg/100g, and 0.048 mg/100g in the 1st and 2nd seasons, respectively.

Also, data in Table (5) indicate that the interaction between potassium humate and potassium sulfate had a significant effect on the carthamin content in the first season, the highest carthamin content was recorded at 0.072 mg/100g compared with the control treatment at 0.032 mg/100g. As for the second season, the highest carthamin percentage was recorded at 0.075 mg/100g compared with the control plant at 0.039 mg/100g. This result was obtained from the treatment when the plants are applied to 4 kg/fed. of K humate and treated with 75kg/fed. K sulfate.

The reason for the effect of potassium in increasing the carbohydrate content of leaves as a result of the increase in the leaves' content of total chlorophyll and then increasing the efficiency of the photosynthesis process is the role of physiological potassium in metabolic processes, which may lead to an increase in the content of soluble sugars in the plant . El-Shayeb et al, 2021 and Rania and Salama (2021).

Potassium also increases the acidity of the soil, which facilitates the movement and absorption of nutrients, especially zinc, iron, and magnesium, which encourages increased formation and activation of chlorophyll, thus increasing the efficiency of the photosynthesis process. El-Shayeb et al, 2021 and Rania and Salama (2021).

As for the effect of potassium on the content of active substances in the plant, it is due to its role in increasing the manufacture and stimulating the production of enzymes, as it has an important role in the work of enzymes through its effect on the nitrogenous bases that act as a nitrogen receptor and thus increase protein production.

The addition of potassium to the plant led to an increase in the activation of the enzymes phosphatase, catalase, phosphorylase, and dehydrogenase, which directly affect the production of protein and active substances within the plant. El-Shayeb *et al.,* 2021 and Rania and Salama (2021).

These results are in accordance with those obtained by Steingrobe and Claassen, (2000) ; Abbadi, *et al.,* (2008); Cakmak (2005); Hafsi *et al.,* (2014); Pal *et al.,* (2016); Khatab (2016); El-Gamal (2015) and Ali *et al.,* (2019).

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