Effect of cultivars, potassium sulphate and tocopherol on the growth of shoots of maize (*Zea mays* L.)

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Abstract

This study was conducted in the Al-Nabhaniyah area 10 km east of Karbala city during the spring agricultural season 2024 to investigate the effect of foliar spraying with potassium sulfate and tocopherol on vegetative growth indicators. The experiment was implemented using a completely randomized design (CRD) as a factorial experiment with three factors: two cultivars of maize (Sorour and 5018), four concentrations of potassium sulfate (0, 25, 50, and 75 mg L^{-1}), and four concentrations of tocopherol (0, 50, 100, and 150 mL^{-1}), with three replicates. The results showed that foliar fertilization with potassium sulfate at a concentration of 50 mg L^{-1} and tocopherol at a concentration of 100 mg L^{-1} significantly affected all studied traits. The two-way interaction between the study factors was significant except for relative and absolute growth. The interaction coefficients between the cultivars and potassium sulfate concentrations 50 mg L^{-1} and between the cultivars and tocopherol concentrations (100 mg L^{-1}) gave the highest rate. The two-way interaction between potassium sulfate and tocopherol was also significant under concentrations (50, 100 mg L^{-1}) of potassium sulfate and tocopherol, respectively. The results also showed that the three-way interaction between the study factors was significant for all studied traits except for the average number of leaves (leaf/$plant^{-1}$) and the relative growth rate. Also, there was a significant interaction between cultivars, Potassium sulfate 50 mg L^{-1} and tocopherol 100 mg L^{-1} for other traits.

Keywords: maize, cultivar, potassium sulphate, tocopherol.

Introduction

Globally, maize occupies a pivotal position among cereals in ensuring food security, due to its vast cultivated area and high production quantity [1,2]. The cultivation of maize is widespread in many countries of the world because of its ability to grow in various climatic conditions [3,4] and its high productivity. The productivity of any of the cultivars depends on the use of new techniques in fertilization and irrigation, which would increase plant growth and yield [5]. The maize grain is also used in manufacturing of pastries and in the composition of concentrated poultry feed and as food for humans in poor countries [6]. Its kernels are characterized by a high nutritional value, as they contain 9% protein, 73% starch, 4% oil, and other components that

constitute 14% [7]. It is regarded as having a good content of vitamins (E, F).Potassium is an essential nutrient for plant growth and productivity and it is one of the most important macronutrients that control the mechanism of opening and closing stomata, regulating the osmotic Potential of plant cells, increasing their permeability, contributing to the process of photosynthesis, cell division, and plant resistance to sluggishness and plant diseases [8,9]. Potassium plays a crucial role in stimulating various enzymes and facilitating the synthesis of sugars, starches, and proteins in plants. It enhances water use efficiency and supports root growth and cell division. [10].

Many studies have found that the addition of potassium increases the surface area of the leaf [12] demonstrated how adding potassium fertilizer to the soil increased plant height and leaf surface area, a study [13] demonstrated how adding potassium fertilizer to maize plants increased stem length, leaf surface area, and dry matter production, and a study [14] noted that the wheat plants fertilized with potassium sulphate and urea exhibited the highest rate of growth characteristics.

Tocopherols are lipophilic chemical compounds and antioxidants that belong to the vitamin E family. Green photosynthetic organisms produce them [15, 16, 17]. This means tocopherols have an essential part to play in the lives of both plants and animals. Plants that use photosynthesis are the only source of tocopherol production for all other living things. Not having enough tocopherols can kill plants, which then has a negative effect on animals. [18,19]. What's more higher salt levels in irrigation water lead to more oxidative stress in plant tissues by upping free radical production [20]. Getting rid of harmful free radicals is a key defense that shields plants from the damage these radicals can cause. This defense includes making substances that mop up free radicals, like tocopherols ascorbic acid, proline, and others [21, 22].

Numerous studies have indicated the beneficial effects of tocopherol foliar application, particularly in enhancing crop productivity. For instance, spraying wheat plants with tocopherol led to an increase in grain carbohydrate and protein content, alongside an overall boost in yield [23]. Another study showed that spraying the bean with tocopherol plays an important role with some antioxidant enzymes such as proline, carotenoids, and inorganic ions (K + and Ca + 2) in reducing the damage caused by watering with dilute seawater, and reduced the harmful effect of salinity and improved growth. Seed yield and quality of seed production [24]. Similarly, finding of another study revealed that spraying broad bean plants with tocopherol led to a significant increase in all growth characteristics such as stem length, number of leaves, leaf surface area, number of branches, fresh weight and dry weight compared to plants that were sprayed with natural water [25]. The aim of the study is to demonstrate the effect of foliar spraying with potassium sulfate and tocopherol on vegetative growth indicators.

Materials and methods

This study is conducted on a farm in the Al-Nabhaniya area (10 km) east of the city of Kerbala in clay-silty soil during the spring agricultural season/ 2024. Table 1 shows some of its chemical and physical properties. The experiment included two cultivars of

maize (*Zea mays L.*) (Surour , 5018), which were obtained from the College of Agriculture / University of Kerbala; four concentrations of potassium sulfate (0, 25, 50, 75) mg. L^{-1} ; concentrations of tocopherol (vitamin E) (0, 50, 100, 150) mg. L^{-1}. The experiment was carried out using plastic pots (15 kg/soil) according to the Completely Randomized Design (CRD) as a factorial experiment of three factors (2 x 4 x 4 m) with three replications. Thus, the number of experimental units was 96 pot. These pots (diameter 35 cm and height 50 cm) were filled with soil after being taken from depths (0-30 cm) and dried air and passed through a sieve with a diameter of 2 mm. The field capacity of the used soil was estimated by taking three pots packed with 15 kg / completely air and sun-dried soil. It was irrigated to full saturation and left for 48 hours. Taking into account the amount of water vapor by placing a plastic cover on each pot. It was left until the last drop of attractive water fell through the bottom holes of the pots, then it was weighed again and the calculation method was as follows [26]:

Weight of water lost = soil wet weight – soil dry weight.

Percentage of water contained in 15 kg/soil = weight of water lost / dry weight of soil x 100.

After conducting field calculations, it was found to be equal to 33.5%.

Four seeds of maize have been sown for each pot [6] at a depth of 2 cm taking into account the selection of healthy seeds of similar sizes, Irrigation was done with river water until reaching (100%) of the field capacity for all experimental units. Diammonium Phosphate (DAP) fertilizer was added at a rate of 2 g. Pot^{-1} in two applications: the first before planting and the second 25 days after planting. After that, irrigation and weeding kept going until just before harvest. After 25 days, irrigation went on at the needed field capacity (100%) until harvest. This happened as needed by weighing the pots and adding water to reach the field capacity mentioned earlier.

The stock solution was prepared by adding 1 g of potassium into 1000 ml of distilled water. Different required concentrations (25, 50, 75) mg. L^{-1} of it were prepared according to the dilution law, in addition to the control treatment, which is (0 mg. L^{-1}). And in the same way, a stock solution of tocopherol was prepared and it is (50, 100, 150) mg. L^{-1}. The above two solutions were sprayed in the early morning after 45-50 days of planting the seeds on 15 and 20 of May respectively. The spraying was evenly until complete wetness, while the control treatments were sprayed with distilled water and while continuing to irrigate until the required field capacity this represents the first spray, thirty days after the first spraying. The second spraying process was carried out on 15 and 20 of June respectively, at the beginning of the emergence of the flag leaf according to the above concentrations, while continuing the irrigation process according to the required field capacity.

Table (1): Some chemical and physical properties of the study soil.*

Ec	**Desi Simmons. M^{-1}**	3.2
pH		7.7
organic matter	**gm kg^{-1}**	10.3
ready nitrogen	**mg kg^{-1}**	101.1
ready phosphorous	**mg kg^{-1}**	8.1
Ready Potassium	**mg kg^{-1}**	210.0
lime	**gm kg-1**	220.0
Soil structure		
sand	**gm kg^{-1}**	70.0
clay	**gm kg^{-1}**	520.0
silt	**gm kg^{-1}**	410.0
Silty clay		

* The analyzes were carried out in the soil analysis laboratories in the College of Agriculture / University of Kufa.

Study indicators

At harvest, the following readings were taken:

(1) Average plant height (cm). (2) Average number of leaves (leaf. $Plant^{-1}$). (3) The average area of the flag leaf (cm^2), The leaf area of the flag leaf was calculated at the stage of (100%) flowering, according to the formula that was followed by [27], which is as follows: = 0.75 x the length of the leaf (cm) x the width of the leaf (cm).

(4) The average dry weight of the shoot (g. $Plant^{-1}$): The samples were dried in the electric oven (Oven) at a temperature of (72 °C) until the weight was proven, then the samples were weighed using a sensitive balance (Sartorius), Then the average dry weight of the shoots was calculated.

(5) Stem diameter (mm) at the flowering stage, and it was done by using Vernier meter.

(6) The absolute growth rate of dry plants (g. day^{-1}): It was calculated in terms of dry weight according to the following equation: $AGR = \frac{W2-W1}{T2-T1}$ [28] where:

W1 = dry weight of the vegetative part in the first season.

W2 = dry weight of the vegetative part at the second time.

T1 = the time of taking the first sample, measured by day.

T2 = the time of taking the second sample, measured by day.

(7) The relative growth rate of the dry plant (g. g^{-1} dry weight. day^{-1}): It was calculated according to equation [28] and as follows:

$RGR = \frac{Loge\ W2-Loge\ W1}{T2-T1}$ where:

Log W1: is (ln) the natural logarithm of the dry weight of the vegetative part at time.

Log W2: is (ln) the natural logarithm of the dry weight of the vegetative part at time.

T1 = the time of taking the first sample, measured by day.

T2 = the time of taking the second sample, measured by day.

Statistical analysis

Statistical analysis of data was performed using SAS (Statistical Analysis System - version 9.1). The results were analyzed statistically and the averages were compared using the Least Significant Difference (L.S.D.) at the probability level of 0.05 according to [29].

Results and Discussion

Average plant height

The results in Table 2 showed that the cultivars had a significant effect on the average stem length of maize plants. the cultivar 5018 gave the highest rate by 137.51 cm, while the cultivar Sorour gave the lowest mean for this trait, which was 121.70 cm, this may be due to the differences between the cultivars in the length of the internodes according to their genetic structure [5]. This is consistent with the results of a study [7] that these genetic differences between maize cultivars have an effect on the above trait. Furthermore, there were significant differences between potassium sulfate concentrations in the mean of the traits under study, it was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best in its effect on the studied traits. It gave an increase in the plant height rate of (6.6%, 3.5%, and 2.0%), respectively. the concentrations of tocopherol were significant, as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities. As the concentration gave the highest increase in the plant height rate of (7.2%, 3.5%, 1.9%), respectively, as compared with other concentrations.

Table (2): Effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the average plant height (cm) of maize.

cultivar	Potassium sulfate concentration (mg. L^{-1})	Tocopherol Concentrate (mg. L^{-1})				impact mean cultivar × Potassium
		0	50	100	150	
Sorour	0	106.78	113.54	120.37	117.23	114.48
	25	112.36	119.50	127.53	124.91	121.08
	50	120.20	128.66	131.85	129.00	127.43
	75	116.97	122.78	129.60	125.91	123.82
5018	0	132.40	135.67	138.86	136.45	135.85
	25	134.17	136.23	139.00	137.89	136.82
	50	137.62	138.96	141.77	139.60	139.49
	75	136.44	137.00	139.88	138.12	137.86

LSD (0.05)	2.03					3.50
Tocopherol effect rate		124.62	129.04	133.61	131.14	cultivar effect rate
LSD (0.05)	1.13					
Effect cultivar × Tocopherol	Sorour	114.08	121.12	127.34	124.26	121.70
	5018	135.16	136.97	139.88	138.02	137.51
LSD (0.05)	2.04					1.20
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	119.59	124.61	129.62	126.84	125.17
	25	123.27	127.87	133.27	131.40	128.95
	50	128.91	133.81	136.81	134.30	133.46
	75	126.71	129.89	134.74	132.02	130.84
LSD (0.05)	1.88					1.02

Average number of leaves

The effect of cultivars on the average number of leaves, the results showed in Table 3 that it had no significant effect on this trait. Furthermore, there were significant differences between potassium sulfate concentrations in the mean of the traits under study, It was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best in its effect compared to the other concentrations (0, 25, 75) mg. L^{-1} gave an increase in the average number of leaves. $plant^{-1}$, which amounted to (11.3%, 6.2%, 3.2%), respectively, as compared with other concentrations. there were also significant differences between the concentrations of tocopherol as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities also gave an increase in the average number of leaves. plant-1, which amounted to (13.0%, 8.4%, 3.4%), respectively, as compared with other concentrations.

Table (3): the effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the average number of leaves (leaf. Plant -1) of maize.

cultivar	**Potassium sulfate concentration ($mg.L^{-1}$)**	**Tocopherol Concentrate (mg. L^{-1})**				**impact mean cultivar × Potassium**
		0	**50**	**100**	**150**	
Sorour	0	10.54	10.96	11.63	11.26	11.10
	25	10.85	11.23	12.54	12.13	11.69
	50	11.76	12.32	13.21	12.77	12.52
	75	11.15	11.65	12.76	12.43	12.00
5018	0	10.33	10.89	11.64	11.18	11.01
	25	10.60	11.21	12.26	11.87	11.57
	50	11.46	11.90	12.87	12.21	12.11

	75	11.12	11.56	12.54	12.19	11.85
LSD (0.05)	N. S.					2.02
Tocopherol effect rate		10.98	11.47	12.43	12.01	cultivar effect rate
LSD (0.05)	1.09					
Effect cultivar × Tocopherol	Sorour	11.08	11.54	12.54	12.15	11.83
	5018	10.88	11.39	12.33	11.86	11.62
LSD (0.05)	1.12					N. S.
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	10.44	10.93	11.64	11.22	11.06
	25	10.73	11.22	12.40	12.00	11.59
	50	11.61	12.11	13.04	12.49	12.31
	75	11.14	11.61	12.65	12.31	11.93
LSD (0.05)	1.55					1.15

Average size of the flag leaf

The effect of the cultivar on the average size of the flag leaf was significant. The cultivars Sorour and 5018 gave 190 cm^2 and 160 cm^2 respectively for this trait (Table 4) it may be because maize cultivars differ about the above trait, depending on the variation in the Genotype. This is consistent with what was reached by [5], as it was found that there are significant differences between the maize cultivars with regard to their effect on this trait. also, there were significant differences between potassium sulfate concentrations, It was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best compared to the other concentrations (0, 25, 75) mg. L^{-1} gave an increase in the average. It also gave an increase in the flag leaf area of (25.0%, 11.1%, and 5.3%), respectively, as compared with other concentrations. There were also significant differences between the concentrations of tocopherol, as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities also gave an increase in the mean size of the flag leaf by (18.8%, 11.8%, 5.6%), respectively, as compared with other concentrations.

Table (4): Effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the mean leaf area (cm^2) of maize.

cultivar	**Potassium sulfate concentration (mg.L^{-1})**	**Tocopherol Concentrate (mg. L^{-1})**				**impact mean cultivar × Potassium**
		0	**50**	**100**	**150**	
Sorour	0	150	160	180	170	170
	25	170	180	200	190	190
	50	190	210	200	210	210
	75	180	190	210	200	200
5018	0	120	130	115	140	140

	25	140	150	117	160	160
	50	160	180	210	200	190
	75	150	170	200	190	180
LSD (0.05)	1.25					1.14
Tocopherol effect rate		160	170	190	180	cultivar effect rate
LSD (0.05)	1.23					
Effect cultivar × Tocopherol	Sorour	170	190	200	190	190
	5018	140	160	180	170	160
LSD (0.05)	1.14					1.39
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	150	160	170	160	160
	25	160	170	190	180	180
	50	180	200	220	210	200
	75	170	180	210	200	190
LSD (0.05)	1.50					1.23

Average dry weight

The results in Table 5 showed that there was a significant effect of the cultivar on the average dry weight of the shoot. The cultivar Sorour gave the highest rate for this trait, amounting to 21.39 g. Plant^{-1}, while cultivar 5018 gave the lowest rate for the same trait, which amounted to 18.45 g. Plant^{-1}. This indicates to existence of genetic differences between cultivars in this trait and its clear impact on it. These results agreed with [6]. also, there were significant differences between potassium sulfate concentrations in the mean of the traits under study, It was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best in its effect compared to the other concentrations (0, 25, 75) mg. L^{-1} also gave an increase in the average dry weight of the shoot total by (16.3%, 9.5%, 4.2%), respectively, as compared with other concentrations. There were also significant differences between the concentrations of tocopherol in their effect on the traits included in the study, as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities also gave an increase in the average dry weight of the shoot total by (14.1%, 9.0%, and 3.7%), respectively, as compared with other concentrations.

Table (5): Effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the average dry weight of shoots (g. plant $^{-1}$) of maize.

cultivar	**Potassium sulfate concentration (mg.L^{-1})**	**Tocopherol Concentrate (mg. L^{-1})**				**impact mean cultivar × Potassium**
		0	**50**	**100**	**150**	
Sorour	0	18.50	19.34	21.23	20.45	19.88

	25	18.98	20.13	22.26	21.55	20.73
	50	22.08	22.76	23.98	23.05	22.97
	75	21.12	21.89	22.67	22.21	21.97
5018	0	15.22	16.33	18.25	17.66	16.87
	25	16.49	17.92	19.61	19.16	18.30
	50	18.31	18.96	21.65	20.21	19.78
	75	18.10	18.36	20.13	19.62	19.05
LSD (0.05)	1.09					1.24
Tocopherol effect rate		18.60	19.46	21.22	20.49	cultivar effect rate
LSD (0.05)	1.38					
Effect cultivar × Tocopherol	Sorour	20.17	21.03	22.54	21.82	21.39
	5018	17.03	17.71	19.91	19.16	18.45
LSD (0.05)						1.62
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	16.86	17.84	19.74	19.06	18.38
	25	17.74	19.03	20.94	20.36	19.52
	50	20.20	20.86	22.82	21.63	21.38
	75	19.61	20.13	21.40	20.92	20.52
LSD (0.05)	2.10					1.38

Average stem diameter

The results in Table 6 showed that the cultivars had a significant effect on the average of stem diameter. As the cultivar 5018 gave the highest rate of this characteristic amounted to 21.08 mm, while the cultivar Sorour gave the lowest rate for the same trait, which was 20.72 mm The results of the study agreed with the findings of [8] that cultivars had a significant effect on the average stem diameter and this may also be due to the variation between cultivars in their Genotype. Furthermore, there were significant differences between potassium sulfate concentrations in the mean of the traits under study, It was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best compared to the other concentrations (0, 25, 75) mg. L^{-1} also gave an increase in the average dry weight of the shoot total by (16.3%, 9.5%, 4.2%), respectively, as compared with other concentrations. There were also significant differences between the concentrations of tocopherol in their effect on the traits included in the study, as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on increasing the average diameter of the stem amounting to (23.0%, 12.4%, 6.0%), respectively, as compared with other concentrations.

Table (6): Effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the average stem diameter (mm) of maize plant.

cultivar	Potassium sulfate concentration ($mg.L^{-1}$)	Tocopherol Concentrate ($mg.\ L^{-1}$)				impact mean cultivar × Potassium
		0	50	100	150	
Sorour	0	15.62	17.85	21.36	18.12	18.24
	25	16.89	19.30	23.24	22.21	20.41
	50	19.22	22.38	25.55	23.84	22.45
	75	18.70	20.59	24.17	22.45	21.48
5018	0	17.45	18.32	20.66	20.10	19.13
	25	18.79	20.65	22.00	21.20	20.66
	50	21.48	22.44	23.80	22.95	22.67
	75	21.00	21.67	22.59	22.09	21.84
LSD (0.05)	1.51					1.37
Tocopherol effect rate		18.64	20.40	22.92	21.62	cultivar effect rate
LSD (0.05)	1.36					
Effect cultivar × Tocopherol	Sorour	17.61	20.03	23.58	21.66	20.72
	5018	19.68	20.77	22.26	21.59	21.08
LSD (0.05)	2.07					2.42
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	16.54	18.09	21.01	19.11	18.69
	25	17.84	19.98	22.62	21.71	20.54
	50	20.35	22.41	24.68	23.40	22.71
	75	19.85	21.13	23.38	22.27	21.66
LSD (0.05)	2.022					1.36

Absolute plant growth rate

The results showed in Table 7 that there is a significant effect of the cultivar on the absolute growth rate. The cultivar Sorour gave the highest rate of 0.21 g for the above trait plant-1, while the other cultivar gave the lowest rate for the same trait amounted to 0.17 g. $Plant^{-1}$. The results of this study agreed with the results of a study [11] on maize. Furthermore, there were significant differences between potassium sulfate concentrations in the mean of the traits under study, was found that the concentration of potassium sulfate was 50 mg. L^{-1} was the best compared to the other concentrations (0, 25, 75) mg. L^{-1} It also gave an increase in the absolute growth rate, which amounted to (23.5%, 16.7%, and 5.0%), respectively, as compared with other concentrations. There were also significant differences between the concentrations of tocopherol in their effect as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities also gave an increase in the absolute growth

rate of the plant (g. day^{-1}) amounting to (17.6%, 11.1%, 5.3%), respectively, as compared with other concentrations.

Table (7): Effect of cultivar, potassium sulfate concentration, tocopherol concentration and the interactions between them on the absolute plant growth rate (g. day $^{-}$1) of maize.

cultivar	Potassium sulfate concentration (mg.L^{-1})	Tocopherol Concentrate (mg. L^{-1})				impact mean cultivar × Potassium
		0	50	100	150	
Sorour	0	0.17	0.18	0.20	0.19	0.19
	25	0.17	0.19	0.21	0.20	0.19
	50	0.21	0.22	0.23	0.22	0.22
	75	0.20	0.21	0.22	0.21	0.21
5018	0	0.13	0.14	0.17	0.16	0.15
	25	0.14	0.16	0.18	0.18	0.17
	50	0.17	0.17	0.21	0.19	0.19
	75	0.16	0.17	0.19	0.18	0.18
LSD (0.05)	0.035					0.025
Tocopherol effect rate		0.17	0.18	0.20	0.19	cultivar effect rate
LSD (0.05)						
Effect cultivar × Tocopherol	Sorour	0.19	0.20	0.22	0.21	0.21
	5018	0.15	0.16	0.19	0.18	0.17
LSD (0.05)	N. S.					N. S.
						Potassium effect rate
Effect of potassium concentration × tocopherol	0	0.15	0.16	0.19	0.18	0.17
	25	0.16	0.18	0.20	0.19	0.18
	50	0.19	0.20	0.22	0.21	0.21
	75	0.18	0.19	0.21	0.20	0.20
LSD (0.05)	0.035					0.022

Relative growth rate

The results also showed in Table 8 that there is a significant effect of the cultivar on the relative growth rate. The cultivar Sorour gave the highest rate of 0.016 g. g^{-1} dry weight. day^{-1}, while the cultivar 5018 gave the lowest rate for the above trait, which amounted to 0.015 g. g^{-1} dry weight. day^{-1} and this is consistent with what was indicated by [7] that the cultivars differ among themselves in their effect on the above trait, depending on their genotype on the other hand, the results shown in Table 8 showed that there was no significant effect of spraying with potassium sulfate on the relative growth rate. This indicates that foliar fertilization with potassium sulfate led to an increase in plant growth, and this is due to its positive role in regulating the osmotic potential by regulating the pressure and water potential which increases the ability of

the cell to withdraw water from the soil, and then increase plant growth and perpetuate the elongation of its cells and perpetuate opening and the closure of stomata and the process of photosynthesis [11]. This is consistent with the findings of [10] and [13] that foliar fertilization with potassium sulfate has a positive role in increasing plant growth due to its effective role in modifying the osmotic potential of the plant cell. There were also significant differences between the concentrations of tocopherol in their effect on the traits included in the study, as the concentration exceeded 100 mg. L^{-1} on other concentrations (0, 50, 150) mg. L^{-1} in its effect on these qualities also gave an increase in the relative growth rate (g. $g.^{-1}$ dry weight, day^{-1}) of (13.3%, 13.3%, and 6.3%), respectively, as compared with other concentrations (Table 8). This indicates that tocopherol plays an important role in the life of both plants and animals so that plants that carry out the process of photosynthesis are the only source of tocopherol production for all other living organisms. Its deficiency may lead to the death of plants [18] and [19]. Also, an increase in salinity in irrigation water leads to an increase in oxidative stress in plant tissues through an increase in free radicals [20]. The removal of toxic free radicals is an important defense mechanism that protects plants from the negative effects of free radicals. One of these mechanisms is the production of anti-free radicals such as tocopherol, ascorbic acid, proline, and others [21,22].

Table (8): Effect of cultivar, concentration of potassium sulfate, concentration of tocopherols and the interactions between them on the relative growth rate (g.$g.^{-1}$ dry weight.day^{-1}) of maize.

cultivar	Potassium sulfate concentration (mg.L^{-1})	Tocopherol Concentrate (mg. L^{-1})				impact mean cultivar × Potassium
		0	50	100	150	
Sorour	0	0.015	0.015	0.015	0.015	0.015
	25	0.015	0.015	0.016	0.016	0.016
	50	0.016	0.016	0.016	0.016	0.016
	75	0.015	0.016	0.016	0.016	0.016
5018	0	0.014	0.014	0.015	0.014	0.014
	25	0.014	0.015	0.015	0.015	0.015
	50	0.015	0.015	0.016	0.015	0.015
	75	0.015	0.015	0.015	0.015	0.015
LSD (0.05)	N. S.					N. S.
Tocopherol effect rate		0.015	0.015	0.017	0.016	cultivar effect rate
LSD (0.05)						
Effect cultivar × Tocopherol	Sorour	0.015	0.016	0.016	0.016	0.016
	5018	0.015	0.015	0.015	0.015	0.015
LSD (0.05)	0.94					1.71
						Potassium effect rate

Effect of potassium concentration × tocopherol	0	0.015	0.015	0.015	0.015	0.015
	25	0.015	0.015	0.016	0.016	0.016
	50	0.016	0.016	0.016	0.016	0.016
	75	0.015	0.016	0.016	0.016	0.016
LSD (0.05)	N. S.					N. S.

The bilateral interactions between cultivar and potassium sulfate concentration indicated that there were significant differences in their effect on the studied traits. Except for the absolute growth rate of maize plants, where the cultivar 5018 gave the recipient 50 mg. L^{-1} potassium sulfate, the highest average plant height was 139.49 cm, while the cultivar Suroor which was not treated with potassium sulfate, gave the lowest mean of 114.48 cm for the trait (Table 2). The cultivar was also given to the recipient, Sorour, 50 mg. L^{-1} has the highest average number of leaves, reaching 12.52 leaves. $Plant^{-1}$. While the cultivar 5018, which was not treated with potassium sulfate, gave the lowest rate of 11.01 leaves. $plant^{-1}$ (Table 3), cultivar 5018 gave the recipient 50 mg. L^{-1} Potassium sulfate has the highest average leaf area of 210 cm^2. While the cultivar Suroor, which was not treated with potassium sulfate, gave the lowest rate for this trait amounted to 140 cm^2 (Table 4). Whereas, cultivar 5018 gave the recipient 50 mg. L^{-1} potassium sulfate had the highest average stem diameter, which was 22.67 mm. Whereas the cultivar Suroor, which was not treated with potassium sulfate, gave the lowest rate for the same trait, which was 18.24 mm (Table 6). The cultivar gave the recipient Sorour, 50 mg. L^{-1} Potassium sulfate had the highest absolute growth rate for the plant, reaching 0.22 g. day^{-1}. While cultivar 5018, which was not treated with potassium sulfate, gave the lowest rate for the same trait, which amounted to 0.15 g. day^{-1} (Table 7). As for the effect of the interaction between maize cultivars and potassium sulfate concentrations, there was no significant effect on the relative growth rate (Table 8). We can conclude from the aforementioned results that yellow maize cultivars differ among themselves in their response to spraying with potassium sulfate, depending on their genotype. This is consistent with the results of [12] in their study of maize plant, that the genetic makeup of the cultivar plays an essential and effective role in its response to spraying with potassium sulfate.

Furthermore, the bilateral interactions between the concentrations of potassium sulfate and tocopherol showed that there were significant differences in their effect on the traits under study, except for the relative growth rate, on which the above concentrations did not have a significant. The treatment was given at a concentration of 50 mg. L^{-1} potassium sulfate and a concentration of 100 mg. L^{-1} tocopherol has the highest average trait: plant height (Table 2), number of leaves. $plant^{-1}$ (Table 3), Flag leaf area (Table 4), shoot dry weight (Table 5), stem diameter (Table 6), absolute growth (Table 7) reached: 136.81 cm, 13.04 leaves. $Plant^{-1}$, 220 cm^2, 22.82 g. $Plant^{-1}$, 24.68 mm, 0.22 g. day^{-1} respectively. Whereas the treatment was given at a concentration of 0 mg. L^{-1} potassium sulfate and 0 mg. L^{-1} tocopherol (control treatment), the lowest average of the above-mentioned characteristics was: 119.59 cm, 10.44 leaves. $Plant^{-1}$, 150 cm^2, 16.86 g. $Plant^{-1}$, 16.54 mm, 0.15 g. day^{-1} respectively.

These results agreed with what was reached by [25] that spraying with tocopherol for broad bean plants led to a significant increase in all growth characteristics such as stem length, number of leaves, leaf surface area, number of branches, fresh weight and dry weight compared to plants that were sprayed with natural water and that were Fertilize it fairly with potassium sulfate.

As for the triple interaction between the factors of the study, it was also significant in these traits, except for the average number of leaves. Plant-1 and the relative growth rate (g. g^{-1} dry weight. day^{-1}) as it did not have a significant effect on these two traits (Table 3) and (Table 8). As the cultivars were given at a concentration of 50 mg. L^{-1} potassium sulfate and a concentration of 100 mg. L^{-1} tocopherol has the highest mean for traits (plant height, flag leaf area, shoot dry weight, stem diameter, absolute plant growth). The cultivar 5018 gave the highest average plant height of 141.77 cm (Table 2) and the cultivar Sorour gave the highest mean leaf area of 0.022 m^2 (Table 4). The cultivar Sorour gave the highest average dry weight of the shoot, which was 23.98 g. $plant^{-1}$ (Table 5). The cultivar Sorour also gave the highest rate of stem diameter amounting to 25.55 mm (Table 6). The cultivar Sorour gave the highest average absolute plant growth of 0.23 g. day^{-1} (Table 7). On the other hand, the triple interaction between cultivars gave a concentration of 0 mg. L^{-1} potassium sulfate and the concentration is 0 mg. L^{-1} Tocopherol has the lowest average of the above traits, where the cultivar Sorour gave the lowest average plant height of 106.78 cm (Table 2) and the cultivar 5018 gave the lowest mean leaf area of 120 cm^2 (Table 4) and the cultivar 5018 gave the lowest average dry weight of the rootstock amounted to 15.22 grams. $Plant^{-1}$ (Table 5). The cultivar Sorour gave the lowest rate of stem diameter amounting to 15.62 mm (Table 6), while cultivar 5018 gave the lowest absolute growth rate of the plant amounting to 0.13 g. $Plant^{-1}$ (Table 7).

We conclude that foliar fertilization with potassium sulfate at a concentration of 50 mg. $L^{-}1$ has a significant effect on all studied traits compared with other concentrations. The spray concentration is 100 mg. L^{-1} of tocopherol was significantly better in its effect on the characteristics under study compared with other concentrations.

The two-way interaction between the study factors was significant in all studied traits except for relative growth and absolute growth, Also, the two-way interaction between the cultivars and the concentrations of tocopherols and between potassium sulfate and tocopherols was also significant. The triple interaction between the study factors was significant for all studied traits except for the average number of leaves.

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