Effect of Ethephon and Planting Distances on Growth and Yield of Three Sorghum Cultivars

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Abstract

A field experiment was conducted during the spring season of the year (2024) in an agricultural land in the Abu Luka area - Al-Musayyab District - at latitude (44) and longitude (32), which is about 40 km away from Babylon province, with the aim of knowing the response of three sorghum cultivars to planting distances and spraying ethephon on some growth and yield traits of sorghum. The experiment was implemented according to a complete randomized block design with split-plot arrangement and three replicates using three factors and three replicates. The main plots included the cultivars (Buhouth 70, Inqath and Rabeh), while sub plots included planting distances (20, 30, 40) cm, while the sub-plots included ethephon concentrations (0, 5 and 10 mg L^{-1}). The results showed a significant difference between the cultivars, as the Inqath cultivar was excelled in plant height, reaching 108.78 cm, the number of leaves reaching 9.23 (leaf-$plant^{-1}$), the chlorophyll content in the leaves reaching 51.58 mg L^{-1}, the number of grains in the head reaching 1571.4 grains $head^{-1}$, the weight of 1000 grains reaching 30.35 g, and the grain yield reaching 1.92 mega grams. It was also noted that there was a significant effect of planting distances, as the planting distance of 40 cm gave the highest average for plant height traits reaching 109.79 cm, the number of leaves reaching 9.20 leaf $plant^{-1}$, the chlorophyll content in the leaves reaching 50.06 mg L^{-1}, the number of grains in the head reaching 1506.3 grain $head^{-1}$, the weight of 1000 grains reaching 30.04 g, and the yield of the grains reached 1.82 Mg, and significant differences were also observed when spraying ethephon at different concentrations, as the concentration of 10 mg L^{-1} gave the highest average in plant height characteristics, reaching 107.52 cm, the number of leaves per plant reaching 8.95 leaf $plant^{-1}$, the chlorophyll content in the leaves reached 48.04 mg L^{-1}, the number of grains per head reached 1470.3 grain $head^{-1}$, the weight of 1000 grains reached 29.55 g, and the grain yield reached 1.77 Mg. A significant effect was also obtained for the double and triple interaction between ethephon and planting distances and cultivars.

Keywords: *Sorghum bicolor* L., Ethephon, planting distances, plant yield, cultivars.

1-Introduction:

Sorghum (*Sorghum bicolor* L. Moench) belongs to Poaceae family and ranks fifth among grain crops in the world in terms of importance, cultivated area and production after wheat, rice, barley and corn (Mufumbo et al., 2016), and its cultivation is widespread in semi-arid regions of tropical regions (FAO, 2021) where the global area cultivated with sorghum reached 45.870 million hectares, most of which are located in India, Sudan and China, while the total global production reached 64.538 million metric tons with a productivity rate of 520 mega grams. In Iraq, the cultivated area reached about 11.29 hectares with a yield average of 475.6 kg/acre and a productivity of 1615.8 tons (Ministry of Agriculture, 2018). Sorghum grains are used in human and animal nutrition. In poor countries, they are used as human food when mixed with wheat flour at a rate of 50%. In developed countries, such as the United States of America, about 90% of its grains are used in human food industries, such as starch and its

derivatives, due to their high nutritional components, as the percentage of protein in them is estimated at about 10-12%, fats 3%, and carbohydrates 70%. In addition, these grains are a source of vitamin B (Rana et al., 2013). In addition, they are used as a basic material in concentrated poultry feed due to the high percentage of protein in them, which reaches 12% (Al-Beiruty et al., 2022). Their importance in Iraq lies in their tolerance to harsh conditions such as drought, salinity, and high temperatures, especially in the southern region (El.Fahdawi et al., 2020). Interest in this crop began in Iraq in 1998 through the sorghum development project of the General Authority for Agricultural Research / Ministry of Agriculture (Ghaseme et al., 2016). Sorghum is described as an annual crop with good fodder productivity and quality (Atiya et al., 2001). Sorghum is also considered one of the crops with the ability to grow and branch after mowing and maintain its good quality, which provides a greater number of mowings during the summer season (Teutsuch, 2006). Interest has begun in using plant growth regulators, including ethephon, which has become an essential part, as it acts as a stimulating factor when sprayed on the plant, which contributes to accelerating the maturation process and shortening the life cycle, which is very important in areas suffering from water shortages. Ethephon encourages better distribution of nutrients within the plant, which enhances growth and improves productivity. For example, a study showed that the use of ethephon contributed to reducing lodging in plants, which in turn leads to an increase in the amount of grains produced (Dhuha and Zulfa, 2023). The spacing between agricultural lines plays an important role in improving sorghum productivity. Determining the optimal distances between agricultural lines contributes to improving the efficiency of using light, water, and nutrients, as the plant competes less with neighbors for nutrients. This appropriate spacing contributes to improving vegetative growth and increasing the grain yield, which leads to raising the overall productivity efficiency (Meena et al., 2022). Interest has begun in searching for suitable agricultural cultivars that have another role in improving productivity. Cultivars differ in their ability to withstand water and heat stress, and some cultivars have genetic capabilities that allow them to adapt to harsh environmental conditions. Research has shown that there is a strong interaction between different cultivars and plant growth regulators such as ethephon, which increases productivity under different environmental conditions. A study indicated that cultivars with stronger and longer stems benefit more from spraying ethephon. This leads to increased grain production in dry environments (Reddy and Pitha, 2024).

Study objectives: This study aims to:

1. Determine the best concentration of ethephon that enhances vegetative growth and gives the best yield.
2. Determine the best planting distance between rows.
3. Determine the best cultivar that gives the best productivity.
4. Determine the best dual and triple interaction between factors (ethephon, planting distances, cultivars).

Materials and methods

2-1 Experiment location

A field experiment was conducted during the spring season of year (2024) in an agricultural land in the Abu Luka area - Al-Musayyab district - at latitude (44) and longitude (32) which is about 40 km away from Babil Governorate with the aim of knowing the

response of three cultivars of sorghum (Buhouth 70, Inqath and Rabeh) to planting distances (20, 30 and 40) cm and spraying Ethephon at a concentration of (0, 5 and 10 mg L^{-1}) on the growth and yield of sorghum.

2-2 Experiment factors

The first factor: Three cultivars of sorghum, which are (Buhouth 70, Inqath and Rabeh) and were given the following symbols (V1, V2 and V3) in sequence. The second factor: Three planting distances between the lines, which are (20, 30 and 40 cm), and were given the symbols (D1, D2 and D3) in sequence.

The third factor: spraying ethephon at three concentrations, which are (0, 5 and 10) mg L^{-1}, and the symbols (E1, E2 and E3) were given in sequence.

3-2 Soil analysis

Random samples were taken from different places of the experimental soil from the layer

(0.30) cm and from different locations. Then, all the samples were mixed and the composite sample was extracted and analyzed in the laboratory of the Soil Department / Al-Musayyab Technical Institute

Table (1) Some chemical and physical characteristics of the field soil before planting

Traits	Spring season	Units
Electrical conductivity (Ece)	7.9	$Ds.m^{-1}$
Soil pH	7.20	-------
Available nitrogen	11.29	$mg.kg^{-1}$
Available phosphorus	13.35	
Available potassium	123.5	
Clay	48	%
Sand	32	
Silt	20	
Organic matter	1.68	%
Soil texture	Clay loamy	---------

4-2 Experimental design

The experiment was implemented according to the design of complete randomized sectors with a split-plot arrangement and three replicates using three factors and three replicates. The main plots included the cultivars, while the secondary plots included the planting distances, while the sub-plots included the concentrations of ethephon. Each replicate contained (27) experimental units. The total number of experimental units in the experiment was (81) experimental units.

5-2 Field operations

Plowing, smoothing and leveling operations were carried out and the land was divided according to the design used. The area of the experimental unit was (9 m^2), and each replicate contained (27) experimental units. The total number of experimental units was (81) experimental units. Sorghum grains, which were obtained from the Agricultural Research Department - Baghdad, were planted manually on 3/21/2024 for the spring season in holes at a rate of three seeds per hole, then they were thinned to only two plants in each hole after twenty days of planting. After that, the thinning process was carried out to one plant a week after the first thinning (Muhammad, 2017). The experimental land was fertilized at a rate of (320 kg ha^{-1}) in the form of urea (46% N) and at a rate of 200 kg ha^{-1} (P_2O_4) in the form of triple superphosphate (p% 21) and at an average of (100 kg ha^{-1}) (K_2SO_4) in the form of potassium sulfate (K% 41.5) (Ali et al., 2014), nitrogen fertilizer was added in four batches in the following stages (emergence, branching, elongation, lining), while the amount of phosphorus and potassium were all added.

"During planting, the granular diazinon pesticide (10% active ingredient) was used as a fertilization to control the corn stalk borer insect in two batches, the first in the 4-leaf stage as a preventive control at a rate of 6 kg ha^{-1}, and the second after 15 days from the first control (Ministry of Agriculture 2002). The field soil was watered as needed during the two growing seasons. Weeding was carried out whenever necessary to eliminate weeds. The heads were covered after flowering before grain formation to avoid bird damage. The ethephon solution was prepared by dissolving (80 mg) of ethephon in 16 liters of water to obtain a concentration of (5 mg L^{-1}), and dissolving (160 mg) of ethephon in 16 liters of water to obtain a concentration of (10 mg L^{-1}), respectively. The spraying process was carried out in two stages: the first stage was forty days after planting, and the second stage was fifteen days after the first spraying, spraying the leaves and the vegetative group. The spraying process was carried out using a backpack sprayer (capacity 16 liters), taking into account the spraying times in the early morning to avoid high temperatures. The harvest was also carried out on 7/15/2024.

6-2 Studied traits

1-6-2 Vegetative growth traits of sorghum crop

1-1-6-2 Plant height (cm)

The height of ten plants taken randomly for each experimental unit was measured after flowering was complete from the soil surface to the end of the inflorescence node.

2-1-6-2 Chlorophyll content

Chlorophyll was measured in the field using the Chlorophyl-metespAD502 chlorophyll measuring device at 75% flowering and as an average of four leaves from one plant and for ten plants taken randomly the two middle lines (Francis et al., 2014).

3-1-6-2 Number of leaves per plant (leaf $plant^{-1}$)

The number of leaves for the crop was calculated as an average for the ten plants at the 75% flowering stage.

4-1-6-2 Leaf area (cm^2)

The leaf area was calculated as an average for ten plants from the two middle lines of the experimental unit when reaching the 75% flowering stage according to the following equation (Liang et al., 1973).

$$LA=L*W*0.75$$

Where LA=leaf area (cm^2)
L=leaf length (cm)
W=leaf width (cm)
0.75=constant

2-6-2 Yield characteristics and components

1-2-6-2 Number of grains in the head (grain $head^{-1}$)

The number of grains was calculated for each experimental unit and for ten plants taken from the two middle lines and the results were divided by ten to extract the average number of grains in the head.

2-2-6-2 Weight of 1000 grains (g)

1000 grains were taken randomly from the plants in which the number of grains in the heads was calculated and weighed with a sensitive electronic balance after being counted manually (House, 1985).

3-2-6-2 Grain yield (Mg)

The harvest of ten plants for each experimental unit was estimated and the average yield was extracted and multiplied by the plant density (66.666 plants ha-1), and the data were converted to Mg.

4-2-6-2 Statistical analysis

The data of the studied traits were collected and statistically analyzed according to the design used by the statistical program (Genstat), the averages of the coefficients were compared using the least significant difference (LSD) at the level (0.05) (Al-Rawi and Khalaf Allah, 1990).

Results and discussion:

1- Plant height (cm)

The results of Table 2 indicate the presence of significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 2 that the concentrations of ethephon have a significant effect on the plant height trait (cm), as the concentration of 10 mg L^{-1} gave the highest average of 107.52 cm, while control treatment gave the lowest average of 104.97. This is due to the fact that ethephon works to protect the photosynthesis process and has an important role in the metabolism of carbohydrates and amino acids. It also participates with some plant growth regulators, including gibberellin, auxin and cytokinin, which in turn lead to an increase in plant height. These results are consistent with (Sarhan, 2021), who indicated that increasing the concentration of ethephon contributed to an increase in plant height. The results of the table also show that planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait of 109.79 cm, while the distance of 20 cm gave the lowest average of 102.76 cm.

The table also shows significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average of 108.78 cm, while the Buhouth 70 cultivar gave the lowest average of 103.47 cm. The reason may be attributed to the differences in the genetic nature between the cultivars that determine the length and number of internodes, and thus differences appear in the height of the plant. As for the effect of the interaction of ethephon with planting distances, it was significant, as the treatment of high concentration of ethephon 10 mg L^{1} and planting distance of 40 cm gave the highest average of 111.42 cm, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 101.52.

Table (2) The effect of ethephon, planting distances, cultivars and their interaction on plant height (cm) for the spring season.

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V3	
ET(0)	D(20)	99.58	103.83	101.59	101.52
	D(30)	102.65	107.66	105.61	105.30
	D(40)	104.97	110.68	108.63	108.09
ET(5)	D(20)	100.66	105.59	102.64	102.96
	D(30)	103.59	108.41	106.41	106.14
	D(40)	105.98	112.92	110.63	109.84
ET(10)	D(20)	101.41	106.33	103.69	103.81
	D(30)	104.77	109.71	107.49	107.32
	D(40)	107.60	114.38	112.28	111.42
L.S.D 0.05		**0.27**			**0.16**

Ethephon

Ethephon × cultivars	ET(0)	102.40	107.24	105.27	104.97
	ET(5)	103.41	108.97	106.56	106.32
	ET(10)	104.59	110.14	107.82	107.52
L.S.D 0.05		**0.15**			**0.08**

Planting distances

Planting distances	D(20)	100.55	105.10	102.64	102.76

× cultivars	D(30)	103.67	108.59	106.50	106.25
	D(40)	106.18	112.66	110.51	109.79
L.S.D 0.05			**0.21**		**0.13**
average cultivars		103.47	108.78	106.55	
L.S.D 0.05			**0.13**		

A significant interaction was also observed between planting distances and cultivars, the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 112.66 cm, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 100.55 cm. The results indicated a bi- interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for Inqath cultivar excelled in giving the highest average of 110.14 cm, while control treatment for the Buhouth 70 cultivar gave the lowest average of 102.40 cm. The results also indicated triple interaction between factors, the treatment of ethephon concentration of 10 mg L^{-1} and planting distance of 40 cm and Inqath cultivar excelled in giving the highest average of 114.38 cm, while control treatment and planting distance of 20 cm and the Buhouth 70 cultivar gave the lowest average of 99.58 cm.

2- Chlorophyll content in leaves (mg L^{-1})

The results of Table 3 indicate that there are significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 3 that the concentrations of ethephon have a significant effect on the trait of chlorophyll content in leaves, as the concentration of 10 mg L^{-1} gave the highest average of 48.04 mg L^{-1}, while control treatment gave the lowest average of 44.59 mg L^{-1}. The reason may be attributed to the positive role of ethephon in protecting chlorophyll and delaying its loss. This excelled is positively reflected in the specific density of the leaves and the duration of the leaf area. These results are consistent with what was reached by (Al-Hiti, 2021).

The results of the Table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait, which amounted to 50.06 mg L^{-1}, while the distance of 20 cm gave the lowest average, which amounted to 42.36 mg L^{-1}. The table also shows significant differences between the cultivars, where the Inqath cultivar excelled in giving the highest average, which amounted to 51.58 mg L^{-1}, while the Buhouth 70 cultivar gave the lowest average, which amounted to 38.59 mg L^{-1}. Perhaps the reason is due to the genetic nature of the cultivars and the differences in the external appearance of the plant and the angle of inclination of the leaf. These results are consistent with what was reached by EL-Saadony (2021), who indicated the variation of cultivars in the trait of chlorophyll content in the leaves.

Table (3) Effect of ethephon, planting distances, cultivars and their interaction on chlorophyll content in leaves (mg L^{-1}) for the spring season

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	35.22	45.47	42.24	40.98
	D(30)	37.43	49.74	46.82	44.66
	D(40)	39.86	53.75	50.74	48.12
ET(5)	D(20)	36.43	46.62	43.58	42.21

	D(30)	38.31	51.80	48.61	46.24
	D(40)	40.56	56.02	52.99	49.85
ET(10)	D(20)	37.32	48.50	45.82	43.88
	D(30)	39.72	53.87	50.54	48.04
	D(40)	42.43	58.47	55.70	52.20
L.S.D0.05		**0.28**			**0.16**

Ethephon

Ethephon × cultivars	ET(0)	37.50	49.65	46.60	44.59
	ET(5)	38.43	51.48	48.39	46.10
	ET(10)	39.82	53.61	50.69	48.04
L.S.D0.05		**0.16**			**0.10**

Planting distances

Planting distances × cultivars	D(20)	36.32	49.86	43.88	42.36
	D(30)	38.49	51.80	48.66	46.32
	D(40)	40.95	56.08	53.14	50.06
L.S.D0.05		**0.16**			**0.10**
average cultivars		38.59	51.58	48.56	
L.S.D0.05		**0.12**			

The effect of the interaction of ethephon with planting distances was significant, as the treatment of high concentration of ethephon 10 mg L^{-1} and planting distance of 40 cm gave the highest average of 52.20 mg L^{-1}, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 40.98 mg L^{-1}. Also, a significant interaction was observed between planting distances and cultivars, as the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 56.08 mg L^{-1}, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 36.32 mg L^{-1}. The results indicated a bi-interaction between ethephon and the cultivars, the concentration of 10 mg L^{-1} for the Enqaz cultivar was excelled by giving the highest average of 53.61 mg L^{-1}, while control treatment for the Buhouth 70 cultivar gave the lowest average of 37.50 mg L^{-1}.The results also indicated triple interaction between the factors, the treatment of ethephon concentration 10 mg L^{-1} and planting distance of 40 cm and Inqath cultivar was excelled by giving the highest average of 58.47 mg L^{-1}, while control treatment and planting distance of 20 cm and Buhouth 70 cultivar gave the lowest average of 35.22 mg L^{-1}.

3-Number of leaves per plant (leaf plant^{-1})

The results of Table 4 indicate the presence of significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 4 that the concentrations of ethephon have a significant effect on the trait of the number of leaves in the plant, as the concentration of 10 mg L^{-1} gave the highest average of 8.95 leaf plant^{-1}, while control treatment gave the lowest average of 8.54 leaf plant^{-1}. The reason may be due to the role of ethylene in the formation of chlorophyll and carotenoids and accelerating the process of photosynthesis. The results of the table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait of 9.20 leaf plant $^{-1}$, while the distance of 20 cm gave the lowest average of 8.26 leaf plant^{-1}. The table also shows that there are significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average of 9.23 leaf plant $^{-1}$, while the Buhouth 70 cultivar gave the lowest average of 8.26 leaf Plant $^{-1}$. The reason may be due to the genetic nature of the cultivars and the differences in the external appearance of the plant and the number of leaves. These results are consistent with what was reached

by EL-Saadony (2021), who indicated the variation of cultivars in the trait of the number of leaves for the cultivars. As for the effect of the interaction of ethephon with the planting distances, it was significant, as the treatment of high concentration of ethephon 10 mg L^{-1} and planting distance of 40 cm gave the highest average of 9.39 leaf $plant^{-1}$, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 0.08 leaf $plant^{-1}$. A significant interaction was also observed between planting distances and cultivars, the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 9.88 leaf $plant^{-1}$, while the interaction treatment of planting distance 20 cm for the Buhouth 70 cultivar gave the lowest average of 8.02 leaf $plant^{-1}$. The results indicated the presence of a bi- interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for the Inqath cultivar excelled in giving the highest average of 9.41 leaf $plant^{-1}$, while control treatment for the Buhouth 70 cultivar gave the lowest average of 8.15 leaf $plant^{-1}$. The results also indicate triple interaction between the factors. The treatment with ethephon concentration of 10 mg L^{-1}, planting distance of 40 cm, and the Inqath cultivar excelled by giving the highest average of 10.03 leaf $plant^{-1}$, while control treatment with planting distance of 20 cm and the Buhouth 70 cultivar gave the lowest average of 7.80 leaf $plant^{-1}$.

Table (4) Effect of ethephon, planting distances, cultivars, and their interaction on the number of leaves per plant (leaf $plant^{-1}$) for the spring season

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	7.80	8.51	7.93	8.08
	D(30)	8.28	8.90	8.41	8.53
	D(40)	8.37	9.71	8.96	9.01
ET(5)	D(20)	8.04	8.58	8.21	8.27
	D(30)	8.31	9.24	8.92	8.82
	D(40)	8.46	9.91	8.26	9.21
ET(10)	D(20)	8.23	8.64	8.40	8.42
	D(30)	8.37	9.57	9.17	9.04
	D(40)	8.49	10.03	9.64	9.39
L.S.D 0.05		**0.09**			**0.05**

Ethephon

Ethephon × cultivars	ET(0)	8.15	9.04	8.43	8.54
	ET(5)	8.27	9.24	8.80	8.77
	ET(10)	8.36	9.41	9.07	8.95
L.S.D 0.05		**0.04**			**0.03**

Planting distances

Planting distances × cultivars	D(20)	8.02	8.58	8.18	8.26
	D(30)	8.32	9.24	8.84	8.80
	D(40)	8.44	9.88	9.29	9.20
L.S.D 0.05		**0.06**			**0.04**
average cultivars		8.26	9.23	8.77	
L.S.D 0.05		**0.03**			

4- Leaf area (cm^2)

The results of Table 5 indicate that there are significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 5 that the concentrations of ethephon have a significant effect on the trait of leaf area, as the concentration of 10 mg L^{-1} gave the highest

average of 211.2 cm^2, while control treatment gave the lowest average of 177.04 cm^2. The reason may be attributed to the role of ethylene in increasing the process of cell division and expansion, which leads to an increase in their number, which was positively reflected in increasing the number of leaves and thus increasing the leaf area. This was confirmed by the results of Abbas and Sarhan (2021), who indicated that increasing the spraying of ethylene led to an increase in the leaf area. The results of the table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait, which amounted to 235.05 cm^2, while the distance of 20 cm gave the lowest average, which amounted to 159.66 cm^2. The table also shows that there are significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average, which amounted to 248.83 cm^2, while the Buhouth 70 cultivar gave the lowest average, which amounted to 127.76 cm2. The reason may be attributed to the genetic nature of the cultivars that affect gene expression, especially with regard to the Inqath cultivar, which has a high competitive genetic ability for growth requirements, which was positively reflected in increasing the leaf area compared to the rest of the cultivars. The effect of the interaction of ethephon with planting distances was significant, as the treatment of high concentration of ethephon 10 mg L^{-1} and planting distance of 40 cm gave the highest average of 251.39 cm^2, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 142.96 cm^2. A significant interaction was also observed between planting distances and cultivars, the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 301.98 cm^2, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 117.99 cm^2.The results indicated the presence of a bi-interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for the Inqath cultivar excelled in giving the highest average of 267.11 cm^2, while control treatment for the Buhouth 70 cultivar gave the lowest average of 117.99 cm^2. The results also indicate triple interaction between the factors. The treatment with 10 mg L^{-1} ethephon concentration, 40 cm planting distance and Inqath cultivar excelled by giving the highest average of 303.98 cm^2, while control treatment with 20 cm planting distance and Buhouth 70 cultivar gave the lowest average of 116.31 cm^2.

Table (5) Effect of ethephon, planting distances, cultivars and their interaction on leaf area (cm^2) for the spring season

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	116.31	181.68	130.88	142.96
	D(30)	119.28	211.24	191.85	174.12
	D(40)	121.14	299.84	221.11	214.03
ET(5)	D(20)	118.60	199.36	170.75	162.90
	D(30)	119.54	243.93	202.65	188.71
	D(40)	144.77	302.11	272.29	239.72
ET(10)	D(20)	119.05	208.81	191.46	173.11
	D(30)	120.57	288.53	218.34	209.15
	D(40)	170.58	303.98	279.60	251.39
L.S.D0.05		**7.81**			**4.80**
Ethephon					
Ethephon ×	ET(0)	118.91	230.92	181.28	177.04

cultivars	ET(5)	127.64	248.47	215.23	197.11
	ET(10)	136.74	267.11	229.80	211.21
L.S.D0.05			**3.95**		**2.58**
Planting distances					
Planting distances × cultivars	D(20)	117.99	196.62	164.36	159.66
	D(30)	119.80	247.90	204.28	190.66
	D(40)	145.50	301.98	257.67	235.05
L.S.D0.05			**4.96**		**3.38**
average cultivars		127.76	248.83	208.77	
L.S.D0.05			**2.10**		

5- No. of grains in the head (grain head $^{-1}$)

The results of Appendix Table 6 indicate the presence of significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 6 that the concentrations of ethephon have a significant effect on the trait of number of grains in the head for the spring and autumn seasons, as the concentration of 10 mg L^{-1} gave the highest average of 1470.3 head grain^{-1}, while control treatment gave the lowest average of 1375.4. The reason for the increase in the number of grains may be due to the positive role of ethephon in improving the physiological and vegetative growth traits, including leaf area and increasing the chlorophyll content of the leaves, thus increasing the transfer of manufactured materials that move to the reproductive parts, thus increasing the number of grains.

The results of the Table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait, which amounted to 1506.3 grain head^{-1}, while the distance of 20 cm gave the lowest average, which amounted to 1323.0 grain head^{-1}. The table also shows significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average, which amounted to 1571.4 grain head^{-1}, while the Buhouth 70 cultivar gave the lowest average, which amounted to 1244.7 grain head^{-1}. This may be due to genetic differences, as well as the Inqath cultivar's excelled in the traits of plant height, number of leaves, and leaf area, which contributes to increasing the preparation of flowering sites with growth requirements, which increases fertilization, which leads to an increase in the number of grains. The effect of the interaction of ethephon with planting distances was significant, as the treatment of high concentration of ethephon 10 mg L^{-1} and planting distance of 40 cm gave the highest average of 1536.3 grains head^{-1}, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 1238.6 grain head^{-1}. Also, a significant interaction was observed between planting distances and cultivars, as the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 1622.3 grain head^{-1}, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 1149.3 grains head^{-1}. The results indicated a bi- interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for the Inqath cultivar was excelled by giving the highest average of 1607.2 grain head^{-1}, while control treatment for the Buhouth 70 cultivar gave the lowest average of 1196.0 grain head^{-1}. The results also indicated triple interaction between the factors, the treatment with the concentration of ethephon 10 mg L^{-1} and the planting distance of 40 cm and the Inqath cultivar was excelled by giving the highest average of 1636.0, while control treatment with the planting distance of 20 cm

and the Buhouth 70 cultivar gave the lowest average of 1065.3 grains head^{-1}.

Table (6) Effect of ethephon, planting distances, cultivars and their interaction on the number of grains per head (grain head^{-1}) for the spring season

Ethephon concentrations mg L^{-1}	Planting distances cm	cultivars			Ethephon × Distances
		Bohuoth 7 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	1065.3	1396.7	1253.7	1238.6
	D(30)	1232.3	1588.3	1421.7	1414.1
	D(40)	1290.3	1608.3	1522.3	1473.7
ET(5)	D(20)	1162.0	1481.3	1344.3	1329.2
	D(30)	1248.7	1624.0	1497.7	1456.8
	D(40)	1330.3	1622.7	1573.3	1508.8
ET(10)	D(20)	1220.7	1572.7	1410.0	1401.1
	D(30)	1279.7	1613.0	1527.3	1473.3
	D(40)	1373.0	1636.0	1600.0	1536.3
L.S.D0.05		**21.25**			**12.04**

Ethephon

Ethephon × cultivars					
	ET(0)	1196.0	1531.1	1399.2	1375.4
	ET(5)	1247.0	1576.0	1471.8	1431.6
	ET(10)	1291.1	1607.2	1512.4	1470.3
L.S.D0.05		**13.58**			**6.36**

Planting distances

Planting distances × cultivars					
	D(20)	1149.3	1483.6	1336.0	1323.0
	D(30)	1253.6	1608.4	1482.2	1448.1
	D(40)	1331.2	1622.3	1565.2	1506.3
L.S.D0.05		**15.42**			**8.66**
average cultivars		1244.7	1571.4	1461.1	
L.S.D0.05		**12.54**			

6- Weight of 1000 grains (g)

The results of Table 7 indicate that there are significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 7 that the concentrations of ethephon have a significant effect on the trait of weight of 1000 grains, as the concentration of 10 mg L^{-1} gave the highest average of 29.55 g, while control treatment gave the lowest average of 28.37. The reason may be attributed to the important and vital role of ethephon in activating the vital and physiological processes within the plant, including photosynthesis and the transfer of the products of these processes from the source to the outlet, which are the seeds, and increasing their fullness and thus increasing the weight. The results of the Table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait of 30.04 g, while the distance of 20 cm gave the lowest average of 28.37 g. The table also shows significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average of 30.35 g, while the Buhouth 70 cultivar gave the lowest average of 28.00 g, perhaps due to the excelled of the Enqaz cultivar in vegetative growth characteristics, especially leaf area and the transfer of nutrients from leaves and stems to seeds and increasing their weight. As for the effect of the interaction of ethephon with planting distances, it was significant, as the treatment of high concentration of ethephon 10 mg L^{-1} and planting distance of 40 cm gave the highest average of 30.41 g, while control

treatment of ethephon and planting distance of 20 cm gave the lowest average of 26.88 g. A significant interaction was also observed between planting distances and cultivars, the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 30.83 g, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 25.84 g.

Table (7) The effect of ethephon, planting distances, cultivars and their interaction on the weight of 1000 grains (g) for the spring season.

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	24.45	29.83	26.37	26.88
	D(30)	28.15	29.89	27.63	28.55
	D(40)	29.22	30.52	29.25	29.66
ET(5)	D(20)	25.68	29.97	27.36	27.67
	D(30)	28.76	30.25	28.79	29.27
	D(40)	29.45	30.87	29.85	30.06
ET(10)	D(20)	27.40	30.12	28.33	28.62
	D(30)	29.00	30.57	29.29	29.62
	D(40)	29.87	31.11	30.24	30.41
L.S.D0.05		**0.40**			**0.23**

Ethephon

Ethephon × cultivars	ET(0)	27.27	30.08	27.75	28.37
	ET(5)	27.96	30.36	28.67	29.00
	ET(10)	28.76	30.60	29.28	29.55
L.S.D 0.05		**0.25**			**0.12**

Planting distances

Planting distances × cultivars	D(20)	25.84	29.97	27.35	27.72
	D(30)	28.64	30.24	28.57	29.15
	D(40)	29.52	30.83	29.78	30.04
L.S.D 0.05		**0.29**			**0.17**
average cultivars		28.00	30.35	28.57	
L.S.D 0.05		**0.23**			

The results indicated the presence of a bi-interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for the Inqath cultivar excelled in giving the highest average of 30.60 g, while control treatment for the Buhouth 70 cultivar gave the lowest average of 27.27 g. The results also indicate the presence of triple interaction between the factors, the treatment of ethephon concentration of 5 mg L^{-1} and planting distance of 40 cm and Inqath cultivar excelled in giving the highest average of 30.87 g, while control treatment and planting distance of 20 cm and the Buhouth 70 cultivar gave the lowest average of 24.45 g.

7- Grain yield (Mg)

The results of Table 8 indicate that there are significant differences between the study factors and the interaction between them in this trait. We note from the results of Table 8 that the concentrations of ethephon have a significant effect on the trait of grain yield, as the concentration of 10 mg L^{-1} gave the highest average of 1.77 Mg, while control treatment gave the lowest average of 1.60. This increase in grain yield can be explained by the positive role of ethephon and its excelled in many physiological processes, including leaf area, net photosynthesis rate, and chlorophyll content in the leaves, which was positively reflected in increasing the components of the yield from the number of grains per head as well as the weight of the

grains, which was positively reflected in increasing the total grain yield. These results are consistent with the results obtained by Al-Taweel et al (2020).

The results of the table also show that the planting distances have a significant effect, as the planting distance of 40 cm gave the highest average for this trait, reaching 1.82 Mg, respectively, while the distance of 20 cm gave the lowest average, reaching 1.55 Mg. The table also shows significant differences between the cultivars, as the Inqath cultivar excelled in giving the highest average, reaching 1.92 (Mg), while the Buhouth 70 cultivar gave the lowest average, reaching 1.44 Mg. The reason may be due to the excelled of the Inqath cultivar in the number of grains per head as well as the weight of 1000 grains, which was positively reflected in increasing the yield of the cultivar. The effect of the interaction of ethephon with planting distances was significant, as the treatment of high concentration of ethephon 10 mg L^{1} and planting distance of 40 cm gave the highest average of 1.94 Mg, while control treatment of ethephon and planting distance of 20 cm gave the lowest average of 1.46 Mg. Also, a significant interaction was observed between planting distances and cultivars, as the planting distance of 40 cm and the Inqath cultivar excelled in giving the highest average of 2.01 Mg, while the interaction treatment of planting distance of 20 cm for the Buhouth 70 cultivar gave the lowest average of 1.26 Mg. The results indicated a bi- interaction between ethephon and cultivars, the concentration of 10 mg L^{-1} for the Inqath cultivar was excelled by giving the highest average of 1.98 Mg, while control treatment for the Buhouth 70 cultivar gave the lowest average of 1.34 Mg. The results also indicated triple interaction between the factors, the treatment of ethephon concentration 10 mg L^{-1} and planting distance of 40 cm and Inqath cultivar was excelled by giving the highest average of 2.12 Mg, while control treatment and planting distance of 20 cm and Buhouth 70 cultivar gave the lowest average of 1.16 Mg.

Table (8) Effect of ethephon, planting distances, cultivars and their interaction on grain yield (Mg) for the spring season

Ethephon concentrations mg L^{-1}	Planting distances cm	Cultivars			Ethephon × Distances
		Bohuoth 70 V 1	Inqath V 2	Rabih V 3	
ET(0)	D(20)	1.16	1.76	1.47	1.46
	D(30)	1.38	1.89	1.54	1.60
	D(40)	1.50	1.94	1.77	1.73
ET(5)	D(20)	1.25	1.85	1.59	1.56
	D(30)	1.46	1.95	1.65	1.69
	D(40)	1.61	1.97	1.83	1.80
ET(10)	D(20)	1.38	1.87	1.66	1.64
	D(30)	1.47	1.96	1.74	1.72
	D(40)	1.74	2.12	1.95	1.94
L.S.D0.05		**0.07**			**0.04**

Ethephon

Ethephon × cultivars	ET(0)	1.34	1.87	1.59	1.60
	ET(5)	1.44	1.92	1.69	1.68
	ET(10)	1.53	1.98	1.79	1.77
L.S.D 0.05		**0.04**			**0.02**

Planting distances

Planting distances × cultivars	D(20)	1.26	1.83	1.57	1.55
	D(30)	1.43	1.93	1.67	1.67
	D(40)	1.61	2.01	1.65	1.82
L.S.D 0.05		**0.04**			**0.02**
average cultivars		1.44	1.92	1.69	
L.S.D 0.05		**0.03**			

3- Conclusions

The adaptation of the variety, “Inqath”, to the conditions of the region was achieved by giving it the best yield. The spacing between the rows played a positive role in improving most of the studied traits of the crop by giving a planting distance of 40 cm the highest yield. Increasing the concentration of ethephon had a positive effect in improving the traits of vegetative growth and yield. The variety, “Inqath”, responded to a planting distance of 40 cm and a concentration of ethephon of 10 mg/L. This is due to the role of this treatment within the district of Al-Musayyab in Babil Governorate in improving growth and the best yield.

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