# 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 autumn season of (2024) in an agricultural land in 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 characteristics 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 (Bohuoth 70, Inkath , Rabih), while sub plots included planting distances (20, 30, 40) cm, while the sub-plots included Ethephon concentrations (0, 5, 10) mg L-1. The results showed a significant difference between cultivars, as the cultivar Inkath was excelled in plant height, reaching 109.78 cm, the number of leaves reaching 9.31 (leaf plant-1), the chlorophyll content in the leaves reaching 52.58 (mg L-1), the number of grains in the head reaching 1671.4 grains head-1, the weight of 1000 grains reaching 31.35 g, and the grain yield reaching 2.13 Mg. Also, a significant effect was observed for planting distances, as Planting distance 40 cm gave the highest average for plant height traits reaching 110.82 cm, the number of leaves reaching 9.28 (leaf-1 plant), the chlorophyll content in the leaves reaching 51.06 (mg L-1), the number of grains in the head reaching 1606.3 (grain. head-1), the weight of 1000 grains reaching 31.04 g, and the grain yield reaching 2.04 (Mg), also significant differences were observed when spraying Ethephon with different concentrations, where the concentration of 10 mg L-1 gave the highest average in plant height characteristics of 108.55 cm, the number of leaves . plant was 9.10 (leaf-1 plant), the chlorophyll content in the leaves was 49.04 (mg L-1), the number of grains per head was 1570.3 (grain head-1), the weight of 1000 grains was 30.55 g, and the grain yield was .971 (Mg), and also a significant effect was obtained for the bi and triple interaction between Ethephon and planting distances and cultivars.

**Keywords: Ethephon, planting distances, plant yield, cultivars, plant height**

## 1- Introduction:

Sorghum 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 yellow [15] 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 Mg. 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 [12]. 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

ISSN 2072-3857

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 [16] 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% [19] Their importance in Iraq lies in their tolerance to harsh conditions such as drought, salinity, and high temperatures, especially in the southern region [4] Interest in this crop began in Iraq in 1998 through the sorghum development project of the General Authority for Agricultural Bohuoth / Ministry of Agriculture [5] Sorghum is described as an annual crop with good fodder productivity and quality [5]. 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 [9] 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 [6]. 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 [11]. 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. Bohuoth 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 [17[

Study objectives: This study aims to:

.1Determine the best concentration of ethephon that enhances vegetative growth and gives the best yield.

.2Determine the best planting distance between rows.

.3Determine the best cultivar that gives the best productivity.

.4Determine the best dual and triple interaction between factors (ethephon, planting distances, cultivars.(

Materials and methods

1-2Experiment 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 Provainc with the aim of knowing the

ISSN 2072-3857

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

2-2Experiment factors

The first factor: Three cultivars of sorghum, which are (Buhouth 70, Inqaz, Rabeh) and were given the following symbols (V1, V2, V3) in sequence.

The second factor: Three planting distances between the lines, which are (20, 30, 40) cm and were given the symbols (D1, D2, D3) in sequence.

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

2-3Soil 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 | --------- |

2-4Experimental 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 .

2-5Field 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 m2), and each replicate contained (27) experimental units. The total number of experimental units was (81) experimental units. Sorghum grains,

ISSN 2072-3857

which were obtained from the Agricultural Bohuoth 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 [14]. 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 (P2O4) in the form of triple superphosphate (p% 21) and at an average of (100 kg ha-1) (K2so4) in the form of potassium sulfate (K% 41.5). [2] 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 [13] 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.

2-6studied traits

2-6-1traits of vegetative growth of sorghum crop

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

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

2-6-1-2Chlorophyll content

Chlorophyll was measured in the field using the Chlorophyl-metespAD502 chlorophyll measuring device at 75% flowering and as an average of a quarter of leaves from one plant and for ten plants taken randomly the two middle lines [8[

2-6-1-3Number 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 stage of 75% flowering.

2-6-1-4Leaf area (cm2(

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 [10[

LA=L*W*0.75

Where LA=leaf area (cm2(

L=leaf length (cm(

W=leaf width (cm(

=0.75constant

2-6-2Yield traits and components

2-6-2-1Number of grains in 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 head0

ISSN 2072-3857

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

1000grains 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, [9[

2-6-2-3Grain 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 Mgs.

2-6-2-4Statistical 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) [3[

Results and discussion:

-1Plant 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 108.55 cm, while control treatment gave the lowest average of 105.97. 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 [18] 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 Planting distance 40 cm gave the highest average for this trait of 110.82 cm, while the distance 20 cm gave the lowest average of 103.76 cm.

The table also shows significant differences between the cultivars, as the Inkath cultivar excelled in giving the highest average of 109.78 cm, while the Bohuoth 70 cultivar gave the lowest average of 104.47 cm. The reason may be due 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 40 cm gave the highest average of 112.53 cm, while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 102.52. Also, significant interaction was observed between planting distances and cultivars, Planting distance 40 cm and Inkath cultivar excelled in giving the highest average of 113.66 cm, while the interaction treatment Planting distance 20 cm for Bohuoth 70 cultivar gave the lowest average of 101.55 cm.The results indicated the presence of a bi-interaction between ethephon and cultivars, the concentration of 10 mg L-1 for Inkath cultivar excelled in giving the highest average of 111.14 cm, while control treatment for Bohuoth 70 cultivar gave the lowest average of 103.40 cm. The results also indicate the presence of triple interaction between factors, the treatment Ethephon concentration 10 mg L-1 and Planting distance 40 cm and Inkath cultivar excelled in giving the highest average of 115.38 cm, while control treatment and Planting distance 20 cm

ISSN 2072-3857

and Bohuoth 70 cultivar gave the lowest average of 100.58 cm.

**Table (2) effect of ethephon, planting distances, cultivars and their interaction on plant height (cm) for autumn season**

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 102.52 | 102.59 | 104.38 | 100.58 | D(20) | ET(0) |
| 106.30 | 106.61 | 108.66 | 103.65 | D(30) | |
| 109.10 | 109.63 | 111.68 | 105.97 | D(40) | |
| 103.97 | 103.64 | 106.59 | 101.67 | D(20) | ET(5) |
| 107.14 | 107.42 | 109.41 | 104.59 | D(30) | |
| 110.84 | 111.63 | 113.92 | 106.98 | D(40) | |
| 104.81 | 104.70 | 107.33 | 102.41 | D(20) | ET(10) |
| 108.32 | 108.49 | 110.71 | 105.77 | D(30) | |
| 112.53 | 113.61 | 115.38 | 108.60 | D(40) | |
| **0.19** | **0.32** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 105.97 | 106.28 | 108.24 | 103.40 | ET(0) | Ethephon × cultivars |
| 107.32 | 107.56 | 109.97 | 104.41 | ET(5) | |
| 108.55 | 108.93 | 111.14 | 105.59 | ET(10) | |
| **0.10** | **0.18** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 103.76 | 103.64 | 106.10 | 101.55 | D(20) | Planting distances × cultivars |
| 107.26 | 107.51 | 109.59 | 104.67 | D(30) | |
| 110.82 | 111.62 | 113.66 | 107.18 | D(40) | |
| **0.13** | **0.21** | | | L.S.D0.05 | |
| | 107.59 | 109.78 | 104.47 | average cultivars | |
| | **0.14** | | | L.S.D0.05 | |

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-2Chlorophyll 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 (mg L-1), where the concentration of 10 mg L-1 gave the highest average of 49.04 (mg L-1), while control treatment gave the lowest average of 45.59 (mg L-1). The reason may be due 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 [2].The table results also show that planting distances have a significant effect, as Planting distance 40 cm gave the highest average for this trait, reaching 51.06 (mg L-1), while the distance 20 cm gave the lowest average, reaching 43.36 (mg L-1). The table also shows significant differences between the cultivars, where the Inkath cultivar excelled in giving the highest average, reaching 52.58 (mg L-1), while the Bohuoth 70 cultivar gave the lowest average, reaching 39.59 (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 [7] who indicated the variation of cultivars in the trait of chlorophyll content in leaves. The effect of the interaction of ethephon with planting distances was significant, where the treatment of high concentration of ethephon 10 mg L-1 and Planting distance 40 cm gave the highest average of 53.20 (mg L-1), while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 41.98 (mg L-1). Also, a significant interaction was observed between planting distances and cultivars, Planting distance 40 cm and the Inkath cultivar excelled in giving the highest average of 57.08 (mg L-1), while the interaction treatment of Planting distance 20 cm for the Bohuoth 70 cultivar gave the lowest average of 37.32 (mg L-1). The results indicated a bi-interaction between ethephon and the cultivars, the concentration of 10 mg L-1 for the Inkath cultivar was excelled by giving the highest average of 54.61 (mg L-1), while control treatment for the Bohuoth 70 cultivar gave the lowest average of 38.50 (mg L-1).The results also indicated triple interaction between the factors, the treatment of ethephon concentration 10 mg L-1 and Planting distance 40 cm and Inkath cultivar were excelled by giving the highest average of 59.47 (mg L-1), while control treatment and Planting distance 20 cm and Bohuoth 70 cultivar gave the lowest average of 36.22 (mg L-1.(

ISSN 2072-3857

**Table (3) Effect of ethephon, planting distances, cultivars and their interaction on chlorophyll content in leaves (mg L-1) for autumn season**

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 41.98 | 43.24 | 46.47 | 36.22 | D(20) | ET(0) |
| 45.66 | 47.82 | 50.74 | 38.43 | D(30) | |
| 49.12 | 51.74 | 54.75 | 40.86 | D(40) | |
| 43.21 | 44.58 | 47.62 | 37.43 | D(20) | ET(5) |
| 47.24 | 49.61 | 52.80 | 39.31 | D(30) | |
| 50.85 | 53.99 | 57.02 | 41.56 | D(40) | |
| 44.88 | 46.83 | 49.50 | 38.32 | D(20) | ET(10) |
| 49.05 | 51.54 | 54.87 | 40.74 | D(30) | |
| 53.20 | 56.70 | 59.47 | 43.43 | D(40) | |
| **0.16** | **0.28** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 45.59 | 47.60 | 50.65 | 38.50 | ET(0) | Ethephon × cultivars |
| 47.10 | 49.39 | 52.48 | 39.43 | ET(5) | |
| 49.04 | 51.69 | 54.61 | 40.83 | ET(10) | |
| **0.10** | **0.17** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 43.36 | 44.88 | 47.86 | 37.32 | D(20) | Planting distances × cultivars |
| 47.32 | 49.66 | 52.80 | 39.49 | D(30) | |
| 51.06 | 54.14 | 57.08 | 41.95 | D(40) | |
| **0.10** | **0.17** | | | L.S.D0.05 | |
| | 49.56 | 52.58 | 39.59 | average cultivars | |
| | **0.13** | | | L.S.D0.05 | |

-3Number 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 (leaf-1 plant, as the concentration of 10 mg L-1 gave the highest average of 9.10 (leaf plant-1), while control treatment gave the lowest average of 8.76 (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 Planting distance 40 cm gave the highest average for this trait of 9.28 (leaf plant -1), while the distance of 20 cm gave the lowest average of 8.48 (leaf plant -1). The table also shows that there are significant differences between the cultivars, where the Inkath cultivar excelled in giving the highest average of 9.31 (leaf plant -1), while the Bohuoth 70 cultivar gave the lowest average of 8.47 (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 [7] 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 40 cm gave the highest average of 9.40 (leaf Plant -1), while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 8.31 (leaf Plant -1).Also, a significant interaction was observed between planting distances and cultivars, Planting distance 40 cm and Inkath cultivar excelled in giving the highest average of 9.65 (leaf plant -1), while the interaction treatment Planting distance 20 cm for Bohuoth 70 cultivar gave the lowest average of 8.22 (leaf plant -1). The results indicated a bi-interaction between ethephon and cultivars, the concentration of 10 mg L-1 for Inkath cultivar excelled in giving the highest average of 9.42 (leaf plant -1), while control treatment for Bohuoth 70 cultivar gave the lowest average of 8.35 (plant leaf-1). The results also indicate triple interaction between the factors. The treatment with ethephon concentration of 10 mg L-1, Planting distance 40 cm, and the Inkath cultivar excelled by giving the highest average of 9.58 (leaf plant -1), while control treatment, Planting distance 20 cm, and the Bohuoth 70 cultivar gave the lowest average of 8.00 (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 autumn season**

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 8.31 | 9.19 | 8.75 | 8.00 | D(20) | ET(0) |
| 8.75 | 8.61 | 9.14 | 8.48 | D(30) | |
| 9.22 | 9.17 | 9.92 | 8.58 | D(40) | |
| 8.48 | 8.42 | 8.80 | 8.23 | D(20) | ET(5) |
| 9.04 | 9.14 | 9.45 | 8.52 | D(30) | |

ISSN 2072-3857

| | | | | | |
|---|---|---|---|---|---|
| 9.21 | 9.47 | 9.46 | 8.69 | D(40) | |
| 8.65 | 8.61 | 8.69 | 8.44 | D(20) | ET(10) |
| 9.25 | 9.38 | 9.78 | 8.58 | D(30) | |
| 9.40 | 9.86 | 9.58 | 8.75 | D(40) | |
| **0.17** | **0.28** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 8.76 | 8.66 | 9.27 | 8.35 | ET(0) | Ethephon × cultivars |
| 8.91 | 9.01 | 9.24 | 8.48 | ET(5) | |
| 9.10 | 9.29 | 9.42 | 8.59 | ET(10) | |
| **0.10** | **0.16** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 8.48 | 8.41 | 8.81 | 8.22 | D(20) | Planting distances × cultivars |
| 9.01 | 9.04 | 9.46 | 8.53 | D(30) | |
| 9.28 | 9.50 | 9.65 | 8.67 | D(40) | |
| **0.09** | **0.15** | | | L.S.D0.05 | |
| | 8.98 | 9.31 | 8.47 | average cultivars | |
| | **0.10** | | | L.S.D0.05 | |

-4Leaf area (cm2(

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, where the concentration of 10 mg L-1 gave the highest average of 213.75 cm2, while control treatment gave the lowest average of 179.89 cm2. The reason may be due 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 [1], who indicated that increasing the spraying of ethylene led to an increase in the leaf area. The results of the table also show that planting distances have a significant effect, where Planting distance 40 cm gave the highest average for this trait, reaching 237.50 cm2, while the distance 20 cm gave the lowest average, reaching 162.69 cm2. The table also shows significant differences between the cultivars, as the Inkath cultivar excelled in giving the highest average, reaching 251.88 cm2, while the Bohuoth 70 cultivar gave the lowest average, reaching 128.95 cm2. The reason may be due to the genetic nature of the cultivars that affect gene expression, especially with regard to the Inkath cultivar, which has a high competitive

genetic ability for growth requirements, which was positively reflected in increasing leaf area compared to the rest of the cultivars. The effect of the interaction of ethephon with planting distances was significant, where the treatment of high concentration of ethephon 10 mg L-1 and Planting distance 40 cm gave the highest average of 253.87 cm2, while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 145.85 cm2.A significant interaction was also observed between planting distances and cultivars, Planting distance 40 cm and the Inkath cultivar excelled in giving the highest average of 304.20 cm2, while the interaction treatment of Planting distance 20 cm for the Bohuoth 70 cultivar gave the lowest average of 118.99 cm2.The results indicated the presence of a bi-interaction between ethephon and cultivars, as the concentration of 10 mg L-1 for the Inkath cultivar excelled in giving the highest average of 269.81 cm2, while control treatment for the Bohuoth 70 cultivar gave the lowest average of 119.91 cm2.The results also indicate triple interaction between the factors. The treatment with ethephon concentration of 10 mg L-1, Planting distance 40 cm, and the Inkath cultivar excelled by giving the highest average of 306.43 cm2, while control treatment, Planting distance 20 cm, and the Bohuoth 70 cultivar gave the lowest average of 117.33 cm2 .

**Table (5) Effect of ethephon, planting distances, cultivars, and their interaction on leaf area (cm2) for autumn season**

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 145.85 | 136.22 | 184.01 | 117.31 | D(20) | ET(0) |
| 177.35 | 196.85 | 214.91 | 120.28 | D(30) | |
| 216.48 | 223.78 | 303.51 | 122.14 | D(40) | |
| 166.35 | 177.42 | 202.02 | 119.60 | D(20) | ET(5) |
| 191.71 | 206.31 | 248.27 | 120.54 | D(30) | |
| 242.17 | 275.96 | 304.78 | 145.77 | D(40) | |
| 175.88 | 196.46 | 211.15 | 120.05 | D(20) | ET(10) |
| 211.49 | 221.01 | 291.86 | 121.59 | D(30) | |
| 253.87 | 281.93 | 306.43 | 173.25 | D(40) | |
| **4.68** | **7.51** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 179.89 | 185.61 | 234.14 | 119.91 | ET(0) | Ethephon × cultivars |
| 200.07 | 219.90 | 251.69 | 128.64 | ET(5) | |

ISSN 2072-3857

| | | | | | |
|---|---|---|---|---|---|
| 213.75 | 233.13 | 269.81 | 138.30 | ET(10) | |
| **2.39** | **3.62** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 162.69 | 170.03 | 199.06 | 118.99 | D(20) | Planting distances × cultivars |
| 193.51 | 208.06 | 251.68 | 120.80 | D(30) | |
| 237.50 | 260.56 | 304.90 | 147.05 | D(40) | |
| **3.50** | **5.07** | | | L.S.D0.05 | |
| | 212.88 | 251.88 | 128.95 | average cultivars | |
| | **1.84** | | | L.S.D0.05 | |

-5Number of grains in the head (head grain-1( shows significant differences between the cultivars, as the Inkath cultivar excelled in giving the highest average, reaching 1671.4 grains.head-1, while the Bohuoth 70 cultivar gave the lowest average, reaching 1344.7 grains.head-1. This may be due to genetic differences, as well as the Inkath cultivar's excelledity in the traits of plant height, number of leaves, and leaf area, which contributes to increasing the preparation of flowering sites with growth requirements, increasing 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 L1 and Planting distance 40 cm gave the highest average of 1636.3 grains.head-1, while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 1338.6 grains.head-1. Also, a significant interaction was observed between planting distances and cultivars, as Planting distance 40 cm and the Inkath cultivar excelled in giving the highest average of 1722.3 grains.head-1, while the interaction treatment of Planting distance 20

The results of Table 6 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 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, where the concentration of 10 mg L-1 gave the highest average of 1570.3 (grain head -1), while control treatment gave the lowest average of 1475.4. 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 Planting distance 40 cm gave the highest average for this trait, reaching 1606.3 grains.head-1, while the distance 20 cm gave the lowest average, reaching 1423.0 grains.head-1. The table also

cm for the Bohuoth 70 cultivar gave the lowest average of 1249.3 grains head-1. The results indicated a bi-interaction between ethephon and cultivars, the concentration of 10 mg L-1 for the Inkath cultivar was excelled by giving the highest average of 1707.2 grains head-1, while control treatment for the Bohuoth 70 cultivar gave the lowest average of 1296.0 grains head-1.The results also indicated triple interaction between the factors, the treatment of ethephon concentration 10 mg L-1 and Planting distance 40 cm and Inkath cultivar was excelled by giving the highest average of 1736.0, while control treatment and Planting distance 20 cm and Bohuoth 70 cultivar gave the lowest average of 1165.3 grains head-1.

**Table (6) Effect of ethephon, planting distances, cultivars and their interaction on the number of grains per head (grains head-1) for autumn season**

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 1338.6 | 1353.7 | 1496.7 | 1165.3 | D(20) | ET(0) |
| 1514.1 | 1521.7 | 1688.3 | 13.32.3 | D(30) | |
| 1573.7 | 1622.3 | 1708.3 | 1390.3 | D(40) | |
| 1429.2 | 1444.3 | 1581.3 | 1262.0 | D(20) | ET(5) |
| 1556.8 | 1597.7 | 1724.0 | 1348.7 | D(30) | |
| 1608.8 | 1673.3 | 1722.7 | 1430.3 | D(40) | |
| 1501.1 | 1510.0 | 1672.7 | 1320.7 | D(20) | ET(10) |
| 1573.3 | 1627.3 | 1713.0 | 1379.7 | D(30) | |
| 1636.3 | 1700.0 | 1736.0 | 1473.0 | D(40) | |
| **12.04** | **21.25** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 1475.4 | 1499.2 | 1631.1 | 1296.0 | ET(0) | Ethephon × cultivars |
| 1531.6 | 1571.8 | 1676.0 | 1347.0 | ET(5) | |
| 1570.3 | 1612.4 | 1707.2 | 1391.1 | ET(10) | |
| **6.36** | **13.58** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 1423.0 | 1436.0 | 1583.6 | 1249.3 | D(20) | Planting distances × |
| 1548.1 | 1582.2 | 1708.4 | 1353.6 | D(30) | |
| 1606.3 | 1665.2 | 1722.3 | 1431.2 | D(40) | |

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| | | | | | |
|---|---|---|---|---|---|
| | | | | | cultivars |
| **8.66** | **15.42** | | | L.S.D0.05 | |
| | 1561.1 | 1671.4 | 1344.7 | average cultivars | |

| | |
|---|---|
| **12.54** | L.S.D0.05 |

-6Weight 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 30.55 g, while control treatment gave the lowest average of 29.37. The reason may be due 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 Planting distance 40 cm gave the highest average for this trait of 31.04 g, while the distance 20 cm gave the lowest average of 28.72 g.The table also shows significant differences between the cultivars, as the Inkath cultivar excelled in giving the highest average of 31.35 g, while the Bohuoth 70 cultivar gave the lowest average of 29.00 g, perhaps due to the excelledity of the Inkath 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 L1 and Planting distance 40 cm gave the highest average of 31.41 g, while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 27.88 g. Also, significant interaction was observed between planting distances and cultivars, Planting distance 40 cm and Inkath cultivar excelled in giving the highest average of 31.83 gm, while the interaction treatment Planting distance 20 cm for Bohuoth 70 cultivar gave the lowest average of 26.84 g.The results indicated the presence of a bi-interaction between ethephon and cultivars, the concentration of 10 mg L-1 for Inkath cultivar excelled in giving the highest average of 31.60 g , while control treatment for Bohuoth 70 cultivar gave the lowest average of 28.27 gm.The results also indicate the presence of triple interaction between factors, the treatment Ethephon concentration 5 mg L-1 and Planting distance 40 cm and Inkath cultivar excelled in giving the highest average of 32.11 g , while control treatment, Planting distance 20 cm and Bohuoth 70 cultivar gave the lowest average of 25.45 gm.

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

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 27.88 | 27.37 | 30.83 | 25.45 | D(20) | ET(0) |
| 29.55 | 28.63 | 30.89 | 29.15 | D(30) | |
| 30.66 | 30.25 | 31.52 | 30.22 | D(40) | |
| 28.67 | 28.36 | 30.97 | 26.68 | D(20) | ET(5) |
| 30.27 | 29.79 | 31.25 | 29.76 | D(30) | |
| 31.06 | 30.85 | 31.87 | 30.45 | D(40) | |
| 29.62 | 29.33 | 31.12 | 28.40 | D(20) | ET(10) |
| 30.62 | 30.29 | 31.57 | 30.01 | D(30) | |
| 31.41 | 31.24 | 32.11 | 30.87 | D(40) | |
| **0.23** | **0.40** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 29.37 | 28.75 | 31.08 | 28.27 | ET(0) | Ethephon × cultivars |
| 30.00 | 29.67 | 31.36 | 28.96 | ET(5) | |
| 30.55 | 30.28 | 31.60 | 29.76 | ET(10) | |
| **0.12** | **0.25** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 28.72 | 28.35 | 30.97 | 26.84 | D(20) | Planting distances × cultivars |
| 30.15 | 29.57 | 31.24 | 29.64 | D(30) | |
| 31.04 | 30.78 | 31.83 | 30.52 | D(40) | |
| **017** | **0.29** | | | L.S.D0.05 | |
| | 29.57 | 31.35 | 29.00 | average cultivars | |
| | **0.23** | | | L.S.D0.05 | |

-7Grain yield (Mg(

The results of Table 8 indicate that there are significant differences between the study

ISSN 2072-3857

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 (Mg), as the concentration of 10 mg L-1 gave the highest average of 1.97 (Mg), while control treatment gave the lowest average of 1.81. This increase in grain yield can be explained by the positive role of ethephon and its excelledity in many physiological processes, including leaf area, net photosynthesis rate, and chlorophyll content in 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. The table results also show that planting distances have a significant effect, as Planting distance 40 cm gave the highest average for this trait, reaching 2.04 (Mgs), respectively, while the distance 20 cm gave the lowest average, reaching 1.75 Mgs. The table also shows significant differences between the cultivars, where the Inkath cultivar excelled in giving the highest average, reaching 2.13 (Mgs), while the Bohuoth 70 cultivar gave the lowest average, reaching 1.64 Mgs. The reason may be due to the Inkath cultivar's excelledity in the number of grains per head as well as the weight of 1000 grains, which was positively reflected in increasing the cultivar's yield. The effect of the interaction of ethephon with planting distances was significant, where the treatment of high concentration of ethephon 10 mg.L1 and Planting distance 40 cm gave the highest average of 2.14 (Mgs), while control treatment of ethephon and Planting distance 20 cm gave the lowest average of 1.66 Mgs. Also, a significant interaction was observed between planting distances and cultivars, as Planting distance 40 cm and the Inkath cultivar excelled in giving the highest average of 2.21 (Mgs), while the interaction treatment of Planting distance 20 cm for the Bohuoth 70 cultivar gave the lowest average of 1.46 Mgs. The results indicated a bi-interaction between ethephon and cultivars, the concentration of 10 mg L-1 for the Inkath cultivar was excelled by giving the highest average of 2.18 (Mgs), while control treatment for the Bohuoth 70 cultivar gave the lowest average of 1.54 Mgs.The results also indicated triple interaction between the factors, the treatment of ethephon concentration 10 mg L-1 and Planting distance 40 cm and Inkath cultivar were excelled by giving the highest average of 2.32 (Mgs), while control treatment and Planting distance 20 cm and Bohuoth 70 cultivar gave the lowest average of 1.36 Mg.

ISSN 2072-3857

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

| Ethephon × Distances | cultivars | | | Planting distances cm | Ethephon concentrations mg L-1 |
|---|---|---|---|---|---|
| | RabihV 3 | Inkath V 2 | Bohuoth 70 V 1 | | |
| 1.66 | 1.67 | 1.96 | 1.36 | D(20) | ET(0) |
| 1.82 | 1.74 | 2.13 | 1.58 | D(30) | |
| 1.95 | 2.00 | 2.14 | 1.70 | D(40) | |
| 1.76 | 1.79 | 2.05 | 1.45 | D(20) | ET(5) |
| 1.89 | 1.85 | 2.15 | 1.66 | D(30) | |
| 2.04 | 2.13 | 2.17 | 1.81 | D(40) | |
| 1.84 | 1.86 | 2,07 | 1.58 | D(20) | ET(10) |
| 1.92 | 1.94 | 2.16 | 1.67 | D(30) | |
| 2.14 | 2.15 | 2.32 | 1.94 | D(40) | |
| **0.04** | **0.08** | | | L.S.D0.05 | |

Ethephon

| | | | | | |
|---|---|---|---|---|---|
| 1.81 | 1.80 | 2.08 | 1.54 | ET(0) | Ethephon × cultivars |
| 1.89 | 1.92 | 2.12 | 1.64 | ET(5) | |
| 1.97 | 1.99 | 2.18 | 1.73 | ET(10) | |
| **0.03** | **0.05** | | | L.S.D0.05 | |

Planting distances

| | | | | | |
|---|---|---|---|---|---|
| 1.75 | 1.77 | 2.03 | 1.46 | D(20) | Planting distances × cultivars |
| 1.84 | 1.85 | 2.14 | 1.63 | D(30) | |
| 2.04 | 2.09 | 2.21 | 1.81 | D(40) | |
| **0.02** | **0.05** | | | L.S.D0.05 | |
| | 1.90 | 2.13 | 1.64 | average cultivars | |
| | **0.04** | | | L.S.D0.05 | |

ISSN 2072-3857

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