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RESEARCH ARTICLE

Effect of Planting Dates and Spraying with Salicylic Acid on Some Growth Traits and Yield of Sorghum (*Sorghum bicolor* L.)

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ABSTRACT

A field experiment was conducted in one of the fields of Ibn Al-Bitar vocational school in Al-Husseiniyah district in the Holy governorate of Kerbala for the spring season of 2023, with the aim of knowing the effect of planting dates and spraying with salicylic acid on some growth indicators and yield in Sorghum. The experiment was carried out according to a randomized complete block design (RCBD), in a split-plot arrangement, with three replications. The main plots included salicylic acid spray concentrations (0, 50, 100 and 150 ml L-1). While the sub plots included planting dates (March 1, March 10, and March 20). The results showed that the third date (March 20) was superior in plant height (235.50 cm), stem diameter (30.44 mm), leaf area (4208 cm2), flowering percentage 75% (77.37 day), number of grains (4938 grain head-1), weight of 1000 grain (35.01 g) and grain yield (8.88 tons ha-1). As for salicylic concentrations, the concentration exceeded 150 mg L-1 in plant height (249.48 cm), stem diameter (29.44 mm), leaf area (4359 cm2), flowering percentage 75% (82.37 day), number of grains (4907 grain head-1), weight of 1000 grain (33.89 g) and grain yield (8.26 ton ha-1).

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is one of the important agricultural crops and ranks fifth among crops in the world. It is grown in different regions of the country and has a high economic value because of the high percentage of protein, carbohydrates and minerals it contains, which makes it a rich and nutritious food for many Third World countries (1, 2). The protein contained in sorghum is used in building tissues and muscles, while carbohydrates provide the necessary energy for the body and also contain important minerals such as iron, zinc, magnesium and phosphorus, Therefore, it has been used in many food industries, such as the food industry, that is, in the production of flour, pasta, bread, and dried foodstuffs. It is also used in the animal feed industry and the production of starch, sugar, oils, and alcohol. From the economic aspects, sorghum plays an important role in achieving food security and providing job opportunities in the country. The agricultural sector because the leading countries in the production of Sorghum export large quantities of it to global markets, and this contributes to strengthening the economy and achieving economic returns (3).

Sorghum is considered one of the crops that is greatly affected by the harsh weather conditions in Iraq. These conditions include drought, high temperatures, and fluctuations in rainfall levels, and thus it is exposed to environmental stress (4, 5). To deal with these harsh conditions and to improve the growth of Sorghum and achieve a better yield, it is recommended to use techniques such as foliar

spraying with salicylic acid, which is a natural compound found in plants and is believed to contribute to improving plants' resistance to environmental stress. Studies show that using salicylic acid in foliar spraying can improve Sorghum growth enhances its resistance to difficult conditions. It also activates the immune system, enhances root growth, and improves the plant's response to environmental stresses (6). It acts as an antioxidant and helps plants get rid of reactive oxygen species (ROS) generated during stress conditions. ROS can cause oxidative damage to plant cells and disrupt normal physiological processes. Through foliar spraying, plants can Maintaining a balanced redox state, reducing oxidative stress, and protecting its cellular components (7). Studies have shown that foliar spraying with salicylic acid can improve the productivity and quality of corn crops and improve the nutritional composition of grains, including protein and carbohydrate content. These effects contribute to increasing yields economic growth for farmers who grow maize as a cash crop (8, 28).

The planting date can greatly affect the crop productivity, as the plant is affected by the weather and environmental conditions surrounding it. Different planting dates can greatly affect the growth and development processes of plants. For example, if plants are planted in spring, there may be a longer growth period due to moderate temperatures and adequate light, which can result in greater plant growth and development of stronger roots and larger leaves. On the other hand, if plants are planted early in the summer, they may be exposed to high temperatures and drought, which may negatively affect growth processes and yield and thus may affect crop productivity (9, 29). Therefore, the current study aimed knowing the effect of planting dates and spraying with salicylic acid on some growth indicators and yield in sorghum.

MATERIALS AND METHODS

A field experiment was carried out during the spring season of 2023 in one of the fields belonging to Ibn Al-Bitar vocational Preparatory school in Al-Husseiniyah district, Karbala, Iraq (latitude: 32' 36' 57.71" north, longitude: 44' 29.57" east). The experiment was carried out according to a randomized complete block design (RCBD), in a split-plot arrangement, with three replications, the main plots included salicylic acid spray concentrations (0, 50, 100 and 150 ml L^{-1}). While the sub plots included planting dates (March 1, March 10, and March 20). After plowing and leveling the field soil, it was divided according to the treatments, the seeds were planted in one hole and on a farrow, one the distance (75 cm) and the distance between another hole (25 cm). Nitrogen fertilizer was added in the form of urea fertilizer in two batches, and phosphate fertilizer was added at planting, both according to the recommendations approved by the Iraqi Ministry of Agriculture. All agricultural operations were carried out during the crop growth period.

Data recorded

The following traits were calculated as an average for five plants chosen randomly from the middle lines of each experimental unit: plant height (cm), leaf area (cm^2): Leaf area was calculated according to (10) by the following equation: leaf length times fourth leaf width × 6.18. The stem diameter (mm) was calculated at the 75% flowering stage using a Vernier micrometer. The number of grains (grain $head^{-1}$), as well as the weight of 1000 grains (g) were calculated using an electronic scale. The number of days from planting to 75% flowering (day) was calculated. As for grain yield (kg ha^{-1}), it was calculated by multiplying the average yield per plant × plant density and then converting it to tons ha^{-1} (11).

Statistical analysis

After collecting and tabulating the data related to the study, it was statistically analyzed according to the factorial experiment system applied by randomized complete blocks designing (RCBD), the least significant difference ($L.S.D_{0.05}$) test was used to compare and separate the means (12). this is done using statistical analysis software GenStat12.

RESULTS AND DISCUSSION

Plant height (cm)

The results showed that there were significant differences between planting dates in plant height (Table 1). The third planting date gave the highest average (235.50 cm), compared to the first and second dates, which gave averages (202.28 and 224.10 cm), respectively. Perhaps the reason for the increase in plant height at the third planting date is that the environmental conditions during this date were suitable for germination, growth, and elongation, which was reflected in their variation in vegetative growth characteristics. This result is consistent with (13).

The results also showed that spraying with salicylic acid caused a significant increase in plant height (Table 1). The concentration exceeded 150 mg L^{-1}, giving the highest average (249.48 cm), compared to the control treatment, which gave an average (196.20 cm). The reason for the plant's high concentration of 150 mg L^{-1} is due to its role in improving the balance of osmotic pressure inside the plant cells and increasing their efficiency in absorbing water from the soil, or perhaps to its role in activating some physiological processes within the plant, such as the process of photosynthesis and improving the absorption of the necessary nutrients that the plant needs in vegetative stages: These results agreed with (8) who indicated that spraying with salicylic acid increases plant height.

Table 1. Effect of planting dates, spraying with salicylic acid, and their interaction on the plant height in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	177.81	196.11	214.68	196.20
50	192.10	200.60	220.59	204.43
100	213.30	241.14	242.80	232.41
150	225.93	258.57	263.95	249.48
Means	202.28	224.10	235.50	
$L.S.D_{0.05}$ Salicylic acid concentration: 8.70, Planting dates: 12.87, Interaction: N.S				

Stem diameter (mm)

The results showed significant differences between planting dates in stem diameter (Table 2). The third planting date gave the highest average (30.44 mm), compared to the first and second appointments, which gave averages (28.55 and 29.32 mm), respectively. The reason for the increase in stem diameter at the third planting date may be attributed to the increase in leaf area (Table 3), which contributed to increasing the efficiency of the photosynthesis process and thus to increasing the accumulation of dry matter, which was reflected in the increase in stem diameter. Also, the direct effect of environmental conditions may lead to changing dates. Planting or the ideal date provides more suitable conditions for plant growth, which can lead to an increase in the size of plant parts (14).

As for the concentrations of salicylic acid, it was observed that there were significant differences between them in terms of stem diameter (Table 2). The concentration of 150 mg L^{-1} reached the highest average (29.44 mm), compared to the control treatment, which gave the lowest average

(26.02 mm). The reason for the increase in stem diameter may be attributed to the role of salicylic acid, which activates plant growth enzymes and the process of cell division, which leads to an increase in cell size and expansion, which is reflected in an increase in stem thickness. This result agreed with (15).

Table 2. Effect of planting dates, spraying with salicylic acid, and their interaction on the stem diameter in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	34.14	26.19	27.75	26.02
50	25.84	27.94	28.33	27.37
100	27.53	28.56	29.80	28.63
150	28.55	29.32	30.44	29.44
Means	26.51	28.00	29.08	
$L.S.D_{0.05}$ Salicylic acid concentration: 1.89, Planting dates: 0.87, Interaction: N.S				

Leaf area (cm^2)

The results indicated that there were significant differences between planting dates in leaf area (Table 3). The third planting date had the highest average (4208 cm^2), while the first and second dates gave averages (3838 and 3533 cm^2) respectively. The increase in leaf area at the third planting date may be attributed to the length of the vegetative growth period. It is natural that the survival of the plant for a longer period leads to an increase in growth indicators, as a result of an increase in the period of conversion of solar energy into chemical energy and thus to an increase in the accumulation of dry matter, which is reflected in the increase in leaf area (16, 17).

It was also observed that there were significant differences between the concentrations of salicylic acid in leaf area (Table 3). The concentration exceeded 150 mg L^{-1}, giving it the highest average (4359 cm^2), compared to the control treatment, which reached the lowest average (3161 cm^2). The reason for increasing the leaf area when spraying with salicylic acid may be attributed to improving and increasing the production of chemical energy stored in the leaves and enhancing cell growth, as salicylic acid helps increase cell growth and development, which contributes to increasing the size of the leaves and thus increasing the leaf area (18).

Table 3. Effect of planting dates, spraying with salicylic acid, and their interaction on the leaf area in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	2805	3223	3454	3161
50	3732	3403	3906	3681
100	3640	4310	4766	4239

150	3956	4417	4704	4359
Means	3533	3838	4208	
L.S.D$_{0.05}$ Salicylic acid concentr86ation: 406.10, Planting dates: 342.60, Interaction: N.S				

Number of days from planting to 75% flowering (day)

The results showed that there are significant differences between planting dates in the number of days from planting to 75% flowering (Table 4). The third planting date had the best average (77.37 days), while the first and second dates had averages (93.80 and 87.73 days) respectively. The reason for this is that the third planting date coincides with a rise in temperatures more appropriately than the other two dates, which pushes the plant towards early flowering. This result is consistent with the results of other studies that found a significant difference between planting dates for this trait (17). Or perhaps the reason is that the plants at this time achieved sufficient thermal units in a shorter time as a result of suitable environmental conditions, which led to an acceleration of the flowering process. These results are consistent with what was reported by (19).

The results indicated that there were significant differences between the concentrations of salicylic acid on the number of days of flowering from planting to 75% flowering (Table 4). The concentration of 150 mg L^{-1} gave the best average (82.37 days), compared to the control treatment, which gave the longest period of (89.27 days). This may be attributed to the role of salicylic acid in encouraging vegetative growth through the production of the Florigen hormone, which is responsible for the formation of the flower neck, which works to stimulate the plant to speed up flowering and form flower stems in a larger number. These results agreed with both (20, 21).

Table 4. Effect of planting dates, spraying with salicylic acid, and their interaction on the number of days from planting to 75% flowering in Sorghum.

Salicylic acid concentration (ml L^{-1})	**Planting dates**			**Means**
	March 1	**March 10**	**March 20**	
0	97.70	91.33	78.77	89.27
50	94.11	91.19	77.94	87.75
100	94.23	85.24	78.01	85.83
150	89.16	83.17	74.77	82.37
Means	93.80	87.73	77.37	
L.S.D$_{0.05}$ Salicylic acid concentration: 2.77, Planting dates: 2.07, Interaction: N.S				

Grains number (grain head^{-1})

The results showed significant differences between planting dates in the number of grains per head (Table 5). The third appointment gave the highest average of (4938 grain head^{-1}), compared to the first and second appointments, which gave averages (3881 and 4460 grain head^{-1}), respectively. The number of grains in the head is one of the quantitative characteristics that are positively related to genetic factors, and this characteristic is considered the most important determining factor in the

yield and one of the main components. It has the strongest connection with it, and it is also affected by environmental factors and the method of crop management. This difference could be due to the superiority of the third planting date (March 20) in leaf area (Table 3), thus increasing the leaves' interception of light, and thus the abundance of materials manufactured in the photosynthesis process, which enabled the plant to improve its performance in the photosynthesis process. This was reflected in an increase in the number of grains in the head. These results agreed with (17).

Spraying with salicylic acid also had a significant effect on the number of grains per head (Table 5). The concentration of 150 mg L^{-1} gave the highest average of (4907 grain $head^{-1}$), compared to the control treatment, which gave an average of (3902 grain $head^{-1}$). Perhaps the reason for the increase in the number of grains in the head at a concentration of 150 mg L^{-1} is because it increases the plant's activity and metabolic processes, such as photosynthesis. This leads to the stimulation of components and their increase from the source to the downstream, if the plant invests its energy in forming additional grains, which helps to increase the number of grains in the head. The head, or its role in regulating many physiological processes, including the process of photosynthesis, which increased the efficiency of dry matter formation in the reproductive stages, and this was reflected in one of the most important components of the yield (22).

The results also showed that there was a significant interaction between planting dates and spraying with salicylic acid in the number of grains per head (Table 5). As the concentration of 150 mg L^{-1} at the third planting date gave the highest average of (5476 grain $head^{-1}$), while the concentration of 50 mg L^{-1} at the third planting date gave the highest average (5476 grain $head^{-1}$), while the concentration of 50 mg L^{-1} at the third planting date gave the highest average (5476 grain $head^{-1}$), the first crop had the lowest average (3598 grain $head^{-1}$).

Table 5. Effect of planting dates, spraying with salicylic acid, and their interaction on the grains number in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	3868	3801	4038	3902
50	3598	4113	5130	4280
100	3824	4915	5108	4616
150	4234	5011	5476	4907
Means	3881	4460	4938	
$L.S.D_{0.05}$ Salicylic acid concentration: 188.20, Planting dates: 351.20, Interaction: 395.50				

1000-grain weight (g)

The results indicated that there were significant differences between planting dates in the weight of 1000 grains (Table 6). The third appointment gave the highest average of (35.01 g), compared to the first and second appointments, which gave averages of (30.99 and 32.86 g) respectively. The reason for the increase in the weight of the grain at the third planting date may be attributed to the fact that there was a timing agreement with regard to heat and light that was ideal for growth rates and the manufacture of photosynthesis products at the highest rates, which reflected positively on most of

the characteristics of vegetative growth, and thus led to an increase in the weight of the grain in the head, and this is consistent with results (23).

The results showed that spraying with salicylic acid caused a significant increase in the weight of 1000 grain (Table 6). The concentration of 150 mg L^{-1} gave the highest average of (33.89 g), compared to the control treatment, which gave the lowest average of (32.34 g). The reason for the increase in grain weight may be due to the role of salicylic acid in stimulating the performance of vital processes in the plant, thus increasing photosynthesis processes and thus increasing the accumulation of dry matter, which leads to increased grain weight (24).

Table 6. Effect of planting dates, spraying with salicylic acid, and their interaction on the weight of 1000 grain in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	29.94	33.00	34.08	32.34
50	30.16	32.96	34.30	32.47
100	31.54	32.39	35.43	33.12
150	32.31	33.11	36.24	33.89
Means	30.99	32.86	35.01	
$L.S.D_{0.05}$ Salicylic acid concentration: 1.39, Planting dates: 1.79, Interaction: N.S				

Grain yield (ton ha^{-1})

The results also showed significant differences between planting dates in grain yield characteristics (Table 7). The third planting date gave the highest average (8.88 tons ha^{-1}), while the first and second dates gave two averages (6.42 and 7.91 ton ha^{-1}), respectively. The reason for the increase in grain yield at the third planting date may be attributed to the plant's ability to create a good leaf area (Table 3), which leads to the accumulation of sufficient photosynthetic products and the interception of the greatest amount of sunlight in the vegetative growth stage, which is directly linked to an increase in grain yield, or the increase in grain productivity may be due to the appropriate planting date, where there is an optimal match between the plant growth requirements and the existing climatic conditions, which encourages the plant to store and accumulate the largest amount of dry nutrients and move it from the source to the downstream, these results are consistent with (25, 26).

The results also indicated that there were significant differences between the concentrations of salicylic acid in grain yield characteristics (Table 7). The concentration of 150 mg L^{-1} gave the highest average (8.26 ton ha^{-1}), compared to the control treatment, which gave the lowest average (6.93 ton ha^{-1}). The increase in grain yield may be attributed to the role of salicylic acid in enhancing the work of the roots, as it is believed that this contributes to improving the absorption of water and nutrients from the soil, as well as to its role in enhancing the plant's response to environmental stresses such as drought and salinity, which leads to an improvement in the ability of plants to adapt to undesirable conditions. Appropriate, or perhaps it is due to the physiological effect of this acid in accelerating the transfer of nutrients within the plant and thus increasing their accumulation in the sites of grain origin, which is reflected in an increase in plant yield (27).

Table 7. Effect of planting dates, spraying with salicylic acid, and their interaction on the grain yield in Sorghum.

Salicylic acid concentration (ml L^{-1})	Planting dates			Means
	March 1	March 10	March 20	
0	5.43	7.13	8.23	6.93
50	6.58	8.10	8.80	7.83
100	6.66	7.86	9.27	7.93
150	7.00	8.57	9.21	8.26
Means	6.42	7.91	8.88	
$L.S.D_{0.05}$ Salicylic acid concentration: 1.35, Planting dates: 0.63, Interaction: N.S				

CONCLUSIONS

From the above, we can conclude that planting time has a fundamental role in increasing growth indicators and yield, by adapting environmental conditions to the nature of crop growth. Spraying with salicylic acid also had a clear effect on increasing yield, and this is only a result of the role of this acid in enhancing the ability of the plant to absorb and transfer nutrients from the soil to the plant and thus has a positive impact on increasing growth indicators and yield.

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