Making of Maize (*Zea mays* L.) Drought Tolerant through Salicylic Acid Foliar Application and Potassium under Fixed Irrigation Interval System

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Abstract:

A The field experiment was conducted at the field of Al-Baitha, located within the College of Agriculture at Anbar University, during the spring of 2023 to knowledge the growth and productivity of maize (Buhooth-5018 variety) under a deficit of irrigation through Foliar spraying with salicylic acid and potassium .The study was conducted organized utilizing a factorial arrangement and structured based on a randomized complete block design (RCBD), incorporating three replicates. It involved two distinct variables in its setup The first factor was the spray of salicylic acid at three concentrations S0, S1 and S2 (0, 100 and 150 mg L-1), while the second factor was the spray of three concentrations of potassium (K0 = 0, K1 = 1000 and K2 = 2 000 mg L-1).

The findings indicated that high concentrations of salicylic acid (S2) and chlorophyll (56.29 spad) and leaf area (5561.8 cm2) and crop components such as 300 - grain weight (55.78 g) and plant yield (158.57 g) were higher than high concentrations of plant height (196.0 cm). As regards potassium, the K2 level showed a significant influence on mean plant height, leaf area, ear length, and 300-grain weight, and plant yield. The mean values for these parameters were 192.44 cm, 5145.3 cm2, 15.61 cm, 56.44 g, and 2159.89 g, respectively. On the other hand, the overlap among the factors studied exerted a significant effect on most characteristics, as the combination of S2K2 yielded maximum values for plant height (200.67 cm), leaf area (5871.0 cm^2), and grain yield per plant (186.69 g).

Key words: *Zea mays* L., potassium, drought tolerance, salicylic acid

1. Introduction

Corn is one of the economic crops, ranking third in economic and nutritional terms after wheat and rice. Yellow corn is grown in two seasons (spring and fall), but demand for spring corn is lower than for fall for several reasons, one of which is the low yield of grains, which result from the flowering period coinciding with high temperatures. This can lead to decrease in the viability of the pollen grain, negatively affecting both processes of pollination and fertilization, consequently the low amount of the total yield. However, spring maize crop beats the autumn maize, including high price and the complete dryness, and lack of rotting during shelling. Furthermore, it is easier to mill and grind its grains and offer them as animal feed. The spring is superior to the autumn in terms of the high price, the full dryness, absence of rot when store. The ease in grinding and crushing of the grain to feed

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animal [1] Maize grains are one of the grains widely used as a human food and beverage. Drinks, it is also a feed material used for feeding animals and birds. In the industrial sector, corn is used in various industries, including the starch industry, fertilizers, ceramics industry and plastics industry, and in recent years its application has been added in the biofuel industry [2].

Plant hormones, including salicylic acid (SA), have been shown to increase plants' tolerance to abiotic stresses including drought and elevated sodium chloride levels in irrigation water and agricultural soils. SA is an organic acid widely used as a plant hormone. Produced through the metabolism of salicin, SA stimulates and activates cellular biological activities, which impacts plant growth by improving most of plant's biochemical activities [3].

Numerous research clarified that applying of SA through spraying significantly contributes to enhancing plant growth and developmental traits. This is achieved by its ability to regulate various biochemical operations, particularly in plants exposed to environmental stress., including photosynthesis, respiration, nutrient uptake and utilization, stomatal control, suppression of ethylene production and others. In addition, it subscribes to an increasing the capacity of plants to endure stresses resulting from increased salinity by enhancing the activity of antioxidant enzymes, including SOD, POD, and CAT [4], and helping plant cells resist damage resulting from extreme temperatures, water shortages, and high salt content [5]. It also works a major performance in organizing the hormones action according to the growth stages and the fashioning of plant organs and tissues to an increase their efficiency in optimally utilizing temperature, light, and available water content with the aim of enhancing the efficiency of all vital and physiological activities in the plant, and their effects on the growth and development of plant organs and on yields in terms of quantity and quality [6, 7].

Potassium is a vital nutrient essential for growth and the ability to tolerate water and salt stress. Sufficient potassium availability significantly contributes to plant tolerance to stress and promotes plant growth, thereby improving plant productivity and crop characteristics. In addition to the multiple vital functions this element performs within the plant [8]. This this research aimed to identify the best concentrations of SA and potassium that can improve growth and yield characteristics, ultimately leading to increased maize productivity. The research also aims to improve plant tolerance to high temperatures and mitigate the effects of water stress resulting from reduced irrigation frequency, partly by adopting a specific irrigation system.

2. Materails and methods

A field trial was carried out at Al-Baitha site, College of Agriculture, University of Anbar during the spring of 2023 on corn (Buhooth-5018 variety). The experiment consisted of two factors, the first being the spray of salicylic acid at three concentrations (S0 = 0, S1 = 100, and S2 = 150 mg L-1). The second factor was the three concentrations of potassium (K0 = 0, K1 = 1000 and K2 = 2,000 mg L-1). The foliar application was performed in two distinct stages, the first at the vegetative

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growth phase and the second during flowering. The experimental area has been plowed and soil samples taken for chemical and physical soil analysis. (Table 1). After this, proved service began – making the soil perpendicular, smoothing it, leveling it, to make a good place to set seed.

A factorial design based on a randomized complete block design (RCBD) with three replicates was applied. The field was divided into 27 plots, each plot having an area of 12 m^2 (4 m × 3 m) which contained 4 rows, 75 cm a part and 25 cm between hills, i.e. 53,333 plant ha^{-1}. The seeds were planted on 04/03/2023. DAP fertilizer was added to the experiment as recommended (N 18% and P_2O_5 46%) at a rate of 320 Kg ha^{-1} [7]. Afterwards, irrigation was carried out for the field every twelve days, and it was not based on the need of the field. Other cropping operations, such as weeding and corn stalk borer control were performed as required. The evaluated parameters were:

2. 1. Plant height: This trait was measured using a graduated ruler for the ten plants measured from ground level to the top of the plant at the male inflorescence.

2. 2. Leaf area: the leaf area of five tagged plants was estimated using the following equation:

LA = maximum leaf length × maximum leaf width × 0.75

2. 3. Leaf chlorophyll content: The chlorophyll index of leaves is determined using a SPAD device.

2. 4. Ear length: This characteristic was measured using a graduated measuring instrument for five samples and then the average was calculated.

2. 5. The raw ears per harvested plant were enumerated, and the mean corn ear number was then calculated.

2.6. Grains number per ear: It was calculated by taking five corn ears of harvested plants, and then the average number for the trait was calculated.

2.7. Grain weight: The trait was measured by recording the weight of 300 seeds of ten samples per experimental unit taken from the harvested raw ears.

2.8. Grain weight ear^{-1}: Grains from five ears of the harvested plants were weighed.

2.9. Plant yield: This trait was measured by calculating the grain weight of five corn sampled plants from each experimental unit, and the mean value was recorded.

The data were statistically analyzed using the Genstat software, and the results were recorded in an ANOVA table., and then the average of each characteristic was compared applying the least significant difference (LSD) test at a 5% probability level [9].

Table (1). Physicochemical characteristics of the experimental soil

Value	Unit	Charact eristics
0.27	g kg^{-1}	Available N
9.6	ppm	Available P
107		Available K
7.81	-----	pH
4.3	ds m^{-1}	Ec
9.1	g kg^{-1}	O. M
485	g kg^{-1}	Sand
265		Clay
280		Silt
Loam	-----	Soil textures

3. Results and discussion

3.1. Plant height

The SA and potassium spraying on this character had significant influence (Table 2), when application of SA at an

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elevated concentration (S2 = 150 mg L^{-1}) gave the highest average of this character (196.00 cm). This could be attributed to the influence of SA in improving growth efficiency by increasing nitrogen absorption by the plant, which contributes to increasing the activity of new meristematic cells that help in increasing the number of dividing cells, which was reflected in promoting plant height. In addition, salicylic acid contributes to enhancing the plant's vegetative development, as it also attributes to the formation of proteins involved in the formation of nucleic acids of the genetic material. [10, 11].

The K2 treatment excelled over other potassium means of 192.44 cm but exceeded by 5.73% compared with the K0. This might be as a result of that the potassium was able to intensify the activity of some phytohormones, thereby augmenting the cell division and elongation and subsequently, it can be manifested by the increase in plant height [12]. These findings also agree with 6 and 17.

As for the overlap between the two factors, the S2K2 combination was shown to be the best among the other combinations for this trait with an average 200.67 cm, while the S0K0 combination had a minimum average, reached 163.67 cm.

3.2. Leaf area

The results indicate that the influence of SA and potassium spraying was highly significant on this character, as the highest leaf area was achieved by using the highest concentration of salicylic acid (SA2) when compared with the other concentrations and highest mean was 5561.8 cm^2. The average leaf area for the SA0 treatment measured 4033.6 cm^2. Salicylic acid enhances chlorophyll and carotene pigment production, boosts photosynthesis rates, and improves the efficiency of certain key enzymes directly influenced by this compound. Its positive impact is reflected in the increased leaf area [11].

Likewise, for potassium, we note that the high potassium concentration (K2) recorded the highest average values, surpassing other concentrations with an average of 5145.3 cm^2 compared to K0 which achieved 4457.7 cm^2. The increasing of this character with the presence of potassium can be due to the capability of K to an increase the efficiency of some plant hormones that significantly contributed to increased cells development of leaves, his findings is agreed with other researchers [14].

The effect of SA 2 interaction with the second level K was also higher with a mean performance of 5871.0 cm2 and in comparison, with the treatment for (S0K0) which had average of 3235.7 cm2 in the amount of the trait.

3.3. Chlorophyll indice

The findings show the influence of SA on the average total chlorophyll content of leaves, as S2 treatment gave the maximum mean of this character, reaching 56.29 SPAD, and there was a significant difference with the S0, which gave the minimum mean, reaching 52.06 SPAD. This influence of SA is due to its capability to an increase the synthesis of pigments. Also, increasing of chlorophyll indice improves the metabolic operations efficiency [11, 15].

Potassium concentration K1 showed the best concentration among the treatments, reaching 56.34 SPAD, achieving

a 7.89% percentage increase over the control group, which had the lowest mean of 51.89 SPAD. This increasing of chlorophyll indice is probably due to the performance of potassium in enhancing of metabolic operations and transport of its products to plant parts. Also, K contributes to in increasing the nitrogen in the leaf, as nitrogen works a major role in chlorophyll formation. Furthermore, potassium contributes to delaying leaf aging by slowing protein degradation [10, 12]. This finding is in agreement with [13, 14], who noted an increasing in the chlorophyll indice with higher K spray concentrations.

Regarding the overlap, all S2K1 overlap the treatments were inferior to the previous treatments, with the mean being the highest score 59.36 SPAD and for the trait, except the participant treatment and the lowest mean was obtained in comparison treatment for both workers, reaching 51.03 SPAD.

3.4. Ear length (cm)

The experimental findings clarify the impact of SA and K foliar application on ear length characteristics of maize crops (Table 2). The addition of sodium acetate at concentration S2 was shown to be superior to other concentrations and achieved the maximum mean value of 16.16 cm, whereas

S0 recorded the minimum mean of 13.97 cm

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The results of the same table also show that the higher potassium concentration in K2 outperformed by giving the highest means, reaching 15.61 cm, without significant variance with K1 treatment, but it was significantly differed with K0 treatment, which gave 14.43 cm. This may be attributed to the plant receiving an adequate amount of K at the required stage, which is the pre-silk emergence and post-silk emergence stage, which provided ideal growth for the plant, making the ear grow in distinct conditions in which all other major and minor nutrients are available, which contributed to increasing the efficiency of the plant's use of ear length [19]. Potassium, which is necessary for plant growth, also plays a role in stimulating many enzymes. It also enhances PGRs, which are answerable for cells development [7].

Regarding the interaction of the two examined factors, the S2K1 overlap excelled compared to other overlaps by recording the highest value (16.86 cm), whilst the S0K0 overlap produced the lowest value (12.29 cm).

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Table (2). Effect of SA and K on maize growth parameters under drought stress

L.S.D	Ear length (cm)	L.S.D	Chlorophll Index (spad)	L.S.D	Leaf ear (cm^2)	L.S.D	Plant height (cm)	Treatment
	13.97		52.06		4033.6		179.11	S0
0.58	15.48	3.38	55.82	544.4	4865.0	12.67	189.66	S1
	16.16		56.29		5561.8		196.00	S2
	14.43		51.89		4457.6		181.44	K0
0.58	15.57	3.56	56.34	544.6	4857.4	15.33	190.88	K1
	15.61		55.82		5145.3		192.44	K2
	12.29		51.03		3235.6		163.67	S0K0
	14.33		53.63		4380.3		187.34	S0K1
	15.30		51.53		4486.0		186.33	S0K2
	15.35		53.73		4682.3		192.67	S1K0
1.01	15.51	9.48	56.03	943.3	4832.6	18.71	186.00	S1K1
	15.58		57.69		5080.0		190.33	S1K2
	15.66		51.28		5455.3		188.00	S2K0
	16.86		59.36		5359.3		199.33	S2K1
	15.96		58.23		5871.0		200.67	S2K2

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3.5. Number of ears per plant:

The impact of spraying maize with salicylic acid (S) and potassium on the number of ears produced is highlighted in the data presented in Table 3. The findings demonstrate how these treatments influence this particular trait in the maize crop. Whereby someone finds that adding salicylic acid to concentrations S2 presented the best concentration among others and produced the maximum mean 2.900 ear plant^{-1}. There was the least trait value of 2.011 ear plant^{-1} in the comparison treatment. These may be genotypically ascribed to the characteristics in numbers of ear in the plant as the increasing by increasing Concentrations of SA as it enhances the efficacy of metabolic operations by raising the amount of chlorophyll pigments in the leaves as well a raise the transfer nutrients from the source to be flowed In the lower limbs in the recollection period And found That the decreasing occur because ear prefixes in first stage of growth as it enhance Distribute to dry resistance for the plant organs Witch leads to ear numbers increase [20]. These results are consistent with [21].

Potassium after K2, the K2 concentration was the best one and the mean of its trait was 2.711 ear plant^{-1}, and the K0 had the minimum mean value (2.188 ear plant^{-1}). This increase was ascribed to the influence of the K on enhancing the activity of plant hormones that stimulate division, elongation of apical cells [7]. These results are compatible with the results of [13, 18].

The interference effect had significant influence, S2K2 interference was superior by producing the maximum average, reached 3.033 ear plant^{-1}, comparison to other interferences and S0K0 which produced the least average (1.533 ear plant^{-1}).

3.6. Number of grains per ear

Table (3) reveal the effects of foliar application with SA and K were highly significant for ear grain number, the SA at a high concentration (S2) was the best as it showed the highest average value of the trait which was 374.1 grain ear^{-1}, due to this concentration remaining significantly differ from S0 (280.8 grain ear^{-1}). That may be in line with [10, 15] on maize. Yield was associated with increasing the area leaf (Table 2) and the weight of 300 seeds (Table 3), which positively contributed to enhancing the percentage of grains fertility and then increasing the grains number for each ear.

In the case of potassium, the highest concentration (K2) was superior to the others by about 15.65% than the K0 treatment that produced a minimum mean (294.7 grains ear^{-1}). This is because the growth of the potassium content absorbed by the leaves has increased the intensity of activation of the absorption of the rest of the elements contained within the plant, including nitrogen that not only participates in the formation of proteins, and then transfers them as nitrogen at the flowering stage in order to an increase the formation of active flower structures, where potassium is also working on regulating the work of the plant hormones that have a direct relation with the formation of the flower, pollination and fertilization, and then increasing the ripened grains number [22, 23]. These findings are in line with [14, 16, 17] that

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reported that there was a potential increasing of grains number with spraying potassium.

Regarding of interference, the application of the S2 level of salicylate and K2 level of potassium performed better than all other treatments with an average of 385.3 grains ear^{-1} compared to S0K0 which provided 250.3 grains. ear^{-1}.

3.7. Weight 300 grains

The findings presented in Table (3) indicate a notable influence of SA and K on the weight of 300 corn grains. The maximum level S2, was the best among the concentrations, reaching a peak value of 55.78 g, which showed no significant difference from the S1 concentration treatment, but was significantly different from the comparison concentration, S0, which recorded an average of 51.51 g for the trait. As for potassium, the high level of K2 was better than the other concentrations (K0 and K1), and gave an average of 56.44 g for the trait, in contrast with the K0 concentration, which recorded a lower mean of 52.29 g. This distinction is attributed to the excellence of the two factors at these levels in expanding the leaf surface area and enhancing the effective transfer of nutrients from the leaves to the grains, resulting in an improvement in the weight of the grains, as the grains represent the ultimate sink for photosynthetic products. Moreover, foliar application of potassium fertilizer enhances the efficiency of photosynthetic activity by generating energy sources such as ATP and transporting sugars to different parts of the plant. Furthermore, the proteins formed are of great importance in positively regulating the utilization of high nitrogen, ultimately increasing the efficiency of the source to the sink (grain). [24]. These findings are in agreement with those of [25, 27], who reported that spraying K led to an increasing the grain weight.

The combination of S1K2 was found to be superior to the remaining treatments in this study by giving an value of 58.21 g compared to S0K0, which produced 48.84g.

3.8. Weight of grains per ear

Data show that spraying of SA and K had a significant influence on corn grain weight, as the high concentration of S2 outperformed and produced the maximum mean, amounting to 74.1 g, which is significantly different from the S0 which gave the minimum value, amounting to 52.2 g. This can be due to the performance of SA in enhancing the formation of plant pigments, which lead to increasing metabolic operations efficacy, as well as increasing the effectiveness of many vital enzymes, which was positively influenced in increasing the grain weight in the ear [15,21].

With respect to potassium, the K2 level outperformed other K levels with a mean value of 64.1 g that did not significantly differ from K1 level (63.9 g) but significantly differed from the K0, which resulted the minimum value (59.0 g). This was attributed to the extended period from anthesis to physiological maturity, which allowed for the completion of the grain filling process [26]. Supplement of potassium is improved in weight of grain, especially during autumn, because of increased leaf area and a rise in transport rate of

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carbohydrates and of proteins from source to sink, increasing the grain weight.

Regarding of interference, the S2 with K1 tended to surpass other treatments with 79.3 g compared to S0K0 which had the minimum value (47.3 g).

3.9. Plant yield

As seen in Table (3), the SA acid and K element have a noticeable effect on the yield of a single individual maize. An among the other concentration and scoop the high est average was 158.47 g Which was lower than the S0 treatment that the average was 106.09 g. The results obtained are in agreement with the results of several researchers, who found that treating plants with salicylic acid enhanced the yield of an individual plant [14, 15, 25]. The S2 treatment also outperformed the other two potassium levels, recording the maximum mean value for the trait (159.89 g), while the control treatment achieved a lower average for the trait (112.05 g). This superiority of the K2 treatment can be explained by its superiority in most growth and productivity traits, which led to improved plant productivity (Tables 2 and 3). This has been confirmed by several researchers, who indicated that the potassium treatment improved the productivity of maize plants [13, 14, 19, 27].

As for the overlap between the two factors, the S2K2 combination outperformed significantly by providing it with the greatest mean trait of 186.69 grams over all other combinations, while S0K0 recorded the minimum mean among all treatments at 78.65 grams.

Table (3). Influence of SA and K on the Yield parameter and components of maize grown under drought stress

L.S.D	Plant yield (g)	L.S.D	Grains per ear (g)	L.S.D	Weight 300 grain (g)	L.S.D	Grain per ear (g)	L.S.D	Ear of plant **ear .plant^{-1}**	Treatment
	106.09		52.2		51.51		280.8		2.011	S0
10.38	137.23	1.83	60.6	2.39	55.39	19.7	288.3	0.152	2.322	S1
	158.47		74.1		55.78		374.1		2.900	S2
	112.05		59.0		52.29		294.7		2.188	K0
11.68	129.86	1.83	63.9	2.39	53.95	19.7	308.4	0.152	2.333	K1
	159.89		64.1		56.44		340.1		2.711	K2
	78.65		47.3		48.84		250.3		1.533	S0K0
	112.09		54.0		51.30		281.3		2.133	S0K1
	127.53		55.2		54.38		311.0		2.366	S0K2
	117.66		63.0		53.19		268.7		2.199	S1K0
17.98	128.60	3.17	58.3	4.14	54.79	34.2	272.3	0.264	2.033	S1K1
	165.44		60.5		58.21		324.0		2.733	S1K2
	139.84		66.6		54.84		365.6		2.833	S2K0
	148.89		79.3		55.77		371.6		2.833	S2K1
	186.69		76.5		56.75		385.3		3.033	S2K2

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Conclusion

Generally, a conclusion is made, which is the data of the study means that salicylic acid contributed significantly in improving the tolerance of Yellow Corn plant to water stress and, for potassium we indicate that the high concentration of this element in plant improved the efficiency of the plant to tolerate the low irrigation, this efficiency increases by the harmony of the SA acid and K element in the improving the yield and its components.

So, these trails should be repeated with increased concentration of SA acid and K at more level of water stress and using more date between irrigation to another to study the length of time to ability of the maize crop to increase their tolerance and their influence on increasing of the efficacy of plant to resist stresses and its influence on increasing of productivity too.

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