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The adaptability of maize (*Zea Mays* l.) to drought tolerance by using Salicylic Acid (SA) foliar application under the middle area conditions of Iraq

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Abstract. A field experiment is carried out in private farm of Silty loam textured soil, in Al-Latifiya, district southern Baghdad, Iraq during the spring season of 2018. The objective is to study Maize's adaptability (*Zea mays* L.) plants to drought using water stress and Salicylic acid foliar application by determining some growth traits. A split-split plots system is used within Randomized Completely Block Design (RCBD) with three replications. The main plots include three irrigation treatments (IQ); 100% (full irrigation), 80% and 60% available water. The subplots involve four Salicylic acids (SA) concentrations; 0, 100, 200 and 300 mg.L^{-1}. The results were as follows: The Salicylic acid (SA) has shown a clear significant effect in all characteristics. The (300 mg.L^{-1}) concentration of SA gives the highest rates of growth traits. Similarly, the irrigation treatments have shown a clear significant effect on all traits. The full irrigation treatment gave highest rates on growth characteristics; leaf area (LA), leaf area index (LAI), plant's height (PLH), number of leaves per plant (LN). Therefore, this study suggests the possibility of making Maise plants (*Zea mays* L.) more adaptable to drought tolerance using water stress and Salicylic acid foliar application. Such tolerance leads to reduce plant water requirement without significant effects on growth and yield characteristics as well.

Keywords; Maise, Adaptability, Drought Conditions, Salicylic Acid, Vegetative Growth.

1. Introduction

Maise (*Zea mays* L.) is one of the most important crops in Iraq. Maise's productivity depends on the optimal use of water according to precise time corresponds to the different stages of plant growth. The study of water stress for quantifying irrigation water is an important topic that aims to save more water volumes to cultivate more areas with fewer water supplies [1].

There are several means to confront drought and water scarcity problems, like plant growth regulators of auxins, which are modifier materials enhance plant's capability for maximum use of its latent physiological and genetical power [2]. Salicylic acid (SA) or ortho-hydroxy benzoic acid is a recognised phenolic compound as an endogenous growth regulator in plants. It is important to improve water stress tolerance to resume natural growth of the plant; salicylic acid has the main role in partially controlling leaves' stomata that reduces transpiration and reserve moisture content in internal plant tissues [3]. SA speeds up the formation of chlorophyll and carotene stains that stimulate photosynthesis and increase some important enzymes [3]. The plants' pathogens were also inhibited by SA, which enhances the systematic immunity of most floras. Furthermore, it can also encourage changes in evolutionary traits that can help plants withstand a wide range of environmental stresses resulting from extremes in temperature, freezing, drought and salinity [3]. The significant differences of plant's height, leaf area, and dry weight mass of maise and soybean plants have been shown by [4] to add SA solutions of 0, 10^{-3}, and 10^{-5} mole for two seasons. In conclusion, the 10^{-5} treatment has the highest means of 53.2 cm, 181.0 cm^2, and 0.731 g.plant^{-1}, for Maise and 51.2 cm, 171.2 cm^2, and 0.697 g.plant^{-1}for soybeans for the above-mentioned traits respectively. The results of [5] have indicated an increase in the plant's height of Maise for SA treatments of 100 and 200 mg. L^{-1}, where they increased from 54.80 cm to 61.80 cm respectively, SA has increased leaves number and leaf area of plants. The spraying of SA on maise plants (concentrations are; 0,100,150,200 mg.L^{-1}) has led to a significant increase in leaves' chlorophyll content, as the highest value is 63.26 mmole. Wet weight was found in 100 $mg.L^{-1}$treatment whereas lowest value is 20.39 mmole wet weight in treatment of 150 $mg.L^{-1}$.

Different plants are affected by drought, but this effect varies from one type to another, and in order to meet the growing need of future communities of food we have to pay attention to the types of plants that need less water or have the potential to withstand low levels of moisture in the soil, and that areas prone to drought will increase further and this will reduce food production, such matter makes it necessary for us to increase the productivity rates of crops under the cultivation of irrigated agriculture [6 and 7]. Therefore, the actual water requirements of crops and when to add them is important to avoid wasting in irrigation water, which causes a reduction of irrigation efficiency and increases production costs.

For the importance of SA in reducing water stress effects, this study is executed to detect the role of external application of SA on increasing tolerance of Maise to water stress and trying to investigate the best concentration of SA.

2. Materials and methods:

A field experiment has been done in one of the private farms in Latifiya district southern Baghdad during the spring season of 2018. This study aims to know how to increase the tolerance of Maise to water stress by using salicylic acid (SA) to decrease drought effects on this plant.

The experiment has two factors, as follows:

1. Salicylic acid (SA); which is applied in four concentrations of 0, 100, 200, and 300 $mg.L^{-1}$ have the symbols of (S_0, S_1, S_2, and S_3) respectively.
2. Irrigation (IQ); which has three levels of (60%, 80%, and 100%) of maximum evapotranspiration estimated formerly by [8] and have the symbols of (I_1, I_2, and I_3) respectively.

2.1. The experimental design

The general design of the experiment is the randomised completely block design (RCBD). The split-split plots system (SSPS) was distributed within RCBD with three replications as the treatment of irrigation occupies the main plots while SA treatments occupied the sub-plots. The whole number of units with replications is estimated as 4 x 3 x 3 = 36 units.

2.2. The field operations

The mouldboard plough is used to plough the land two times perpendicularly. Later, the operations of thinning, levelling, and splitting to plots are done. Each plot's dimension is nine square meters (3 x 3) and 2 meters space between every two plots and among blocks to control side movement of irrigation water among plots. Four furrows of 0.75-meter space per two furrows and 0.25-meter distance among pits on the same furrow are included.

Random samples of the field's soil are collected before cultivation from two depths; 0 – 30 cm, and 30 – 60 cm. All soil samples are transferred to laboratories of the Ministry of Science and Technology for analysis, as shown in table 1.

On Tuesday 15th of March 2018, Maize's seeds (IBAA 5018) are implanted (3 – 4 seeds per pit). Three batches (of 30 mm depth) of irrigation are applied; the first one is the germination batch in 15th of March 2018, the second batch is added in the 20th of March 2018 to stimulate the growth and to complete germination process. In the 25th of March 2018, the third batch was inserted to reserve suitable moisture in the soil and stimulate new seedlings [8]. In the 1st of April 2018, which is the default date, all failed pits are replanted after the emergence of 75% of seedlings. After reducing the number of plants to one per pit, the density of pants becomes 5333 plants per hectare, and then, treatments are isolated by symbols and signs. The treatments are irrigated every ten days from germination date. The tri-superphosphate (46% P_2O_5) by 86 kg P. ha^{-1} is applied as a phosphorus source manually as one batch at the period between tillage and thinning [9]. Nitrogen fertiliser is added by 200 kg $N.h^{-1}$ using urea fertiliser (46%N) in four equal batches. The first batch is added immediately after the germination. The second batch is added 20 days after the first batch, and the third is added at the beginning of the flowering. At the beginning of the grain formation in the heads, the fourth batch is added [10]. All the field procedures of controlling weeds, pathogens, and birds attacks are executed. At the early morning of the next day, all the plants are washed by distilled water to remove stacked dust. The Salicylic acid (SA) solution is applied by spraying it on the vegetative mass after one month of germination for every experimental unit until total wetting [11,12]. After excluding auxiliary plants in every furrow, ten plants were randomly resampled from each experimental unit's middle furrows on the 6th of July 2018. The following traits are studied; plants' height (PLH) (cm), leaves number (LN) (leaf. Plant^{-1}), leaves' area (LA) (cm^2.plant^{-1}) and leaf index (LI),

Table 1: chemical and physical properties of soil for the spring of 2018.

Sample depth		0-30 cm	30-60 cm
Sand	g. kg^{-1}	270	130
Silt	g. kg^{-1}	390	560
Clay	g. kg^{-1}	340	310
Texture		Clay Loam	Silty clay loam
Organic matter (g.kg^{-1})		8.5	3.4
Electrical conductivity		2.94	1.98
pH		7.75	7.56
Available nitrogen	mg.kg^{-1}	83	21
Available phosphor	mg.kg^{-1}	7.5	6.2
Available potassium	mg.kg^{-1}	169	89
Permanent wilting point	%	20.4	13.5
Field capacity	%	30.3%	23.8%
Available water	%	23%	17.5%
Bulk density	Mg.ha^{-1}	1.29	1.38

3. Results

3.1. Plants' height (PLH) (cm.plant^{-1}):
The significant differences are indicated in (table 2) because of SA increase. As the highest PLH is found in S_3 treatment, which is 183.80 cm.plant^{-1}, however, reduced significantly to 179.78 cm in S_2 treatment and declined to 175.69, 172.91 cm.plant^{-1} in the treatments of S_1, S_0 respectively. The average PLH is decreased significantly with the drop in IQ levels (table 2). As the highest PLH value of 183.17 cm.plant^{-1} is indicated in I_1. Nevertheless, it decreased significantly to 180.62 cm.plant^{-1} in I_2 and the minimum is recorded in I_3, which is 170.35 cm.plant^{-1}.

The interaction between SA and IQ indicates significant differences. The highest PLH of 188.67 cm is found in the (S_3 x I_1) interaction. Nevertheless, the lowest value of PLH is 163.40 cm for interaction (S_0 x I_3).

3.2. Leaves number per plant (LN) (leaf.plant-1):
The results of the table.3 reveals significant LN differences and increases SA concentrations as the highest LN value is 13.84 leaf.plant^{-1} in S_3 treatment. Then it decreased to 13.05 and 11.94 leaves.plant^{-1} in S_2 and S_3 respectively. The lowest LN value of 10.76 leaves.plant^{-1} is found in S_0.

Concerning the irrigation treatments, the contrast is found in I_3 treatment, indicating the minimum LN of 11.44 leaf.plant^{-1}; however, it is increased significantly to 12.84 leaves.plant^{-1}in I_2 which does not differ significantly from I_1 which reveals 12.91 leaves.plant^{-1}.

Table 2: the effect of SA foliar application and irrigation levels on the average PLH of Maize.

Irrigation levels	SA concentrations (mg.L^{-1}) S0 0	S1 100	S2 200	S3 300	Average of irrigation levels
I_1 100%	179.07	181.47	183.47	188.67	183.17
I_2 80%	176.27	178.60	181.93	185.67	180.62
I_3 60%	163.40	167.00	173.93	177.07	170.35
Average of SA concentrations	172.91	175.69	179.78	183.80	
L.S.D 0.05	**Irrigation levels** 1.94	**SA** 1.21	**Interaction** 2.35		

Table 3: the effect of SA foliar application and irrigation levels on the average LN of Maize.

Irrigation levels	SA concentrations (mg.L^{-1}) S0 0	S1 100	S2 200	S3 300	Average of irrigation levels
I_1 100%	11.33	12.33	13.66	14.33	12.91
I_2 80%	11.00	12.05	13.27	15.05	12.84
I_3 60%	9.94	11.44	12.22	12.14	11.44
Average of SA concentration	10.76	11.94	13.05	13.84	
L.S.D 0.05	**Irrigation concentration** 0.45	**SA** 0.47	**Interaction** 0.78		

There are significant differences in the interaction between (SA) and (IQ) (table 3). The highest average value of LN is 14.33 leaf. Plant^{-1} for (S_3 x I_1) interaction while the least LN is 10,76 leaves per plant for (S_0 x I_3) interaction.

3.3. Leaves area (LA) (cm2.plant-1):

The results of table (4) indicate that there were significant differences in the average LA when the concentration of the spray solution for SA increased on the plant, with the highest average of LA at the time of treatment S_3 which was 1931.9 cm^2.plant^{-1}, while the lowest average for this characteristic at the S_0 treatment of 1184.72 cm^2.plant^{-1}.

The same table also shows that irrigation levels have a significant effect on this trait. As it was noticed that the average LA decreased significantly from 1711.2 $cm^2.plant^{-1}$ at treatment I_1 (100%) to the lowest average at I_3 treatment (60%) It reached 1319.5 $cm^2. plant^{-1}$.

Table 4: the effect of SA foliar application and irrigation levels on the average LA of Maize.

Irrigation levels	SA concentrations ($mg.L^{-1}$)				Average of irrigation levels
	S0 0	**S1 100**	**S2 200**	**S3 300**	
I_1 100%	1284.7	1579.1	1782.3	2198.6	1711.2
I_2 80%	1184.7	1479.1	1749.0	2098.6	1627.9
I_3 60%	1084.7	1312.5	1382.3	1498.6	1319.5
Average of SA concentration	1184.7	1456.9	1637.9	1931.9	
L.S.D 0.05	**Irrigation levels** 61.21	**SA** 36.00	**Interactio n** 71.87		

It is noticed that the interaction (S_3 x I_1) has the highest value of 2198.6 $cm^2.plant^{-1}$ compared to 1084.7 $cm^2.plant^{-1}$ in the interaction between S_0 and I_3.

3.4. Leaf area index (LAI):

The results of the table (5) show that there are significant differences in the average of LAI by increasing the spray concentration of SA solution on the plant, where the treatment of S_3 records the highest average of this trait which is 4.95, while the lowest average LAI is 3.33 in S_0 treatment.

Table 5: the effect of SA foliar application and irrigation levels on the averages LAI of Maize.

Irrigation levels	SA concentrations $mg.L^{-1}$				Average of irrigation levels
	S0 0	**S1 100**	**S2 200**	**S3 300**	
I_1 100%	4.13	4.50	5.00	5.70	4.83
I_2 80%	3.12	3.55	4.20	4.85	3.93
I_3 60%	2.76	3.38	3.86	4.31	3.58
Average of SA contraptions	3.33	3.81	4.35	4.95	
L.S.D 0.05	**Irrigation levels** 0.03	**SA** 0.10	**Interaction** 0.14		

The same table shows that irrigation levels have a significant impact on LAI. It is noticed that it is decreased significantly from 4.83 at the treatment I_1 (100%) to the highest average at the treatment I_3

(60%) reaches 3.58. The (S x I) interaction revealed a significant effect on LAI. The combination (S_3 x I_1) records the highest value of 5.70, whereas the least LAI is found in (S_0 x I_3) interaction.

4. Discussion

The use of salicylic acid, which the plant easily absorbs by the vegetative parts, will increase the transfer of plant sap, photosynthesis and growth speed. Then the photosynthesis products are transferred to the grains to cause their fullness, such a process leads to their large size and increases in weight, thus increasing the yield [13].

Soil that suffers from moisture deficiency causes it to hold water firmly to enable the plant to absorb this small amount; it must make an extra effort. This shortage of moisture content leads, as a result, to a decrease in plant growth. Thus a decrease in the plants' height, the number of leaves in the plant, the leaf area, and the leaf area (Tables 2, 3, 4 and 5). The reason for this may be that the vegetative growth phase is an active phase of plant's growth and expansion of cells and their division, which is influenced by water stress. The availability of sufficient moisture during the stages of plant growth, especially in the vegetative phase, has led to increasing photosynthesis speed and increasing the bulk of absorbed elements by the plant. It was positively reflected in the increase in cell division and elongation, and increased total plant growth, including plant height, number of leaves per plant and leaf area [14,15]. The water stress reduces the area index of leaves of Maise; this decrease can only be treated by water availability [16]. It inhibits the action of auxin, which leads to a reduction in plant height [17]. In this area, [18, 19] were found an increase in the height of maise plants and the average leaf area associated with the increase of added water.

The increase in the averages of all growth characteristics resulting from the addition of salicylic acid as a spray to the shoot mass of the plant, especially the concentration of 300 mg. L^{-1}, may be attributed to its stimulating role for vegetative growth as it is classified within the group of stimulating plant hormones [15]. Furthermore, it works to reduce the effect of abiotic stress inhibiting growth and level of plant hormones such as auxins and cytokines that affect cell expansion and division [20]. Which resulted in increased plant height, a number of leaves per plant, leaf area and leaf area index (Tables 2, 3, 4 and 5). These results coincide with [4] findings.

Many studies and research have indicated that treating plants with salicylic acid increases the stains' concentration essential for photosynthesis in most crops [21]. It also has an important role in regulating ion absorption, hormonal balance, and stomatal opening and closing [17]. It also contributes to inhibiting ethylene synthesis and has an opposite effect on abscisic acid. It stimulates the formation of the chlorophyll pigment and increases the proficiency of the photosynthesis process and enzymes' activity [22].

5. Conclusions:

1. Increasing the hormonal influence responsible for growth by increasing the concentration of hormones responsible for the growth.
2. We are increasing the concentration of basic pigment for photosynthesis in most crops.
3. Preventing chloroplasts from degradation by inhibiting the effect of free radicals or preventing their formation.
4. Induction of ABA acid formation.
5. We are increasing the period of plant absorption of water during plants subject to stress during the vegetative growth stage.

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