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Impact of Drought Stress on Maize (*Zea mays*) Plant in Presence or Absence of Salicylic Acid Spraying

Dina A. Ghazi
Soils Department, Faulty of Agriculture, Mansoura University, Mansoura, Egypt.
E-mail: dinaghazi3@gmail.com

ABSTRACT

A field experiment was carried out during the summer season of 2013 at the Experimental Farm, Faculty of Agriculture, Mansoura University to study the impact of spraying salicylic acid (SA) on mitigating the negative effect of drought conditions on maize hybrid plants (cross cv. Giza 10). The experiment was laid out in split plot design with three replications. In the present study, three levels (100, 75 and 50 % of water holding capacity) were arranged as main plots and two foliar applications of salicylic acid (zero "sprayed with tap water as control treatment" and 200 mg.L^{-1}) as sub-plots. The results showed that growth parameters, plant height (cm), fresh and dry weight of flag leaf (g), yield components (cob length (cm), no of grains/cob, 100 grains weight (g), grain yield, straw yield, cob yield ton/fed), mineral content of leaves (N, P and K in flag leaf), seed quality characteristics (crude protein, oil content and total carbohydrates %) were significantly decreased with drought stress at 50% of water holding capacity. While, the effect of salicylic acid sprayed at rate of 200 mg.L^{-1} on the previously mentioned traits recorded positive impact of high water deficit as compared with the control treatment (zero mg L^{-1} SA) which gave the lowest parameters. N, P and K concentrations in tested soil were significantly response ($P \leq 0.05$) to drought stress, foliar spraying of (SA) and their combinations. Reduced level of water application at 50% resulted in decreases in the concentration of available N, P and K in soil. The highest concentrations of available N, P and K in soil were recorded at 75% of water holding capacity combined with 200 mg.L^{-1} SA, while the lowest concentrations were recorded at 50% of water holding capacity in the absence of spraying with SA. It can be conclude that, foliar application of salicylic acid at rate of 200 mg.L^{-1} could be used as appropriate growth regulator for reducing the negative effects on maize plant under water deficiency conditions.

Keywords: drought stress, foliar spray, maize, salicylic acid.

Abbreviations: DS-drought stress, SA- salicylic acid

INTRODUCTION

Maize is one of the principle crop cultivated worldwide with a production and accessed 7,100 million tons forecast in 2017 (http://faostat3.fao.org,) and plays essential role and utilized in human and animal feeding in Egypt and grown in the humid tropics and sub-tropical region (Harris *et al.,* 2007). It ranks the second to wheat and equal to rice. All over the world, 5 percent of corn can be used for seed purposes to sow next crop, 25 percent for human utilization and industrial purposes, while 67 percent is utilized for livestock feed. Therefore, maize occupies the second rank after wheat and equivalent to rice.

Abiotic environmental conditions are critical elements towards restricting the crop efficiency and can adverse effect on yield capability of maize plant such as drought stress. However, maize plants are highly oversensitive to water deficiency conditions (Lobell *et al.,* 2011; Zafar-ul-Hye *et al.,* 2014). Drought stress decreases agricultural production and reduces the availability and productivity efficiency in semi-arid and rain-fed areas. Drought stress has a negative effect on ion uptake, photosynthesis, food metabolism, respiration, transport, stem expansion, root propagation, ionic imbalance and disturbances in solute accumulation, depression of enzymatic activities, alteration in metabolic activities or interaction of all these factors as a physiological and biochemical processes that the seriousness of harm relies upon the exposed to drought and varied growth stages. It is considered a standout and amongst prevalent ecological stresses (Farooq *et al*., 2009; Farahvash *et al*., 2011).

Salicylic acid is one of the most significant growth regulators which are known as phytohormones. It has low molecular weight and regulation of plant growth, biochemical and physiological processes response in plant under environmental stresses like photosynthesis, production of glycinebetaine (GB), nitrogen metabolism, proline (Pro) metabolism and antioxidant defense system that may provide security for plants against a biotic stresses under environmental stresses (Fayez and Bazaid, 2014; Nazar *et al*., 2015).

Along these lines, the fundamental target of the current investigation was to alleviate the harmful effect of water stress on maize plant by using salicylic acid as foliar spray.

MATERIALS AND METHODS

With regard to achieve the goal of this investigation; a field experiment was carried out on maize hybrid plants (cross cv. Giza 10) grown on an Experimental Farm of the faculty of agricultural, Mansoura university during the summer season of 2013 to study the alleviation of the negative effect of water deficiency on maize plant by spraying of salicylic acid. The experimental design was split plots which arranged in three replicates was done as follows: three levels of water drought stress; 100, 75 and 50 % of water holding capacity as main plots and two levels of salicylic acid; 0 and 200 mg.L^{-1} as sub-plots. The treatment combinations were six (3 water stress x 2 rates of SA), and therefore the numbers of the experimental plots were 18 plots. Soil of the experimental field was light clay in texture according to Farshad, (1984), non-saline or alkaline and moderately fertile soil. Some physical and chemical properties of the soil used in the experiment are shown in Table (1).

Seeds of maize *(Zea mays L.)* (hybrid cross, cv. Giza 10) were sown in the second week of May with an average 60 kg/fed. Plot area was 10.5 m2 (3 x 3.5 m) and consisted of 5 ridges (0.7 m wide and 3.0 long). In hills (one plant per hill) spaced at 30 cm. Fertilization was done according to the recommendations of Ministry of the Agriculture and Land Reclamation, Egypt for corn plant. A recommended fertilizer amount of NPK (200: 100: 75, kg. ha^{-1}) was applied. The sources of fertilizer were added as following: urea (46% N), super phosphate

(15% P_2O_5), and potassium sulphate (48% K_2O). The fertilizers were used in such a way that half the amount of N from urea and full amount of P and K were applied at the time of sowing, while the remaining half amount of the urea was applied with second irrigation.

Table 1. Physical and chemical properties of the study area soil during study period season 2013.

Soil characteristics								
A:Physical analysis Particle size distribution:				Saturation (%)	*B: Chemical analysis:*			
Sand (%)	Silt (%)	Clay (%)	Soil texture class		*pH value	**E.C (dS.m^{-1})	Organic matter (O.M.%)	Calcium carbonate ($CaCO_3$%)
22.4	36.2	41.4	Clay Soil	62.5	7.79	1.09	0.87	3.09
C: Available macronutrient (mg.kg^{-1})								
N							48.9	
P							6.84	
K							173	

***pH: (1:2.5) soil: water suspension; **EC: (1:5) soil: water extract**

Irrigation treatment:

The main-plots were included the following three levels of irrigation 100, 75 and 50 % of water holding capacity. Soil samples were taken from the surface soil layer (15 cm) and sub-surface layers representing the root zone (up to 60 cm) to determine the soil moisture content before and after irrigation, up to harvesting to calculate the actual water consumed by growing plants.

The sub-plots were devoted to two foliar application of amendment resistance to stresses as follows:

1- Zero mg.L^{-1} as control treatment (spraying with tap water).

2-Salicylic acid (SA): 200 mg.L^{-1}. Salicylic acid (SA) is as natural plant hormone in the form of (2-hydroxybenzoic acid) was obtained as abure powder from El-Gomhoria Company. It was prepared as stock solution at rate of 200 mg.L^{-1} and foliar applied on maize leaves 3 times, the total amount in liters of salicylic acid sprayed which used were five liter per plot at rate of 200 liter/fed; the first after 21 days after sowing and the others were two weeks later.

Plant samples were taken from each plot after 70 days from planting for measuring plant growth parameters (fresh and dry weight of flag leaf, g) and to determine the N, P and K concentrations in flag leaf. At harvesting stage; 120 days from sowing 10 plants from each plot were collected to determine (plant height (cm), cob length (cm), no of grains/cob, 100 grains weight (g), grain yield, straw yield, cob yield (ton/fed), crude protein, oil content and total carbohydrates (%).

Soil analysis

Particle size distribution of soil samples was determined according to Klute, (1986). Saturation percentage was determined according to Klute (1986). The pH was determined in soil suspension 1:2.5 and Electrical conductivity (EC) was determined in (1:5 extract) as described by page *et al.,* (1982). Calcium carbonate was determined using Collin's calcimeter method (Jackson, 1967). Organic matter content was determined using Walkely's & Black method (Jackson, 1967). Available N, P and K were determined according to Black (1965).

Plant analysis

Plant samples were oven dried at 70 ºC and digested using a mixture of H_2SO_4 and $HClO_4$ acids. Total N was determined by Micro-Kjeldahl method (Piper, 1947). Then protein values were estimated by multiplying Total N % by conversion factor 6.25 according to (Merrill and Watt 1973). Phosphorus was determined using ascorbic acid method by using spectrophotometer and K was determined by using flam photometer (Chapman and Pratt, 1961). Total carbohydrates content was estimated spectrophotometrically at 630 n.m. by the method of Hedge and Hofreiter (1962). By using soxhlet apparatus, oil content in maize grain was determined according to the method described by A.O.A.C. (2000).

Statistical analysis

Experimental design was split plots which arranged in three replicates. Data were subjected to a two-factorial analysis of variance (two-way ANOVA) between two foliar applications of salicylic acid (SA) treatments and irrigation regimes. The treatment combinations were six (3 water regimes x 2 rates of SA). Means were separated using the least-significant-difference (LSD) test at the 5% level of significance using COSTAT software according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Effects of drought stress (DS), salicylic acid (SA) as foliar spray and their interactions on some growth parameters, yield and yield components of maize plant.

Data presented in Table (2) show the effect of water stress, spraying of salicylic acid and their interactions on plant growth parameters; plant height (cm), fresh and dry weight of flag leaf (g) of maize plant through the season of 2013. It can be observed that under this study the values of all growth characteristics were significantly affected due to the tested treatments during the season.

As for the effect of drought stress, Table (2) reveal that the highest means values of all growth traits (239.68 cm, 13.05 g and 3.47 g) for plant height, fresh and dry weight of flag leaf, respectively were recorded for the plants treated with irrigation water under 75 % drought stress, while, the lowest mean values for such traits were obtained by the treatment of 50 % of water holding capacity.

Concerning the effect of salicylic acid at rate of 200 mg.L^{-1} on maize plant, data of Table (2) has been recorded a high significant increase in all the previously mentioned traits over the control treatment. Comparing with the untreated plants rate of increases were accounted to be (16.2, 19.8 and 15.6 %) for plant height (cm), fresh and dry weight of flag leaf (g) , respectively.

Referring the combination impact between water deficiency and foliar application of SA on plant growth parameters of maize plant, data of the same Table revealed that; the most suitable treatment which realized the highest means values for all growth parameter (253.63 cm, 13.87 g and 3.71 g) for plant height, fresh and dry weight of flag leaf, respectively were associated with the treatment of 75 % + salicylic acid (200 mg.L-1). While, the lowest values of plant height, fresh and dry weight of flag leaf were recorded for the plants treated with 50 % drought stress in absence of salicylic acid. Such effect was significant during the summer season of the experimentation.

Table 2. Effect of drought stress (DS), foliar application of salicylic acid (SA) and their interactions on plant height, fresh and dry weight of flag leaf of maize plants.

Treatment	Plant height (cm)	Fresh weight of flag leaf (g)	Dry weight of flag leaf (g)
A- Irrigation treatments	Drought stress (DS)		
100%	223.15	12.44	3.28
75%	239.68	13.05	3.47
50%	212.15	11.92	3.13
LSD at 5%	6.46	0.27	0.16
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	208.07	11.62	3.06
200	241.91	13.32	3.53
LSD at 5%	3.60	0.21	0.11
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	205.33	11.6	3.04
100 % + 200 SA	240.96	13.27	3.53
75 % + 0 SA	225.73	12.24	3.24
75 % + 200 SA	253.63	13.87	3.71
50 % + 0 SA	193.16	11.01	2.9
50 % + 200 SA	231.13	12.82	3.36
LSD at 5%	6.23	0.37	0.19

*** Control = Zero mg.L^{-1} SA (spraying with tap water).**

The effect of different water regimes, salicylic acid as foliar additive and their interactions on plant growth parameters; cob length (cm), no of grains/cob and 100-grains weight (g) of maize plant during the season of 2013 is shown in Table 3. Results showed that all the examined parameters were significantly differed at $p \leq 5\%$ in the study.

Regarding the effect of drought stress, data in Table (3) illustrate the highest mean values which were 18.93 cm, 468.00 and 29.66 g for cob length (cm), number of grains/cob and 100-grains weight (g), respectively for the plants irrigated at water holding capacity of 75 % and these values were reduced dramatically with irrigation water under 50% drought stress. Where, the lowest means values were (16.00 cm, 427.16 and 27.8 g) for all previous growth parameters, respectively.

Data in Table (3) show that, foliar application of SA treatments significantly affected on maize growth performances; cob length, number of grains/cob and 100-grains weight of maize plant when compared with the untreated plants. The high values in previously mentioned traits study were obtained by using the treatment (SA 200 mg.L^{-1}) over the control. The corresponding percentages increases reached (29.9, 15.02 and 3.7 %) for cob length, number of grains/cob and 100-grains weight, respectively.

Significant interaction effects were found between drought stress and foliar spraying with (SA 200 mg. L-1) on cob length, no of grains/cob, 100-grains weight of maize plant (Table 3). The highest means values of all growth parameter of maize plant (21.20 cm, 500.0 and 31.16 g) for previously mentioned traits respectively were recorded with the treatment of 75 % + salicylic acid (200 mg.L^{-1}). Plants exposed to water deficit at 50 % of water holding capacity in absence and presence of foliar application of SA showed the lowest means values of cob length, no of grains/cob, 100-grains weight than that of normally irrigated ones at 100 %. The lowest mean values were (13.76 cm, 397.0 and 26.46 g) with the treatment of 50% of water holding capacity while, with the treatment of 50 % + 200 mg. L-1 SA, cob length (cm), no of grains/cob and 100-grains weight (g) were (18.23 cm, 457.33 and 29.13 g) of maize plant, respectively.

Table 3. Effects of drought stress (DS), foliar application of salicylic acid (SA) and their interactions on cob length, no of grains/cob and 100- grains weight of maize plant.

Treatment	Cob length (cm)	No of grains/cob	100-grains weight (g)
A- Irrigation treatments	Drought stress (DS)		
100%	17.48	449.83	28.76
75%	18.93	468.00	29.66
50%	16.00	427.16	27.8
LSD at 5%	1.05	13.3	1.13
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	15.20	417.00	27.27
200	19.74	479.66	30.21
LSD at 5%	0.76	8.4	0.63
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	15.16	418.00	27.20
100 % + 200 SA	19.80	481.66	30.33
75 % + 0 SA	16.66	436.00	28.16
75 % + 200 SA	21.20	500.00	31.16
50 % + 0 SA	13.76	397.00	26.46
50 % + 200 SA	18.23	457.33	29.13
LSD at 5%	1.33	14.56	1.09

*** Control = Zero mg.L^{-1} SA (spraying with tap water).**

Data in Table (4) show that, the effect of drought stress, foliar application of salicylic acid and their interactions on plant growth parameters; grain yield, straw yield and cob yield (ton/fed) of maize plant. Results of statistical analysis on grain yield, straw yield and cob yield (ton/fed) showed that all treatments achieved significant effect with regarded to the average values of all maize growth traits. The maximum values of grain yield, straw yield and cob yield (ton/fed) of maize plant were obtained by 75% of water holding capacity. Meaning that, some growth parameters were reduced as the drought stress increased. Values of results of grain yield, straw yield and cob yield (ton/fed) of maize plant at 75% of water holding capacity were (3.09, 4.41 and 0.496 ton/fed) followed by 100 % (2.90, 4.24 and 0.477 ton/fad) while these values (2.73, 4.09 and 0.460 ton/fed) were recorded with maize plant exposed to severe stress (50%).

It can be stated that all studied yield components such as grain yield, straw yield and cob yield (ton/fed) of maize plants were significantly incremented as a result of spraying with SA 200 mg.L^{-1} compared to untreated plants and the differences among them were obvious in the summer seasons. Foliar application of SA 200 mg.L^{-1} on maize plants produced the highest values of grain yield, straw yield and cob yield (ton/fed). The lowest values of grain yield, straw yield and cob yield (ton/fed) were resulted from control treatment. Comparing with the untreated plants the increases were accounted to represent 20.1, 10.9 and 11.9 % grain yield, straw yield and cob yield (ton/fed) of maize crop, respectively.

With reference to grain yield, straw yield and cob yield (ton/fed) of maize the output from the interaction effect of water stress and salicylic acid is presented in Table (4), the highest values were (3.34, 4.63 and 0.524 ton/fed), respectively with the irrigation level of 75 % of water holding capacity with foliar application of 200 $mg.L^{-1}$ of SA and the lowest values gave (2.47, 3.88 and 0.434 ton/fed) were obtained for all previous traits of maize plant at 50 % of water holding capacity without application of SA.

Table 4. Effect of drought stress (DS), foliar application of salicylic acid (SA) and their interactions on grain yield, straw yield and cob yield of maize plant.

Treatment	Grain yield (ton/ fed)	Straw yield (ton/ fed)	Cob yield (ton/ fed)
A- Irrigation treatments	Drought stress (DS)		
100%	2.90	4.24	0.477
75%	3.09	4.41	0.496
50%	2.73	4.09	0.460
LSD at 5%	0.10	0.1	0.02
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	2.64	4.03	0.451
200	3.17	4.47	0.505
LSD at 5%	0.06	0.08	0.01
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	2.63	4.02	0.451
100 % + 200 SA	3.17	4.46	0.504
75 % + 0 SA	2.84	4.18	0.468
75 % + 200 SA	3.34	4.63	0.524
50 % + 0 SA	2.47	3.88	0.434
50 % + 200 SA	2.99	4.31	0.486
LSD at 5%	0.1	0.14	0.02

*** Control = Zero $mg.L^{-1}$ SA (spraying with tap water).**

Salicylic acid (SA) has the ability to alleviate the drought impact on plants growing under these conditions. Enhanced growth of plant probably because of the improved mitosis, carbon assimilation, promote synthesis of metabolites, an improvement in the water status in cell, plant height may be attributed to enhance cell elongation and by foliar application of SA under water deficit conditions. The appropriate effect of additive of Salicylic acid on maize growth traits exposed to drought conditions, appeared in the current study, was identical to Hamada and el Hakimi (2001) who showed that the negative effect of water stress was mitigated and induced growth by improving photosynthetic rate and reduction dark respiration by wheat seeds soaked in 100 SA treatments. Results in the current study are compatible with the results of other researches Khodary (2004) ; Aydin *et al*., (2007) and Mahdi *et al*., (2013).

Effects of drought stress (DS), salicylic acid (SA) as foliar spray and their interactions on the concentration of nitrogen, phosphorus and potassium of maize plant.

The impact of soil drought stress, foliar application of SA at rate of 200 $mg.L^{-1}$; and their interaction on the total nitrogen, phosphorus and potassium percentage of maize crop is shown in Table (5). The average values of total nitrogen, phosphorus and potassium content in maize plant significant effect as a result of all the investigated treatments during the summer season 2013.

Data presented in Table 5 showed that the effect of drought stress on the total nitrogen, phosphorus and potassium percentage of maize plant considerable variation among the treatments 100 %, 75 % and 50 % of water holding capacity. Irrigation deficit treatments markedly decreased total nitrogen, phosphorus and potassium percentage by average values (2.26, 2.48 and 2.05 %) for the total N percentage, (0.265, 0.280 and 0.245 %) for the total P percentage and (1.86, 2.05 and 1.66 %) for the total K percentage, respectively. Also, salicylic acid application was achieved significant results for the above traits. Treatment of 200 $mg.L^{-1}$ of salicylic acid had the highest values of total NPK percentage, in maize plant, while, control treatment had the lowest one. The corresponding percentages increases were (34.19, 23.30 and 40 %) for N, P and K, respectively. Furthermore, the interaction effect of drought stress and salicylic acid on the total nitrogen, phosphorus and potassium percentages in maize was illustrated in the same Table. The most suitable treatment which realized the highest means values of total NPK percentages of maize plant (2.81, 0.307 and 2.38 %), respectively due to the treatment of 75 % + salicylic acid (200 $mg.L^{-1}$). While, the lowest one was recorded for the plants irrigated at 50 % drought stress in absence of salicylic acid.

Table 5. Effect of drought stress (DS), foliar application of salicylic acid (SA) and their interactions on the concentration of nitrogen, phosphorus and potassium of maize plant.

Treatment	N %	P %	K %
A- Irrigation treatments	Drought stress (DS)		
100%	2.26	0.265	1.86
75%	2.48	0.280	2.05
50%	2.05	0.245	1.66
LSD at 5%	0.07	0.013	0.17
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	1.93	0.236	1.55
200	2.59	0.291	2.17
LSD at 5%	0.11	0.007	0.09
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	1.93	0.236	1.56
100 % + 200 SA	2.59	0.294	2.17
75 % + 0 SA	2.15	0.253	1.72
75 % + 200 SA	2.81	0.307	2.38
50 % + 0 SA	1.73	0.218	1.37
50 % + 200 SA	2.38	0.272	1.96
LSD at 5%	0.19	0.013	0.15

*** Control = Zero $mg.L^{-1}$ SA (spraying with tap water).**

Plants exposed to water deficit, may be suffer from reduction in plant nutrient uptake by declining nutrient absorption. In addition to, depressing in soil moisture can decrease in carbon dioxide induction rates, transfer, redistribution, stomatal conductance, photosynthesis and transpiration rates were gradually reduced due to drought conditions. Hamada and Al-Hakimi, (2001) found that in both wheat cultivars, K concentration in shoots and roots was progressively reduced with the increasing of stress. These obtained results are in a agreement with those obtained by (Lambers *et al*., 2008; Ali and Ashraf 2011 ; Farooq *et al*., 2012). Khan *et al*., (2010) also indicated that application of SA at lower concentration enhanced the root growth and root length, increasing root capacity in absorption of nutrients from rhizosphere zone and distribution to different organs of plants as a result of increasing the yield of wheat and maize due to the role of SA in enhancing some physiological processes in plant and has inducement effect.

Influence of drought stress (DS), salicylic acid (SA) as foliar spray and its interactions on the quality characteristics of maize crop.

Influence of drought stress, foliar spraying of (SA) and their combination on crude protein content, oil content and total carbohydrates % of maize plants are shown in Table (6). The results showed that the values of all quality characteristics were significantly affected by studied treatments.

Different water stress treatments showed varying effects on (i.e., crude protein, oil content and total carbohydrates %) of maize plant as shown in Table (6). All obvious quality characteristics were in descending decreased as drought stress increased, up to 50 % of water holding capacity. The highest mean values of all quality characteristics were 15.5, 3.8 and 74.65 % for crude protein, oil content and total carbohydrates %, respectively for the plants treated with 75 % of water holding capacity. The lowest mean values related with the treatment of severe stress 50 % (12.86, 3.26 and 77.35 %) for the obviously mentioned traits, respectively. On the other hand, maize plants treated with salicylic acid (200 mg.L^{-1}) gave an increase in the mean values of quality characteristics; crude protein, oil content and total carbohydrates %. For the untreated plants (without SA), the tested quality characteristics were decreased by (33.9, 22.8 and 4.7 %), respectively as compared to treated ones. Studying the interactions between drought stress and foliar spray of salicylic acid (200 mg.L^{-1}) (table 6) results showed that maize plants treated with 200 mg.L^{-1} SA increased quality characteristics at all tested treatments of irrigation (100%, 75 and 50 % of water holding capacity), respectively. Crude protein, oil content and total carbohydrates % of maize plants were recorded the highest mean values with the treatment of 75 % + SA 200 mg.L^{-1} (17.56, 4.26 and 81.46 %), respectively while, the lowest ones were associated with (50 %) severe stress (10.83, 2.97 and 75.56 %), respectively for Crude protein, oil content and total carbohydrates % in absence of SA and (14.89, 3.55 and 79.13 %), respectively in presence of SA. Ahmad *et al.,* (2003) found that drought conditions may be due to reducing photosynthesis rates thus, protein concentration and biosynthesis and enhancing degradation, depress the nitrate reeducates activity and nitrogen metabolism in plants gradually reduced. Salicylic acid cause increasing protein synthesis through increased nitrate reductase activity and mitigate the deleterious effect of stress by increasing the antioxidant compounds formation and improving antioxidant enzymes activity as well as inducing proteins formation. Several researchers such as (Mohamed and Naglaa 2010 ; Ali and Ashraf 2011) reported similar results.

Water deficiency had negative effect on carbohydrates producing in maize plant, this may be related to the reducing of water status in leaves, decreases in CO_2 inducing as a result of reducing physiological open of leaf stomata also, drought stress causes decline in the formation of plant pigments. Meanwhile, Chaves *et al.,* (2002) revealed that in maize plants, reduced photosynthesis rate and the decrease of the activity of ribulose 1,5-bisphosphate carboxylase resulted in decreasing of synthesis of carbohydrates under saline stress. The incrimination in carbohydrates content probably due to increasing photosynthetic process activity cause by SA foliar application which has inducing effects on plants thus, increasing total carbohydrates content in maize plant. These results are in harmony with those of (Baghizadeh *et al.,* 2009 and Mohamed, 2015).

Table 6. Effect of drought stress, foliar application of salicylic acid and their interaction on the crude protein, oil content and total carbohydrates % of maize crop.

Treatment	Crude protein (%)	Oil content (%)	Total carbohydrates (%)
A- Irrigation treatments	Drought stress (DS)		
100%	14.14	3.47	78.43
75%	15.50	3.80	79.65
50%	12.86	3.26	77.35
LSD at 5%	0.45	0.39	0.44
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	12.12	3.15	76.66
200	16.23	3.87	80.28
LSD at 5%	0.69	0.24	0.73
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	12.06	3.14	76.6
100 % + 200 SA	16.23	3.80	80.26
75 % + 0 SA	13.44	3.35	77.83
75 % + 200 SA	17.56	4.26	81.46
50 % + 0 SA	10.83	2.97	75.56
50 % + 200 SA	14.89	3.55	79.13
LSD at 5%	1.19	0.43	1.26

*** Control = Zero mg.L^{-1} SA (spraying with tap water).**

The oil content was decreased as result of seed yield decline in spite of oil percentage increment of maize plants under drought conditions because the oxidation process that is done in cells of maize plants exposed to water deficiency resulting in production many metabolites. Drought stress increases the oil percentage because more metabolites are produced in the plants and substances prevent from oxidization in the cells, but oil content reduces under drought stress, because the interaction between the amount of the oil percentage and seed yield is consider important as two components of the oil content, therefore essential oil content reduces (Ali *et al.,* 2009 and Aliabadi *et al.,* 2009 ; Ali and Ashraf 2011).

Regarding foliar spraying with salicylic acid, the oil content, crude protein and total carbohydrates percentage of corn plant were progressively increased because SA has positive effect on enhancing active transfer of the photosynthesis products from source to sink, maize growth parameters, influences on enzymatic activity and nutrients uptake. Results obtained were in harmony with those of El-Khallal *et al.,* (2009) on corn plant.

Influence of drought stress (DS), salicylic acid (SA) as foliar spray and its interactions on available nitrogen, phosphorus and potassium concentrations in soil.

Data in Table 7 show the effect of drought stress, foliar spraying of (SA) and their combination on the nitrogen, phosphorus and potassium concentrations in soil under the present study after harvest during the season of 2013. The results indicated that, N, P and K concentrations in studied soil were significantly responsive to drought stress, foliar spraying of (SA) and their combination during the summer season. Reduced level of irrigation water applied resulted in decreases in the concentration of N, P and K in soil. N, P and K concentration in soil were the highest (2.66, 0.31 and 2.32 %), respectively at 75 % of water holding capacity as compared to (1.97, 0.22 and 1.80

%), respectively at 50 % of water holding capacity (Table 7). Salicylic acid (SA) increased nitrogen, phosphorus and potassium by18.01, 16.66 and 19.87 %, respectively as shown in Table 7. Furthermore, the interaction effects of drought stress and salicylic acid on the concentration of nitrogen, phosphorus and potassium in studied soil were illustrated in the same Table 7. The most suitable treatment which realized the highest means values of available N, P, and K concentrations in studied soil were (2.89, 0.336 and 2.54 %), respectively associated with the treatment of 75 % of water holding capacity plus salicylic acid (200 mg.L^{-1}). While, the lowest concentrations of available N, P and K were recorded for the soil irrigated with 50 % of water holding capacity in absence of salicylic acid.

Table 7. Effect of drought stress (DS), foliar application of salicylic acid (SA) and their interactions on available nitrogen, phosphorus and potassium concentrations in soil of experiment.

Treatment	% N	% P	% K
A- Irrigation treatments	Drought stress (DS)		
100%	2.27	0.25	2.04
75%	2.66	0.31	2.32
50%	1.97	0.22	1.80
LSD at 5%	0.03	0.03	0.05
B- Foliar application (Salicylic Acid) mg L^{-1}	Foliar application		
Control(0)*	2.11	0.24	1.87
200	2.49	0.28	2.24
LSD at 5%	0.01	0.001	0.01
C- Interaction (A X B)	(Irrigation treatments X Foliar application)		
100% + 0 SA	2.08	0.237	1.86
100 % + 200 SA	2.43	0.270	2.22
75 % + 0 SA	2.46	0.293	2.11
75 % + 200 SA	2.89	0.336	2.54
50 % + 0 SA	1.81	0.209	1.65
50 % + 200 SA	2.12	0.237	1.96
LSD at 5%	1.01	0.07	0.03

*** Control = Zero mg.L^{-1} SA (spraying with tap water).**

This could be attributed to the reduction of water content the microbial activity weakened and declined as soil drought stress intensified which caused changes and degradation of soil structure in soil ecosystem productivity. In semi-arid and Mediterranean-type ecosystems, a rainfall reduction often leads to nutrient accumulation in the soil during the dry period, because of a stronger reduction in plant uptake compared with mineralization rates in the soil, thus the soil content of available nitrogen, phosphorus and potassium were decreased (Matıas *et al.,* 2011). This is consistent with findings by Hueso *et al*., (2012) who found that microbial activity and community structure could be seriously damaged by drought stress, and microorganisms would disappear under the adverse condition because they could not adapt to drought stress. Schimel *et al*., (2007) showed that drought stress and associated reduction in soil moisture can reduce plant nutrient uptake by reducing nutrient supply through mineralization, also by reducing nutrient diffusion and mass flow in the soil. Exogenous applications of SA participate in regulation of several physiological processes in plants, such as, ion uptake and transport. Also, it meliorates the growth of crop and nutrient content in maize plants where enhanced under reduction of water content (Khan *et al.,* 2010).

CONCLUSION

It can be referred that treating maize plant with salicylic acid (SA) mitigated the effect of drought stress on maize plant growth. Parameters, maximum yield, yield components and quality characteristics were increased and also the concentrations of available N, P and K in studied soil where, it improved the growth of root system. All of these parameters are realized for the plants treated with the suitable treatment of salicylic acid at rate of 200 mg.L^{-1} as foliar application. Salicylic acid has the capability to improve the negative effect of drought stress on maize growth via reducing the oxidative damage of plant membranes resulted in water deficiency conditions. Additionally, it enhanced morphological growth parameters, biochemical characteristics and chemical composition of maize.

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تأثير الجفاف على نبات الذرة في وجود أو غياب الرش بحمض السلسليك

دينا عبد الرحيم غازي

قسم الاراضي – كلية الزراعة – جامعة المنصورة – المنصورة – مصر

أجريت تجربة حقلية خلال الموسم الصيفي 2013 في المزرعة التجريبية بكلية الزراعة – جامعة المنصورة لدراسة تأثير الرش الورقي بحمض السلسليك في التخفيف من الأثار السلبية لظروف الجفاف علي نبات الذرة الهجين (جيزة 10) بتصميم القطع المنشقة بثلاث مكررات وشملت التجربة ثلاث مستويات من الاجهاد المائي (100% - 75% - 50% من قدرة التربة علي الاحتفاظ بالماء) كقطع رئيسية والرش الورقي بحمض السلسليك بتركيزين (صفر"الرش بماء الصنبور كمعاملة الكنترول و 200 ملجرام / لتر) كقطع تحت رئيسية . أظهرت النتائج أن الاجهاد المائي يقلل من خصائص النمو (ارتفاع النبات (سم) والوزن الطازج والجاف لورقة العلم) ومكونات المحصول (طول الكوز ، عدد الحبوب / الكوز، وزن 100 حبة ، محصول الحبوب، محصول القش،محصول الكيزان (طن /فدان) ، و المحتوى المعدني للأوراق (النسبة المئوية للنيتروجين ، الفوسفور ، البوتاسيوم)، خصائص جودة الحبوب (النسبة المئوية للبروتين الخام، ومحتوى الزيت، والكربوهيدرات الكلية) حيث أنها انخفضت بشكل ملحوظ مع إجهاد الجفاف عند 50٪ من قدرة التربة علي الاحتفاظ بالماء. في حين أن تأثير رش حامض السلسليك بمعدل 200 جزء في المليون على الصفات المذكورة سابقا لمحصول الذرة سواء للنباتات المعرضة للاجهاد أو غير المعرضة للاجهاد سجل تأثير إيجابي مع الاجهاد المائي العالي و بشكل ملحوظ مقارنة مع معاملة الكنترول (صفر جزء في المليون حمض سلسيليك) التي أعطت أقل النتائج. ويمكن أن نستنتج من ذلك أنه يمكن استخدام الرش الورقي لحمض السلسليك بمعدل 200 جزء في المليون كمنظم نمو مناسب يستخدم للحد بشكل كبير من الآثار السلبية للجفاف على نبات الذرة تحت ظروف نقص المياه.