Annals of Biology **38** (2) : 199-205, 2022

Impact Score : 0.32 (Scopus)

The Tolerance of Maize (*Zea mays* L.) to Dry Season Conditions in Iraq

EMAD T. ABDEL GHANI*, ABDULNASER T. M. AL-RAWI AND NAWFAL A. SABRY

Upper Euphrates Basin Developing Center (UEBDC), University of Anbar, 31001, Anbar, Iraq
**(e-mail : emadabdulghani@uoanbar.edu.iq; Mobile : +964 78221 51920)*

(Received : April 5, 2022; Accepted : May 8, 2022)

ABSTRACT

During the spring of 2018, a field investigation was carried out at one of the private clay loam soil fields in the Latifiya region (southern Baghdad, Iraq). The goal was to determine the effect of water stretch (WS) and foliar application of salicylic corrosive on yield attributes of corn (*Zea mays* L.) plants during the dry season. The randomized completely block design (RCBD) of three replications inside the split-split plotting system was used. The main plots showed four different concentrations of salicylic acid (SA : 0, 100, 200 and 300 mg/l). Three irrigation remedies (IQ) were used in the sub-plots : One hundred % (full irrigation), 80% and 60% of accessible water. The salicylic acid (SA) and the irrigation remedies (IQ) had proven a considerable impact on all traits. The (300 mg/l) level of SA offered the absolute best average of chlorophyll and proline content material in leaves (CCL and PCL) and yields as well. The interplay between SA and IQ showed great variations as the maximum green yield was 8870.7 kg detected at D_3 x I_1. However, the lowermost rate of grain yield was 6346.4 kg in comparison with S_0 x I_3. The grain yield of 7714.0 kg existed in the D_1 x I_3 because it used 40% of available water to the cultivated area. Therefore, these findings suggested the opportunity of making corn vegetation (*Zea mays* L.) greater adaptable to drought conditions by the use of water stress and salicylic acid foliar application. Such tolerance led to limiting plant-water requirements without massive consequences on the yield properties.

Key words : Salicylic acid, irrigation amount, chlorophyll, proline, production

INTRODUCTION

Drought influences most of the plants, although the effect differs from one variety to the next. To meet the developing food needs of future societies, it is essential to consider the sorts of flora that require much less water or require low moisture content in the soil, as well as the truth that areas susceptible to drought will surge, decreasing food production. As a result, farmers must increase the productivity rates of crops grown under irrigation (Yasmin, 2022). Therefore, the proper water necessities of plants and when to add them are important to keep away from losing irrigation water, which motives a discount of irrigation proficiency and makes bigger production expenses as well.

There are numerous procedures to confront drought and water shortage problems, like plant boom regulators (auxins), which are modifier substances that decorate a plant's functionality for most use of its latent physiological and genetic energy (Akbar *et al.*, 2022). SA additionally accelerates the formation of chlorophyll and carotene stains, which stimulate photosynthesis and enlarge the pastime of some necessary enzymes; additionally, SA inhibits plant pathogens, which improves systematic immunity in most floras; and finally, it can inspire adjustments in evolutionary features that can assist plant life face up to a vast vary of environmental stresses induced through extremes in temperature, freezing, drought and salinity (Li *et al.*, 2020). Maize (*Zea mays* L.) is one of Iraq's most significant crops. The productiveness of maize relies upon the ultimate use of water in accordance to precise time which corresponds to the distinct ranges of plant growth. The measurement of irrigation water by assessing water stress is an essential subject matter that seeks to save extra volumes of water for use in farming additional regions with fewer water sources (Changjian *et al.*, 2020). Because of the relevance of SA in reducing the effects of water stress, this research was carried out to perceive the feature of the exterior utility of SA on enhancing maize tolerance to water stress and to discover the best awareness of utilized SA.

MATERIALS AND METHODS

During the spring season of 2018, a supervision study was done on one of the personal farms in the Latifiya area of southern Baghdad. The purpose of this research was to learn how to increase maize's resilience to water stress by using salicylic acid (SA) to reduce the effects of drought on this plant.

The research had the following factors :

Salicylic corrosive (SA) was utilized at four particular levels of 0, 100, 200 and 300 mg/l represented by D_0, D_1, D_2 and D_3, successively. Irrigation (IQ) had three tiers (60, 80 and 100%) of maximum evapo-transpiration assessed through Qi *et al.* (2020) and included descriptions correspondingly.

The general experimental design was the randomized completely block design (RCBD). The split-split plots framework (SSPS) was once scattered via RCBD with three replications, with water machine redress possessing the most plots and SA remedies occupying the sub-plots. The entire range of gadgets with replications was predicted to be four × three x three = 36.

A moldboard was utilized to plough the field twice vertically. Then, the works of diminishing, levelling, and plots dividing were executed. The measurements of every single plot were 9 m^2 (3 x 3) in addition to 2 m distance between every two plots and also between every two blocks, to prevent cross drive of water among plots. There were four furrows with a 0.75 meter area per two furrows and 0.25 meter spacing between pits on the same furrow.

Before cultivation, random soil samples were collected from two depths : 0-30 and 30-60 cm. As indicated in Table 1, soil samples were completely translocated to the Ministry of Science and Technology labs for examination. On March 15, 2018, the seeds of corn (IBAA 5018) were cultivated (3-4 seeds per single pit). Irrigation was provided in three batches (each with a depth of 30 mm). The first batch was the germination batch, which was introduced on March 15, 2018, and the second batch was presented on March 20, 2018, to boost the boom and complete the germination process. On March 25, 2018, the 0.33 batches were inserted to preserve enough moisture in the soil whilst additionally stimulating the boom of sparkling seedlings (Qi *et al.*, 2020). All unsuccessful pits were replanted on the 1st of April 2018, which was the default date, once 75% of seedlings had emerged. After limiting the number of flowers to one per pit, the plant density was 5333 vegetations per hectare. Treatments were separated by symbols and signs. The treatments were watered every 10 days from the germination date. Then the tri-superphosphate (46% P_2O_5) at 86 kg P/ha was added as a phosphorus source by hands in one batch during the period between tillage and thinning. Nitrogen topdressing was added by 200 kg N/ha using urea fertilizer (46% N) in four equal batches. The 1st lot of fertilizer was added directly after the germination, the second batch was applied 20 days after the first batch, while the third one was applied at the beginning of the booming stage. The fourth lot was applied at the beginning of the formation of the grains in the heads. All the field operations of removing weeds, pathogens and birds attacks were performed. The next morning, all of the flowers were washed with distilled water to remove accumulated dirt from each trial unit completely moist. After one month of germination, the salicylic acid (SA) solution was sprayed on the vegetative portion. Auxiliary flowers in every furrow, 10 flora were randomly resampled from the middle. The weight of 500 grains (WOG), the content of chlorophyll in leaves (CCL), proline content in leaves (PCL), the number of grains per ear (NGPE), and grain yield (GY) were estimated.

Table 1. Chemical and physical characteristics of soil during spring of 2018

Depth	0-30 cm	30-60 cm
Clay	34	31
Sand (%)	39	56
Silt	27	13
Texture class	Clay loam	Silty clay loam
Perpetual wilting point (%)	20.4	13.5
Field capability (%)	30.3	23.8
Available water (%)	23.0	17.5
Bulk density (Mg/ha)	1.29	1.38
Organic matter (g/kg)	8.5	3.4
EC (Electrical conductivity)	2.94	1.98
pH (Hydrogen potential)	7.75	7.56
Existing nitrogen	83.0	21.0
Existing phosphorus (ppm)	7.5	6.2
Existing potassium	169.0	89.0

RESULTS AND DISCUSSION

The highest average CCL at the S_3 was 5.06 mg/g, though the lower most average for this property was found in S_0 (the control treatment) of 3.40 mg/g (Table 2). It was noticed that the CCL average decreased along with IQ reduction, as the I_1 treatment (100%) recorded the highest CCL of 4.88 mg/g and it decreased to 3.96 mg/g for the treatment I_2 (80%), then it decreased to the minimum average of 3.69 mg/g at the treatment of I_3 (60%). The interaction between SA and IQ implied significant differences. The interaction (S_3 x I_1) had the simplest CCL of 5.76 mg/g. Nonetheless, the lowest value of 2.90 mg/g was found in the interaction of S_0 x I_3.

There were significant differences among plants in PCL because of increasing SA (Table 3). The averages of PCL were 60.92, 67.61, 73.41 and 78.78 mm/g for S_0, S_1, S_2 and S_3, respectively. The interface between SA and IQ showed important changes. The maximum PCL was 93.63 mm/g existed in the (D_3 x I_3) exchange. Yet, the lower most PCL was 47.70 mm/g for the interaction of S_0 x I_1.

There were significant differences in the average GNPE as a result of the increased application of SA level in the corn plants (Table 4). GNPE increased compared to the control treatment as the concentration of SA increased. The averages were 343.2, 385.0, 441.4 and 505.8 grains/ear for the treatments S_0, S_1, S_2 and S_3, respectively. It was observed that there were important disparities in the prevalence of this characteristic due to irrigation levels. The average GNPE decreased significantly by increasing water stress on the plant by reducing irrigation levels, with the maximum mean GNPE recorded at the transaction I_1 (100%) reached 488.2 grains/ear. Whereas the least mean for this trait at the I_3 transaction (60%) was 369.1 grains/ear. The interplay between SA and IQ displayed large variations. The best GNPE was 575.7 grains/ear in the interplay (D_3 x I_1). Despite this, the lowermost determined was once 292.7 grains/ear for interplay with (S_0 x I_3).

There was substantial variation for the average GW when raising the level of SA

Table 2. The impact of SA foliar spray and irrigation ranges on corn CCL means (mg/g)

Irrigation level	SA				Irrigation level means
	S_0 0	S_1 100	S_2 200	S_3 300	
I_1–100%	4.16	4.54	5.05	5.76	4.88
I_2–80%	3.16	3.59	4.22	4.88	3.96
I_3–60%	2.90	3.40	3.93	4.53	3.69
Average of irrigation level	3.40	3.84	4.40	5.06	
L.S.D. (P=0.05)	Irrigation level	SA	Interaction		
	0.07	0.10	0.16		

Table 3. The impact of SA foliar spray and irrigation ranges on corn PCL (mm/g)

Irrigation level	SA				Average irrigation level
	S_0 0	S_1 100	S_2 200	S_3 300	
I_1–100%	47.70	51.70	55.00	62.23	54.16
I_2–80%	63.80	66.93	72.67	80.47	70.97
I_3–60%	71.27	84.20	92.57	93.63	85.42
SA	60.92	67.61	73.41	78.78	
L.S.D. (P=0.05)	Irrigation level	SA	Interaction		
	5.40	5.31	8.85		

Table 4. The impact of SA foliar spray and irrigation ranges on the mean highest GNPE (grains/ear)

Irrigation level	SA				Average irrigation level
	S_0 0	S_1 100	S_2 200	S_3 300	
I_1–100%	417.7	454.3	505.3	575.7	488.2
I_2–80%	319.3	361.0	428.3	488.3	399.2
I_3–60%	292.7	339.7	390.7	453.3	369.1
SA average	343.2	385.0	441.4	505.8	
L.S.D. (P=0.05)	Irrigation level	SA	Interaction		
	7.2	8.8	14.1		

applied to maize (Table 5). The highest GW average was noticed at the treatment S_3 143.3 g, while the lowest average for this trait was 132.4 g for control. There were important alterations in the mean of plant properties by affecting irrigation levels. The average GW decreased significantly as the levels of irrigation decreased leading to increased water stress in the crop, as the maximum mean GW in I_1 (100%) was 142.8. However, the lowest average for this trait was 129.8 for I_3 (60%). The interference between IQ and SA designated important variances. The maximum GW of 148.3 g was noticed in the (D_3 x I_1) interference. However, the lower most rate GW was 123.0 g at the interference of S_0 x I_3.

There were substantial variations in the average GY as the amount of SA applied to the plants increased (Table 6). The highest GY value was 8377.8 kg/ha at the treatment of S_3, but it was significantly decreased to 7975.7 kg/ha in the treatment S_2 and to 7579.6 kg/ha in S_1 treatment. However, the lowest average of GY was 7301.9 kg/ha in the control treatment (Table 4). The interplay between SA and IQ revealed substantial variations. The maximum GY of 8870.7 kg/ha was indicated in the D_3 x I_1 interference. However, the minimum GY was 6346.4 kg/ha for the interference (S_0 x I_3).

SA treatment of crops raised the level of basic photosynthesis in the majority of plants. It additionally had a necessary function in regulating the absorption of ions, hormonal balance, and opening and closing of stomata (Arif *et al.*, 2020). Additionally, subsidized the shape of ethylene and had the contrary impact on abscisic acid, as it prompted the creation of chlorophyll stain to upsurge the efficiency of photosynthesis and enzyme effectiveness. This was evident through the increase in the content of chlorophyll in leaves (Table 2). The reason for the increase in the content of chlorophyll in leaves by SA was as it played an important role in maintaining green plastids from catabolism (caused by increased production of free roots) and increased the proportions of antioxidants that kept plastids and stains from decomposing due to environmental stress potential (Afzal *et al.*, 2022). It was also because SA had a wide range of important functions such as antioxidants, photoprotective, photosynthesis, growth and hydrogen peroxide sweep. These results were matched by the findings of both.

The role of SA and proline is interconnected and complementary to each other when environmental stress occurs, as proline adjusts the osmosis of leaves and maintains cell hydration and energy production during the duration of stress as well as being a source of carbon and nitrogen, while SA prevents the decomposition of proline due to oxidative enzymes and the effect of free roots (Nazar *et al.*, 2015). The SA also plays a role in the

Table 5. The impact of SA foliar spray and irrigation ranges on the GW average of maize

Irrigation level	SA				Average irrigation level
	S_0 0	S_1 100	S_2 200	S_3 300	
I_1–100%	138.7	141.0	143.3	148.3	142.8
I_2–80%	135.7	138.0	141.3	145.3	140.1
I_3–60%	123.0	126.7	133.3	136.3	129.8
SA	132.4	135.2	139.3	143.3	
L.S.D. (P=0.05)	Irrigation level	SA	Interaction		
	1.8	1.2	2.2		

Table 6. The impact of SA foliar spray and irrigation ranges on the maize average GY

Irrigation level	SA				Average irrigation level
	S_0 0	S_1 100	S_2 200	S_3 300	
I_1–100%	7909.0	8148.4	8352.4	8870.7	8320.1
I_2–80%	7647.2	7865.6	8174.9	8547.6	8058.6
I_3–60%	6346.4	6724.0	7399.9	7714.0	7046.3
Average of SA concentration	7301.9	7579.6	7975.7	8377.8	
L.S.D. (P=0.05)	Irrigation level	SA	Interaction		
	188.4	122.6	233.1		

catabolism of nitrogen, which is one of the factors influencing the accumulation of proline acid. SA stimulates some processes and inhibits others depending on its concentration in the plant, the stage of growth, and environmental conditions. It also induces the production of abscisic acid (ABA) to protect plant reactions from stress damage such as dehydration and drought and increases the accumulation of proline. Several studies conducted on various crops, such as legume and wheat crops, have stated that SA increases water stress and relieves stress damage when the plant grows at the seedling stage, increasing the accumulation of proline (Ding and Ding, 2020). It also increases the proportion of proline and osmotic pressure in the leaves and then increases the plant's ability to absorb water from the soil, especially in the stage of vegetative growth of the plants exposed to environmental stress. This was evident through the increase in the content of proline in the leaves as shown in Table 3. The significant superiority of SA is due to its role in the accumulation of proline by protecting the proline production enzymes from oxidation, as SA is one of the most important non-enzymatic antioxidants.

The use of SA, which is easily absorbed by the plant through vegetative parts, increases the speed of transmission of plant juicer, photosynthesis, and rapid growth, and thus the transmission of photosynthesis products to grains and their fill, leading to large size and GW and thus increases the GY (Table 6).

The stains found within green plastids are the most important compounds in converting photovoltaic energy into chemical energy in the plant, and chlorophyll is one of the most important active strains in the photosynthesis process (Hassan, 2014). The concentration of this strain in the leaves is influenced by environmental stresses such as temperatures, high lighting and abundant water. Several studies have shown that the content of chlorophyll in plant leaves decreases in the final stages of plant growth due to chlorophyll decomposition in addition to leaf aging, as the chlorophyll stability and the heat tolerance decreases due to water stress as it leads to the formation of decomposition enzymes (Proteolytic enzymes) such as chlorophyllase, which is responsible for chlorophyll decomposition.

The exposure of maize plants to water stress increased their amino acid content, including proline, in varying proportions (Zhang *et al.*, 2018), as shown in Table 3. This was the accumulation of proline having an important role in the process of osmotic regulation within the cell, as it concentrated in the cytoplasm to balance the osmotic potential of cellular liquid. It acted as a keeper of enzymatic activity under dry conditions and salinity (Rajasheker *et al.*, 2019) as well as maintained the compositions of large molecules and organs within the cell, underwater stress conditions, the rate of proline oxidation decreased, and the accumulation occurred for it. The water stress increased the accumulation of proline acid in plant cells. It was also found that exposing plant leaves to water stress caused an increase in the content of bromine in wheat and maize crop leaves.

Many researchers found a clear decrease in grain yield for the maize crop under water stress conditions. The results (Yao *et al.*, 2022) indicated that exposing the plant to water stress during the period of the flowering stage reduced fertilization and grain knotting. Therefore, they attributed this to several reasons, including the low average of leaf area and its index or the slowdown in plant growth rate, as water stress affected the compatibility between male and female flowering, which in turn negatively affected the number and weight of grains and thus the total yield of grains through *in vitro* fertilization (IVF) did not occur in its normal form (Shi *et al.*, 2021). This was what was found in Table 4 and these results agreed with those of Wang *et al.* (2018) that the lack of irrigation in the phase of flowering led to a decrease in the yield of maize by about 42% compared to the treatment of complete irrigation. The results confirmed a 38% decrease in the yield of maize grains due to lack of irrigation during the stages of vegetative growth and flowering. Further, stated that grain yields decreased when water stress occurred at any stage of crop growth. Lack of irrigation during the vegetative growth and flowering phases led to a significant reduction in the yield of maize grains.

Results of Ndlovu *et al.* (2021) pointed out that water stress during the duration of the filling of the seeds led to small size and low weight of corn grains, where the loss of grain size reached 50%. The researcher (Para *et al.*, 2022) found that the weight of grains was among the most yield components from one generation to another, and was influenced by growth factors, and that water stress had a significant impact on the weight of 500 grains (Table 5) as the final weight of the grains was the consequence of the interference between genetic and growth issues. The citation stated that water stress during the flowering phase reduced the weight of the grains per ear. The signs stated that water stress affected the weight rate of grains, and the exposure of plants to water stress in the vegetative phase led to the production of small grains because of the low fullness of their grains and it was concluded that the surplus was stored in the stem and thus, the weight of the grains decreased. The adequacy of irrigation in the stages of vegetative growth and flowering had increased the leaf area of the plant and thus increased the products of the photosynthesis process, which had effectively contributed to increasing the fullness and weight of the grain, as well as the role of water in increasing the flow of photosynthesis-produced materials to their places of need in the plant. The weight of the grain was determined by the cultivar, the number of formed grains, and the number of metabolic substances available to them (Ignacio *et al.*, 2019).

CONCLUSION

The following conclusions were reached :

- Good spray of salicylic acid on the vegetative part of maize for growth and yield properties.
- The amount of irrigation water added to the crop can be reduced without affecting the growth and yield properties.
- The apparent effect of salicylic acid played a major role in the tolerance of the maize plant to water stress conditions.
- The maize plant showed good resistance to water stress conditions, making it possible to grow it in the central region of Iraq.

RECOMMENDATIONS

- Use 80% irrigation as well as spray 300 mg/l of salicylic acid on the vegetative part to get the best growth and yield properties.
- Continue future studies and research including higher concentrations of salicylic acid with irrigation levels to find the best combination of irrigation for maize crops.

ACKNOWLEDGEMENT

The authors would like to acknowledge the contribution of the University of Anbar (www.uoanbar.edu.iq) by their prestigious academic staff in supporting this research with all required technical and academic support.

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