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Response of Three Yellow Maize Hybrids to Exogenous Salicylic Acid under Two Irrigation Intervals

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ABSTRACT
Two field experiments were conducted during 2010 and 2011 successive seasons to investigate the response of three yellow maize hybrids (S.C. Giza 166, S.C. Pioneer (N 11) and S.C. Hosary) to exogenous Salicylic Acid (SA) under two irrigation intervals. Treatments included SA concentrations (0, 0.1, 0.5 and 1.0 mM) and two irrigation intervals [12-day (normal irrigation) and 18-day (drought stress)]. Results indicated that, drought stress significantly decreased total chlorophyll, Relative Water Content (RWC), number of grains/row (NGR) and Grain Yield (GY) especially in S.C. Hosary, while percentages of carotenoids and membrane permeability (MP) were significantly increased. Generally, drought stress did not affect flag leaf area (FLA), number of rows/ear (NRE) and 100-Grain Weight (GW). Under both irrigation treatments, total chlorophyll, FLA, RWC and GY significantly increased with increasing SA concentration; whilst MP and carotenoids were significantly decreased. Exogenous SA not only alleviated the inhibitory effect of drought stress but also had a stimulatory effect on physiological traits and grain yield of tested maize hybrids. The highest values of GY and total chlorophyll concentration were recorded in S.C. Pioneer (N 11), while S.C. Hosary attained the highest values of GW and carotenoids and S.C. Giza 166 recorded the highest percentage of MP. Among tested maize hybirds, S.C. Hosary was the most sensitive to drought stress while S.C. Pioner (N11) was the most tolerent one. In addition, foliar application of SA (0.5 and 1.0 mM) could be used to increase productivity of maize plants and its tolerance to drought stress.

Key words: Maize, salicylic acid, irrigation intervals, drought stress, physiological traits, grain yield

INTRODUCTION
Maize (*Zea mays* L.) is considered one of the most economically-important crops as human food and livestock feed, and it comes third in world production after wheat and rice (Saleem *et al.*, 2009). Continuous attempts were carried out for increasing maize productivity to face urgent demands of increasing population especially in Egypt. This can be obtained through breeding programs as well as applying growth regulators which may modify morphological and physiological characters and may also induce better adaptation of plant to environment which improve the growth and yield (Amin *et al.*, 2007).

Drought is one of the major abiotic stresses influencing the agricultural production worldwide (Bhardwaj and Yadav, 2012). Various plant physiological and biochemical processes are affected by drought result in the production of reactive oxygen species, which can in turn damage cell components, alter plant metabolism and retard plant growth leading to death (Gunes *et al*., 2007; Abdelkader *et al*., 2012). Drought stress is an important factor that limits maize growth and production in arid and semiarid regions (Edalat *et al*., 2009; Hajibabaee *et al*., 2012). Babaogli *et al*. (2012) reported that, delay in irrigation with subsequent increase in drought stress severity resulted in a significant decrease in grain yield of maize plants. Although maize plants are susceptible to drought stress, there is a marked genotypic variation in morphological and physiological characteristics in maize (Farhad *et al*., 2011).

Plants respond to stress by the synthesis of signaling molecules such as jasmonic acid, ethylene and salicylic acid (Gunes *et al*., 2007). Salicylic Acid (SA) is a potent endogenous plant growth regulator that can effectively modulate various plant growth responses. Furthermore, exogenous application of SA enhances the growth and productivity of plants and provides a considerable protection against various biotic and abiotic stress, viz., heavy metals, salinity, temperature, UV radiation, drought, etc (Hayat *et al*., 2010). SA can enhance some physiological processes and can inhibit others depending on its concentration, plant species, developmental stage and environmental conditions (EI-Mergawi and Abdel-Wahed, 2004). It could reduce the adverse effects of drought stress and provide tolerance to stress by decreasing water loss and inducing antioxidant system in plants (Saruhan *et al*., 2012). Electrolyte leakage as an indicator of reduction of membrane damage, increased membrane stability and tolerance of plants (Orabi *et al*., 2010) could be decrease as a response to SA application (Ahmad *et al*., 2011). It also promotes various physiological and biochemical parameters in plants, viz., photosynthetic pigments (Dawood *et al*., 2012; Jalal *et al*., 2012), leaf area (Abdel-Wahed *et al*., 2006), relative water content (Habibi, 2012).

Future applications of SA hold a great promise as a management tool for providing tolerance to crops against different constrains consequently aiding to accelerate potential crop yield in near future (Joseph *et al*., 2010). Therefore, the aim of the study was to investigate the physiological and productivity responses of three maize hybrids to exogenous salicylic acid under normal irrigation and drought stress conditions.

MATERIALS AND METHODS

Plant material: Grains of three Single Cross (S.C.) maize hybrids (Giza 166, Pioneer N 11 and Hosary) were obtained from the National Research Centre at Dokki, Cairo, Egypt.

Treatments: Four SA concentrations (0, 0.1, 0.5 and 1.0 mM) were used under two irrigation intervals, viz., 12 day interval (normal irrigation) and 18 day interval (drought stress).

Experimental design: The experiment was carried out at Agricultural Faculty Farm, Tanta, Gharbia Governorate, Egypt during the summer season of 2010 and 2011. The soil was a clay loam with organic matter 1.5%, pH 7.25 and EC/25°C 4.03 mmhos/cm. The experiment was laid out in Randomized Complete Blocks Design (RCBD) using split-split-plot arrangement with three replicates. Irrigation intervals, salicylic acid levels and maize hybrids were assigned main plots, sub-plots and sub-sub-plots, respectively. Grains of maize hybrids were sown in 30 May and 9 June in the first season (2010) and second season (2011), respectively. All cultural practices were carried out as recommended for maize production in both seasons. Various SA concentrations (0, 0.1, 0.5 and 1.0 mM) were applied as foliar application to the plants twice, after three weeks from sowing and two weeks later. Irrigation treatments (12 and 18 day intervals) were applied at the tenth day from sowing until harvest.

Physiological traits: At milky stage (after 90-100 day from sowing), flag leaves of maize hybrids in each treatment were collected and taken rapidly to the Laboratory of Agricultural Botany department to determine physiological parameters, viz., photosynthetic pigments, flag leaf area, relative water content and membrane permeability. The amount of photosynthetic pigments, (chlorophyll a+b and carotenoids) was determined according to the method of Dere *et al.* (1998). The pigment extract was measured against a blank of 96% methanol at wavelengths of 666 and 653 nm for chlorophyll a and b, respectively and 470 nm for carotenoids. Photosynthetic pigments (mg g^{-1} FW) were calculated using the following formulas:

Chlorophyll, a = $(15.65A_{666} - 7.34A_{653})$
Chlorophyll, b = $(27.05A_{653} - 11.21A_{666})$
Total chlorophyll = (chl. a+chl. b)
Carotenoids = $[(1000A_{470} - 2.86 \text{ Chl. a} - 129.2 \text{ Chl. b})/245]$

Flag leaf area (cm^2) was determined by the method described by Quarrie and Jones (1979) using the following equation:

$$\text{Leaf area} = (\text{Length} \times \text{Breadth} \times 0.75)$$

Relative Water Content (RWC) of flag leaves was measured according to Weatherley (1950); three leaf samples were collected and weighed to determine their Fresh Weight (FW). The leaves were rehydrated by placing them in distilled water for 12 h at 25°C in order to obtain Turgid Weight (TW), followed by oven drying at 80°C for 48 h and reweighed the leaf samples to get their Dry Weight (DW). Meanwhile, RWC was calculated using the following formula:

$$\text{RWC (\%)} = \frac{(\text{FW-DW})}{(\text{TW-DW})} \times 100$$

Membrane permeability of the excised leaves was measured according to Yan *et al.* (1996). Briefly, a portion of fresh material at the middle of flag leaves was weighed into a glass beaker containing distilled water. The beakers were immersed at 30°C for 3 h and then the conductivity (C1) of the solution was measured by using CMD 830 WPA conductivity meter. After boiling the samples for 2 min, their conductivity (C2) was measured again when the solution was cooled to room temperature. The percentage of electrolyte leakage was calculated by using the formula:

$$\text{EC (\%)} = \frac{C_1}{C_2} \times 100$$

Grain yield and its components: At harvest stage (120 days post-sowing), ten plants for each treatment were taken randomly to calculate grain yield (ton ha^{-1}) and yield components, viz., number of rows/ear, number of grains/row and 100-grain weight (g).

Statistical analysis: According to Gomez and Gomez (1984), the experimental data were statistically analyzed by ANOVA using MSTAT-C Statistical Software Package (Michigan State

University, 1983). In addition, Duncan's Multiple Range Test (DMRT) at 5% probability was employed for assessing the significant differences among the mean values of different attributes.

RESULTS AND DISCUSSION

Drought is one of the principal abiotic factors that strongly limit crop production (Babaogli *et al.*, 2012) and restricts the normal growth and development of plants; hence, several chemical materials have been used to reduce its harmful effects (Jalal *et al.*, 2012). Maize is one of the most important cereals which its global production is severely affected by drought (Hajibabaei and Azizi, 2012). Evidences put forward that externally applied SA increased plant's tolerance to several abiotic stresses including drought (Patel and Hemantaranjan, 2012). Therefore, this study was conducted to evaluate the responses of three maize hybrids to exogenous SA under normal irrigation and drought stress conditions.

Physiological traits: Mohsenzadeh *et al.* (2011) stated that, chlorophyll pigments, as the main component of photosynthetic apparatus, play a pivotal role in plant metabolism and energy supply. Results in Fig. 1 revealed that, drought stress (18 day irrigation interval) significantly ($p \le 0.05$) decreased the amount of total chlorophyll (a+b) of tested maize hybrids in both seasons. This effect of drought stress on total chlorophyll supports the findings of Aldesuquy *et al.* (2012), Dawood *et al.* (2012) and Tirani *et al.* (2012) in wheat, sunflower and canola plants, respectively. Decline in photosynthetic pigments in flag leaves of wheat under drought may accelerated ageing process in the sensitive cultivars more than in the resistant ones (Aldesuquy *et al.*, 2012).

Carotenoids which are essential components of the photosynthetic apparatus of plants serve as accessory light-harvesting pigments and play a vital role in protecting the photosynthetic apparatus against the destructive effects of excess light and act as quenchers to prevent the formation and damaging affects of singlet oxygen (Britton, 2008). Under drought stress, carotenoids concentration increased significantly in S.C. Giza 166 while, in S.C. Pioneer (N 11) there weren't significant differences under both irrigation treatments. Carotenoids concentration in S.C. Hosary increased with exposure to drought stress in the first season, while it was not affected in the second season (Fig. 2). These results are in agreement with those of Xiao *et al.* (2008) in *Populus cathayana*. However, the ratio of carotenoids to total chlorophyll increased as a response to drought stress. These results supported the findings of Liu *et al.* (2011).

Aldesuquy *et al.* (2012) reported that, SA application induced noticeable increases in photosynthetic pigments content in wheat cultivars. The stimulating effect of SA may be due to the fact that SA led to increase leaves longevity on droughted plants by retaining their pigments content and therefore inhibit their senescence. Results shown in Fig. 1 and 2 revealed that, total chlorophyll concentration increased with increasing SA levels, while increasing SA levels significantly decreased carotenoids concentration under both irrigation treatments. This effect was pronounced at level 0.5 mM SA in S.C. Giza 166 and at level 1.0 mM SA in S.C. Pioneer (N 11) and S.C. Hosary. The highest concentration of total chlorophyll was recorded in S.C. Pioneer (N 11), while the highest concentration of carotenoids was found in S.C. Hosary followed by S.C. Pioneer (N 11). However, S.C. Giza 166 attained the lowest concentration of photosynthetic pigments. In this respect, pretreatment of canola with 1 mM SA (Tirani *et al.*, 2012), *Plectranthus tenuiflorus* with 0.5 mM SA (Jalal *et al.*, 2012) and wheat with 1 mM SA (Abdelkader *et al.*, 2012) caused significant increases of their photosynthetic pigments. Photosynthetic pigments were enhanced in maize plants by application of 0.5 mM SA under Cd stress (Mohsenzadeh *et al.*, 2011), 0.5 or 1.0 mM SA under paraquat stress (Shahrtash *et al.*, 2011) and 10^{-2} M SA under salt stress

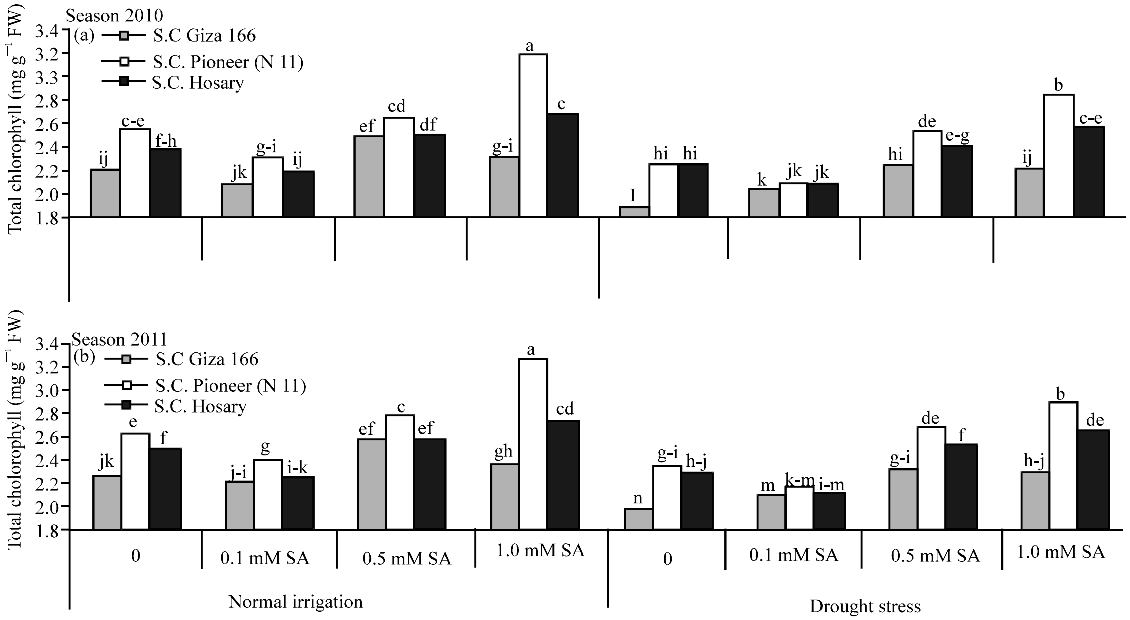

Fig. 1: Interaction effect of irrigation intervals and exogenous salicylic acid on total chlorophyll concentration of maize hybrids, Means with the same letter are not significantly different ($p \leq 0.05$)

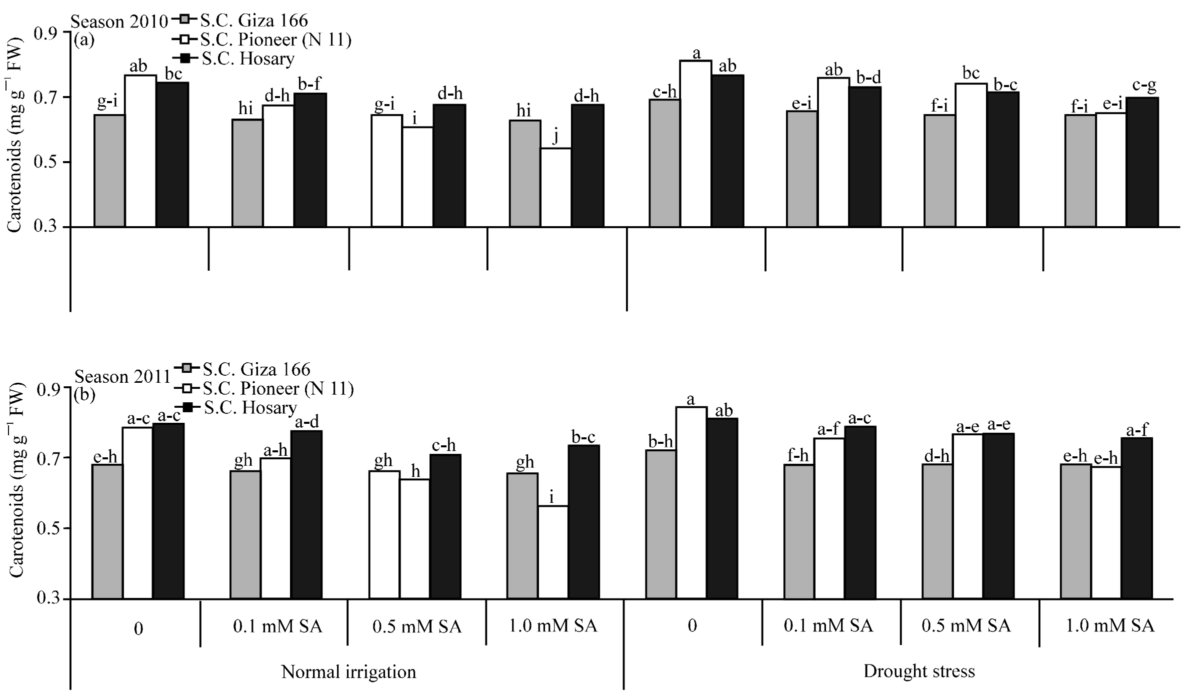

Fig. 2: Interaction effect of irrigation intervals and exogenous salicylic acid on the concentration of carotenoids of maize hybrids, Means with the same letter are not significantly different ($p \leq 0.05$)

Table 1: Interaction effect of irrigation intervals and exogenous salicylic acid on flag leaf area (cm^2), relative water content (%) and membrane permeability (EC %) of maize hybrids

		Maize hybrids					
		2010			2011		
Irrigation interval (day)	Salicylic acid (mM)	S.C. Giza 166	S.C. Pioneer (N 11)	S.C. Hosary	S.C. Giza 166	S.C. Pioneer (N 11)	S.C. Hosary (N 11)
Flag leaf area (cm^2)							
12	0	729.1^{d-h}	682.6^{hi}	737.9^{c-h}	753.1^{f-i}	717.7^{h-j}	802.3^{c-f}
	0.1	721.8^{d-h}	683.9^{hi}	764.1^{b-f}	742.7^{g-i}	700.0^{ij}	804.8^{c-f}
	0.5	858.0^{a}	729.6^{d-h}	767.6^{b-e}	893.4^{a}	775.4^{d-h}	811.8^{c-e}
	1.0	798.5^{a-c}	771.9^{b-e}	846.0^{a}	889.8^{a}	815.7^{c-e}	886.2^{ab}
18	0	710.7^{e-h}	693.6^{g-i}	699.0^{f-i}	738.7^{g-i}	724.2^{hi}	741.8^{g-i}
	0.1	697.3^{f-i}	639.0^{i}	739.6^{c-h}	727.6^{hi}	666.4^{j}	744.8^{g-i}
	0.5	780.0^{b-d}	718.5^{d-h}	760.3^{b-g}	833.5^{b-d}	758.1^{e-i}	803.0^{c-f}
	1.0	746.1^{c-h}	756.1^{c-g}	821.3^{ab}	817.6^{cd}	789.5^{c-g}	841.0^{a-c}
Mean		755.2^{a}	709.4^{b}	767.0^{a}	799.5^{a}	743.4^{b}	804.5^{a}
Relative water content (%)							
12	0	84.20^{l}	85.99^{i-k}	86.45^{h-j}	85.17^{k}	88.60^{f-h}	87.84^{g-i}
	0.1	88.89^{c-f}	88.29^{e-g}	90.38^{a-c}	90.04^{d-f}	89.04^{fg}	90.80^{c-e}
	0.5	89.97^{b-d}	88.85^{c-f}	90.86^{ab}	92.54^{ab}	90.64^{c-e}	91.88^{a-c}
	1.0	89.01^{c-f}	89.56^{b-e}	91.82^{a}	91.26^{b-d}	91.58^{bc}	93.22^{a}
18	0	80.92^{m}	81.42^{m}	70.42^{n}	83.00^{l}	83.63^{l}	72.43^{m}
	0.1	83.86^{l}	83.54^{l}	81.42^{m}	85.73^{jk}	86.00^{jk}	82.56^{l}
	0.5	88.72^{d-f}	85.06^{j-l}	84.84^{kl}	91.33^{b-d}	86.08^{jk}	86.57^{i-k}
	1.0	87.66^{f-h}	86.87^{g-i}	85.93^{i-k}	89.60^{ef}	88.08^{gh}	87.17^{h-j}
Mean		86.65^{a}	86.20^{a}	85.26^{b}	88.58^{a}	87.96^{b}	86.56^{c}
Membrane permeability (EC %)							
12	0	16.80^{b-d}	14.79^{fg}	12.36^{i}	17.92^{bc}	15.33^{e}	13.53^{fg}
	0.1	16.29^{cd}	14.25^{f-h}	12.09^{ij}	17.02^{cd}	14.97^{e}	13.38^{gh}
	0.5	12.10^{ij}	11.16^{j}	11.90^{ij}	12.80^{g-i}	12.46^{hi}	13.30^{gh}
	1.0	13.89^{gh}	11.15^{j}	11.89^{ij}	14.44^{ef}	12.11^{i}	12.16^{i}
18	0	17.95^{a}	17.21^{a-c}	16.63^{b-d}	19.03^{a}	18.45^{ab}	17.41^{cd}
	0.1	17.53^{a-b}	14.10^{gh}	15.95^{de}	18.50^{ab}	14.68^{e}	17.01^{cd}
	0.5	15.17^{ef}	15.20^{ef}	14.75^{fg}	16.35^{d}	16.70^{d}	16.38^{d}
	1.0	15.90^{de}	14.16^{gh}	13.65^{h}	16.39^{d}	14.85^{e}	14.69^{e}
Mean		15.70^{a}	14.00^{b}	13.65^{c}	16.56^{a}	14.94^{b}	14.73^{b}

Means with the same letter are not significantly different ($p \leq 0.05$)

(Khodary, 2004). In contrarily, SA application (0.5 and 1.0 mM) did not affect total chlorophyll concentration and it decreased the concentration of carotenoids in maize plants under salinity stress (Gunes *et al.*, 2007).

Leaf area might be used as an indicator of water relations in maize plants under drought stress condition (Farhad *et al.*, 2011). Relative Water Content (RWC) reflects water status in plants and it is considered as one of the most important factors affecting plant growth and stress resistance (El-Khallal *et al.*, 2009). The remarkable decrease in electrolyte leakage is used as indicator of reduction of membrane damage, increased membrane stability and tolerance of plants (Orabi *et al.*, 2010).

As shown in Table 1, drought stress did not affect the mean values of Flag Leaf Area (FLA) of tested plants. Relative Water Content (RWC %) decreased significantly with exposure to drought

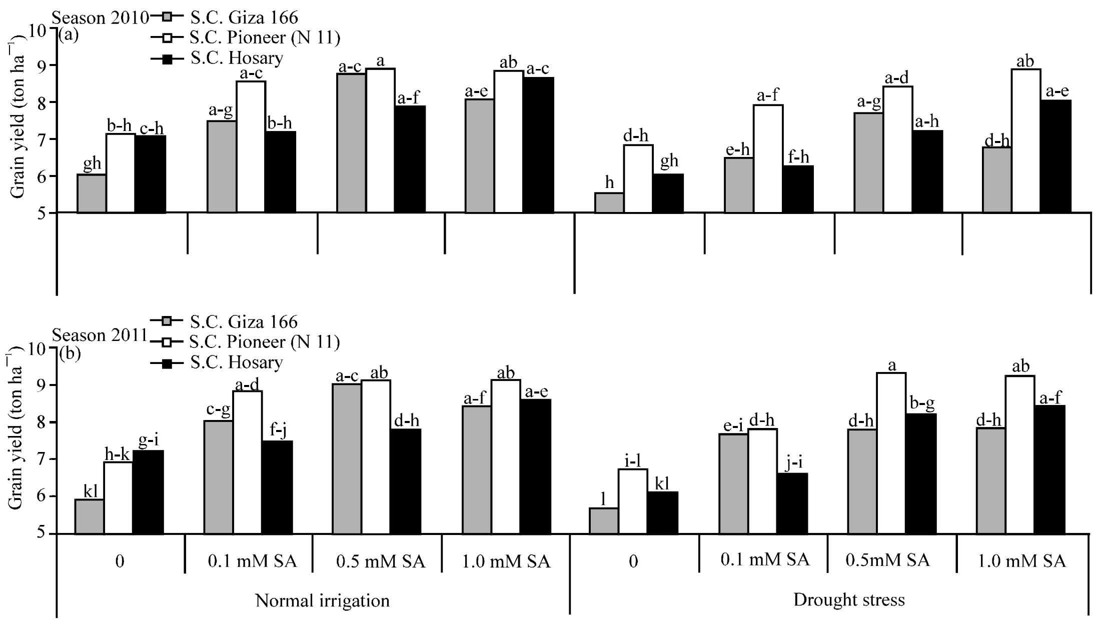

Fig. 3: Interaction effect of irrigation intervals and exogenous salicylic acid on grain yield (ton ha^{-1}) of maize hybrids, Means with the same letter are not significantly different ($p \le 0.05$)

stress especially in S.C. Hosary. While, drought stress significantly increased the percentages of Membrane Permeability (MP) in both seasons. The highest mean values of FLA were recorded in both S.C. Giza 166 and S.C. Hosary in both seasons. Furthermore, the highest percentages of RWC and MP were found in S.C. Giza 166 followed by S.C. Pioneer (N 11). In this concern, progressive drought stress noticeably reduced leaf area of barley (Habibi, 2012) and maize plants (Anjum *et al.*, 2012; Hajibabaee *et al.*, 2012). Bhardwaj and Yadav (2012) stated that, the highest level of RWC of plants could play an important role in drought stress tolerance. In addition, they found that RWC were higher in tolerant plants than other in sensitive ones. Therefore, in the present study it could be concluded that S.C. Hosray is the sensitive hybrid to drought stress than other tested hybrids.

Exogenous SA treatment (0.5 mM) significantly increased the mean values of FLA and RWC of S.C. Giza 166 than other treatments, while the mean values of FLA and RWC increased significantly with exposure to 1.0 mM SA treatment in S.C. Pioneer (N 11) and S.C. Hosary. High doses of SA (0.5 and 1.0 mM) significantly ameliorated the membrane deterioration (Table, 1). Accordingly, SA treatments (0.5 or 1.0 mM) alleviated the deleterious effects of drought on FLA, RWC and MP in maize plants. This effect of SA treatments was in a harmony with that obtained by Sadeghipour and Aghaei (2012) on leaf area index of common bean at 0.5 mM SA under drought stress, Abdel-Wahed *et al.* (2006) on leaf area and leaf area index of yellow maize cv. Pioneer 3062 at 3 mM SA, Ahmad *et al.* (2011) on RWC and electrolyte leakage in mustard plants at 1.0 mM SA under Cd stress, Habibi (2012) on RWC of barley plants at 0.5 mM SA under drought conditions, Gunes *et al.* (2007) and Sayyari (2012) on leaf electrolyte leakage of maize and cucumber plants at 0.5 and 1 mM SA under salinity and chilling stress, respectively.

Grain yield and its components: Results presented in Fig. 3 show that, grain yield (ton ha^{-1}) of the tested maize hybrids decreased significantly ($p \le 0.05$) as a response to drought stress. Maize

Table 2: Interaction effect of irrigation intervals and exogenous salicylic acid on yield components of maize hybrids

		Maize hybrids					
		2010			2011		
Irrigation interval (day)	Salicylic acid (mM)	S.C. Giza 166	S.C. Pioneer (N 11)	S.C. Hosary	S.C. Giza 166	S.C. Pioneer (N 11)	S.C. Hosary
Number of rows/ear							
12	0	13.00^{de}	13.00^{de}	14.67^{a-d}	12.67^{e}	12.67^{e}	14.67^{a-c}
	0.1	15.00^{a-c}	13.00^{de}	14.00^{a-e}	15.33^{a}	13.33^{c-e}	14.33^{a-d}
	0.5	15.67^{a}	13.00^{de}	14.00^{a-e}	15.00^{ab}	13.33^{c-e}	14.00^{a-e}
	1.0	14.67^{a-d}	13.00^{de}	14.00^{a-e}	14.33^{a-d}	13.00^{de}	14.00^{a-e}
18	0	12.67^{e}	13.00^{de}	14.33^{a-e}	13.00^{de}	13.00^{de}	14.33^{a-d}
	0.1	13.00^{de}	13.33^{c-e}	13.33^{c-e}	15.00^{ab}	12.67^{e}	13.67^{b-e}
	0.5	15.33^{ab}	13.67^{b-e}	12.67^{e}	14.33^{a-d}	13.33^{c-e}	14.33^{a-d}
	1.0	14.00^{a-e}	13.00^{de}	13.00^{de}	14.33^{a-d}	13.33^{c-e}	13.33^{c-e}
	Mean	14.17^{a}	13.13^{b}	13.75^{a}	14.25^{a}	13.08^{b}	14.08^{a}
Number of grains/row							
12	0	37.67^{a-e}	36.00^{c-f}	33.67^{e-g}	37.67^{c-g}	36.00^{f-i}	34.00^{h-j}
	0.1	40.00^{a-c}	36.67^{c-e}	32.00^{fg}	40.00^{a-c}	37.00^{c-h}	32.00^{jk}
	0.5	41.33^{a}	37.33^{a-e}	36.33^{c-e}	42.00^{a}	37.33^{c-g}	36.00^{f-i}
	1.0	38.67^{a-d}	38.00^{a-d}	36.00^{c-f}	39.33^{a-e}	38.67^{b-f}	35.67^{f-i}
18	0	35.67^{d-f}	35.67^{d-f}	30.67^{g}	35.67^{f-i}	35.33^{g-i}	30.67^{k}
	0.1	39.00^{a-d}	36.00^{c-f}	33.67^{e-g}	39.67^{a-d}	36.67^{d-i}	33.67^{ij}
	0.5	39.33^{a-d}	37.00^{b-e}	37.33^{a-e}	39.67^{a-d}	41.33^{ab}	37.00^{c-h}
	1.0	38.33^{a-d}	41.00^{ab}	36.33^{c-e}	38.67^{b-f}	41.33^{ab}	36.33^{c-i}
	Mean	38.75^{a}	37.21^{b}	34.50^{c}	39.08^{a}	37.96^{b}	34.42^{c}
100-grain weight (g)							
12	0	24.71^{gh}	21.83^{ij}	28.73^{bc}	24.91^{e-g}	21.56^{h}	28.91^{cd}
	0.1	24.77^{gh}	25.39^{f-h}	29.03^{bc}	26.05^{e}	25.54^{ef}	29.57^{c}
	0.5	26.93^{c-g}	26.00^{d-h}	30.61^{b}	28.49^{c-d}	26.07^{e}	30.96^{b}
	1.0	28.39^{b-d}	25.44^{f-h}	34.14^{a}	27.82^{d}	25.79^{ef}	34.30^{a}
18	0	24.66^{gh}	21.02^{j}	27.51^{c-f}	24.63^{fg}	20.81^{h}	27.82^{d}
	0.1	25.65^{e-h}	23.59^{hi}	28.07^{c-e}	25.87^{e}	23.90^{g}	28.49^{cd}
	0.5	25.43^{f-h}	23.76^{hi}	30.54^{b}	25.80^{ef}	24.10^{g}	30.78^{b}
	1.0	25.27^{f-h}	23.64^{hi}	34.02^{a}	25.68^{ef}	23.81^{g}	34.63^{a}
	Mean	25.73^{b}	23.83^{c}	30.33^{a}	26.16^{b}	23.95^{c}	30.68^{a}

Means with the same letter are not significantly different ($p \leq 0.05$)

hybrid, S.C. Hosary was the most sensitive to drought stress, while S.C. Pioneer (N 11) was the most tolerant one among tested hybrids. Moreover, S.C. Pioneer (N 11) attained the highest mean values of grain yield (8.17 and 8.35 ton ha^{-1} in the first and second seasons, respectively). The interaction effect of irrigation intervals and salicylic acid on yield components including number of rows/ear (NRE), numbers of grains/row (NGR) and 100-Grain Weight (GW) as shown in Table 2 revealed that, drought stress has no effect on NRE and GW, while it significantly decreased NGR especially in S.C. Hosary. These results are in consistency with that observed by Edalat *et al.* (2009) who reported that grain yield of maize plants as well as yield components, viz., grain weight and grain number/ear decreased with increasing irrigation intervals from 7 to 10 days and from 10 to 14 days.

Yield of maize is adversely affected by drought. Exogenous application of different chemicals may reduce stress induced inhibition of plant growth such as SA. Foliar application of SA can play a role in reducing the effect of drought in maize (Rao *et al.*, 2012). Under both irrigation treatments, grain yield was significantly enhanced with foliar application of SA. It is also noted that, SA not only alleviated the inhibitory effect of drought stress on grain yield of maize plants but also induced a great stimulation. The highest stimulation of grain yield was pronounced at 0.5 and 1.0 mM SA in S.C. Giza 166 and S.C. Pioneer (N 11) as well as 1.0 mM SA in S.C. Hosary (Fig. 3). The grain yield of the most sensitive hybrid (S.C. Hosary) may be increased as a response to higher SA concentration than 1.0 mM. SA (0.05 M) was found to improve the drought tolerance of wheat plants particularly the sensitive cultivars (Aldesuquy *et al.*, 2012). In maize hybrid S.C. Giza 166, NRE and NGR were significantly increased with increasing SA concentration under drought stress, while SA did not affect NGR under normal irrigation (Table 2). Vice versa in hybrids S.C. Pioneer (N 11) and S.C. Hosary where SA levels did not affect NRE while it increased NGR especially at 1.0 mM SA. 100-grain weight in all tested plants increased significantly as response to increasing SA concentration. It is also observed that, the highest NGR was recorded in S.C. Pioneer (N 11), while the highest GW was recorded in S.C. Hosary. The highest NRE was recorded in both hybrids, S.C. Giza 166 and S.C. Hosary. In relation to these results in maize plants, Abdel-Wahed *et al.* (2006) reported that, number of rows/ear and number of grains/row of maize cultivar, Pioneer 3062 were insignificantly affected by SA foliar spray (1, 2 and 3 mM), while 100-grain weight and grain yield increased significantly with increasing SA concentration. SA (0.15 ppm) enhanced productivity of grain yield under salt stress (El-Khallal *et al.*, 2009). In contrast, drought tolerance of maize plants was not improved as response to preliminary treatment with 0.5 mM SA (Nemeth *et al.*, 2002).

CONCLUSION

In conclusion, the results of this study signify the role of SA (0.5 and 1.0 mM) in regulating the drought stress response of maize hybrids especially in sensitive one (S.C. Hosary), and suggest that SA could be used as a potential growth regulator to improve physiological characters and grain yield under both normal irrigation and drought stress conditions.

REFERENCES

Abdel-Wahed, M.S., A.A. Amin and E.M. Rashad, 2006. Physiological effect of some bioregulators on vegetative growth, yield and chemical constituents of yellow maize plants. World J. Agric. Sci., 2: 149-155.

Abdelkader, A.F., R. A. Hassanein and H. Ali, 2012. Studies on effects of salicylic acid and thiourea on biochemical activities and yield production in wheat (*Triticum aestivum* var. Gimaza 9) plants grown under drought stress. Afric. J. Biotechnol., 11: 12728-12739.

Ahmad, P., G. Nabi and M. Ashraf, 2011. Cadmium-induced oxidative damage in mustard [*Brassica juncea* (L.) Czern. Coss.] plants can be alleviated by salicylic acid. South Afr. J. Bot., 77: 36-44.

Aldesuquy, H.S., S.A. Abo-Hamed, M.A. Abbas and A.H. Elhakem, 2012. Role of glycine betaine and salicylic acid in improving growth vigour and physiological aspects of droughted wheat cultivars. J. Stress Physiol. Biochem., 8: 149-171.

Amin, A.A., E.M. Rashad, M.S. Hassanein and N.M. Zaki, 2007. Response of some white maize hybrids to foliar spray with benzyl adenine. Res. J. Agric. Biol. Sci., 3: 648-656.

Anjum, S.A., M.F. Saleem, L. Wang, M.F. Bilal and A. Saeed, 2012. Protective role of glycinebetaine in maize against drought-induced lipid peroxidation by enhancing capacity of antioxidative system. Aust. J. Crop Sci., 6: 576-583.

Babaogli, F., F.R. Khoeai and Y. Mehrdad, 2012. Effect of biological fertilizer on yield and yield components of corn (*Zea mays*) CV. S.C. 504 in drought condition. J. Applied Environ. Biol. Sci., 2: 117-122.

Bhardwaj, J. and S.K. Yadav, 2012. Comparative study on biochemical parameters and antioxidant enzymes in a drought tolerant and a sensitive variety of horsegram (*Macrotyloma uniflorum*) under drought stress. Am. J. Plant Physiol., 7: 17-29.

Britton, G., 2008. Functions of intact carotenoids. In: Carotenoids: Natural Functions, Britton, G., S. Liaaen-Jensen and H. Pfander (Eds.). Vol. 4. Birkhauser Verlag, Berlin, Germany, pp: 189-212.

Dawood, M.G., M.S. Sadak and M. Hozayen, 2012. Physiological role of salicylic acid in improving performance, yield and some biochemical aspects of sunflower plant grown under newly reclaimed sandy soil. Aust. J. Basic Applied Sci., 64: 82-89.

Dere, A., T. Gunes and R. Sivaci, 1998. Spectrophotometric determination of chlorophyll-a,b and total carotenoid contents of some algae species using different solvents. Truk. J. Bot., 22: 13-17.

EI-Mergawi, R.A. and M.S. Abdel-Wahed, 2004. Diversity in salicylic acid effects on growth criteria and different indole acetic acid forms among faba bean and maize. Egypt. J. Agron., 26: 49-61.

Edalat, M., S.A. Kazemeini, E. Bijanzadeh and R. Naderi, 2009. Impact of irrigation and nitrogen on determining the contribution of yield components and morphological traits on corn kernel yield. J. Agron., 8: 84-88.

El-Khallal, S.M., T.A. Hathout, A.E.A. Ashour and A.A. Kerrit, 2009. Brassinolide and salicylic acid induced growth, biochemical activities and productivity of maize plants grown under salt stress. Res. J. Agric. Biol. Sci., 5: 380-390.

Farhad, W., M.A. Cheema, M.F. Saleem and M. Saqib, 2011. Evaluation of drought tolerant and sensitive maize hybrids. Int. J. Agric. Biol., 13: 523-528.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., New York, USA., ISBN: 13-9780471879312, Pages: 680.

Gunes, A., A. Inal, M. Alpaslan, F. Eraslan, E.G. Bagci and N. Cicek, 2007. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. J. Plant Physiol., 164: 728-736.

Habibi, G., 2012. Exogenous salicylic acid alleviates oxidative damage of barley plants under drought stress. Acta Biol. Szegediensis, 56: 57-63.

Hajibabaee, M., F. Azizi and K. Zargari, 2012. Effect of drought stress on some morphological, physiological and agronomic traits in various foliage corn hybrids. Am. Eur. J. Agric. Environ. Sci., 12: 890-896.

Hajibabaei, M. and A. Azizi, 2012. Evaluation of new maize hybrids based on irrigation efficiency and water use efficiency and kernel and forage yield. Int. J.Agric. Crop Sci., 4: 652-657.

Hayat, Q., S. Hayat, M. Irfan and A. Ahmad, 2010. Effect of exogenous salicylic acid under changing environment: A review. Environ. Exp. Bot., 68: 14-25.

Jalal, R.S., S.O. Bafeel and A.E. Moftah, 2012. Effect of salicylic acid on growth, photosynthetic pigments and essential oil components of Shara (*Plectranthus tenuiflorus*) plants grown under drought stress conditions. Int. Res. J. Agric. Sci. Soil Sci., 2: 252-260.

Joseph, B., D. Jini and S. Sujatha, 2010. Insight into the role of exogenous salicylic acid on plants grown under salt environment. Asian J. Crop Sci., 2: 226-235.

Khodary, S.E.A., 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. Int. J. Agric. Biol., 6: 5-8.

Liu, C., Y. Liu, K. Guo, D. Fana and G. Li *et al*., 2011. Effect of drought on pigments, osmotic adjustment and antioxidant enzymes in six woody plant species in karst habitats of southwestern China. Environ. Exp. Bot., 71: 174-183.

Michigan State University, 1983. MSTAT-C Micro-Computer Statistical Program. Version 2, Michigan State University, USA.

Mohsenzadeh, S., M. Shahrtash and H. Mohabatkar, 2011. Interactive effects of salicylic acid and silicon on some physiological responses of Cadmium-stressed maize seedlings. Iran. J. Sci. Technol., A1: 57-60.

Nemeth, M., J. Tibor, E. Horvath, E. Paldi and S. Gabrella, 2002. Exogenous salicylic acid increases polyamine content but may decrease drought tolerance in maize. Plant Sci., 162: 569-574.

Orabi, S.A., S.R. Salman and M.A. Shalaby, 2010. Increasing resistance to oxidative damage in cucumber (*Cucumis sativus* L.) plants by exogenous application of salicylic acid and paclobutrazol. World J. Agric. Sci., 6: 252-259.

Patel, P.K. and A. Hemantaranjan, 2012. Salicylic acid induced alteration in dry matter partitioning, antioxidant defence system and yield in chickpea (*Cicer arietinum* L.) under drought stress. Asian J. Crop Sci., 4: 86-102.

Quarrie, S.A. and H.G. Jones, 1979. Genotypic variation in leaf water potential, stomatal conductance and abscisic acid concentration in spring wheat subjected to artificial drought stress. Ann. Bot., 44: 323-327.

Rao, S.R., A. Qayyum, A. Razzaq, M. Ahmad, I. Mahmood and A. Sher, 2012. Role of foliar application of salicylic acid and L-tryptophan in drought tolerance of maize. J. Anim. Plant Sci., 22: 768-772.

Sadeghipour, O. and P. Aghaei, 2012. Impact of exogenous salicylic acid application on some traits of common bean (*Phaseolus vulgaris* L.) under water stress conditions. Int. J. Agric. Crop Sci., 4: 685-690.

Saleem, M.F., M.S. Randhawa, S. Hussain, M.A. Wahid and S.A. Anjum, 2009. Nitrogen management studies in autumn planted maize (*Zea mays* l.) hybrids. J. Anim. Plant Sci., 19: 140-143.

Saruhan, N., A. Saglam and A. Kadioglu, 2012. Salicylic acid pretreatment induces drought tolerance and delays leaf rolling by inducing antioxidant systems in maize genotypes. Acta Physiol. Plant., 34: 97-106.

Sayyari, M., 2012. Improving chilling resistance of cucumber seedlings by salicylic acid. Am. Eur. J. Agric. Environ. Sci., 12: 204-209.

Shahrtash, M., S. Mohsenzadeh and H. Mohabatkar, 2011. Salicylic acid alleviates paraquat oxidative damage in maize seedling. Asian J. Exp. Biol. Sci., 2: 377-382.

Tirani, M.M., F. Nasibi and K.M. Kalantari, 2012. Effects of salicylic acid on *Brassica napus* L. under water stress. Iran. J. Plant Physiol., 2: 371-379.

Weatherley, P.E., 1950. Studies in the water relations of the cotton plant I. The field measurement of water deficits in leaves. New Phytol., 49: 81-97.

Xiao, X., X. Xu and F. Yang, 2008. Adaptive responses to progressive drought stress in two *Populus cathayana* populations. Silva Fennica, 42: 705-719.

Yan, B., Q. Dai, X. Liu, S. Huang and Z. Wang, 1996. Flooding-induced membrane damage, lipid oxidation and activated oxygen generation in corn leaves. Plant Soil, 179: 261-268.