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Original Article

Salicylic acid improves yield and grain quality of hybrid maize under deficit irrigation in subtropical region

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Abstract

The regulatory effect of salicylic acid under biotic and abiotic stresses can be constructive for maize cultivation in water deficit conditions of subtropical environments. Therefore, we investigated the effect of applying salicylic acid (SA) on growth, yield attributes and quality related traits of two maize hybrids (ICI-9091 and Pioneer-1543) under limited irrigation. The plants were grown at the Agronomic Research Area of Bahauddin Zakariya University Multan, Pakistan during spring 2016. We conducted one independent experiment with completely randomized design (CRD) with factorial arrangement and repeated thrice, under green-house, using four treatments viz. control, irrigation deficit with 0% SA, irrigation deficit with 1% SA and full irrigation with 1% SA. Salicylic acid was sprayed at 10-12 leaf stage. The obtained data revealed that, irrigation deficit ($p \leq 0.05$) affected different growth and yield variables like plant height, stem diameter, cob length, number of rows per cob, number of grains per row, 1000-grain weight, biological and economic yield (t ha^{-1}). Additionally, relative water content, chlorophyll content, soluble sugar and grain protein content were also affected ($p \leq 0.05$) by irrigation deficit. Moreover, spraying maize hybrids with 1% SA significantly ($p \leq 0.05$) increased the growth, yield and quality parameters of both maize hybrids under full and deficit irrigation conditions except the proline content. Between maize hybrids, Pioneer-1543 proved significantly ($p \leq 0.05$) better tolerance under irrigation deficit condition as compared to ICI-9091. On the basis of results, it is suggested that under limited irrigation maize yield may be linked with the effect of SA application on the yield attributes.

Keywords: Chlorophyll content, Irrigation deficit, Oil quality, Proline, Salicylic acid

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Introduction

Due to high yielding capacity of maize, it is ranked third among global cereal crops, which is grown as a primary source of grain and fodder production (Viruel et al., 2014). It is warm season crop and has wide adoptability in nature and cultivated under divergent conditions of tropical, subtropical and temperate regions of the world (Kumar et al., 2007). In scenario of changing climate and fast rise in population, the

water scarcity is becoming an alarming threat for agricultural systems (Maswada et al., 2018) of various abiotic stresses known in nature, water scarcity poses the most critical threat to crop production (Farooq et al., 2012).
Drought was categorized as one of the most harmful environmental stress, which has deleterious effect on biochemical and physiology of crop at the cellular level and restrict the production (Shirani et al., 2012). Maize is highly sensitive to the water deficiency particularly at reproductive stages that can diminish yield up to 50% (Cakmak, 2005). Drought dominantly affect the seed germination and results in poor stand establishment (Farooq et al., 2012). Moreover, water deficiency significantly declines the fresh and dry biomass production, leaf photosynthesis pigment, ions content and produces oxidative stress in leaves (Farooq et al., 2012). Furthermore, water deficiency brings significant changes in antioxidant activity, soluble carbohydrate, malondialdehyde (MDA), ions contents, total phenolic compounds and proline contents occurs (Farooq et al., 2012). Owing to these deleterious effects of water deficiency, there is dire need to adopt such practices that overcome the effects of water deficiency and enhanced crop productivity for safeguard of food in future (Anjum et al., 2011). Limiting irrigation, or applying water according to optimum crop needs, can be a good option to save water through cutting irrigation (Ehsanullah et al., 2015).
Salicylic acid (SA) is a phenolic compound with imperative role in the stimulation of plant defense against a number of biotic and abiotic stresses through morphological, physiological and biochemical mechanisms (Durrant and Dong, 2004). Exogenous supply of SA performs as a non-enzymatic antioxidant that trigger several functions within plants such as stomatal closure, photosynthetic activity, ion uptake, transpiration, depletion of ethylene biosynthesis and stress tolerance (Khan et al., 2003).
Additionally, SA has role as signaling molecule, which stimulates the plant immunity system (Vlot et al., 2009) and prompts resistance against various stresses (Karlidag et al., 2009). Under water deficit, SA improved vigour and height of seedlings (Saeidnejad et al., 2012), fresh and dry weight of the roots and shoots (Deef, 2007) fresh and dry biomass, chlorophyll (a and b) and carbohydrate contents (El-Feky et al., 2014). Pretreatment of maize seedling with SA stimulates seedling emergence and increase crop yield (Bedi and Dhingra, 2008). Spray of SA at 10-12 leaf stage can mitigate the drought stress (Zamaninejad et al., 2013) and trigger the growth and production (Hussain et al., 2008).
Importance of SA is well known for improving the physiological performance of various crops by eliminating the deleterious effects of abiotic stresses. However, a little is known about performance of hybrid maize with foliar application of SA under deficit irrigation. Present work was planned with objectives to examine the adverse effect of irrigation shortage on growth, grain yield and its components of hybrid maize and to cope irrigation deficit by applying exogenous SA. It is hypothesized that application of SA on foliage of hybrid maize under limited irrigation could relieve the inhibitory effects of water shortage.

Material and Methods

A pot experiment to study the role of SA on hybrid maize growth and yield under deficit was conducted at Agronomic Research Area, Bahauddin Zakariya University, Multan (30.10°N, 71.25°E and 128.3 meter Altitude). Before sowing of pots during March, 2016, soil physico-chemical properties were tested at the depth of 0-15 cm and 15-30 cm. Experimental soil was sandy loam with pH 7.90, organic matter 0.76 %, total nitrogen 0.036 %, available phosphorus 5.1 ppm, available potassium 250 ppm. The prevailing climate of the experimental area is semi-arid subtropical having annual rainfall of almost 500 mm from which more than 70% occurs from June to September. The mean monthly minimum temperature was 13˚C during January, while maximum temperature was recorded in July i.e. 45 ˚C (Figure. 1).
Seeds of two maize hybrids ICI-9091 and Pioneer-1543 (10 seeds each) were sown in earthen pots (25 cm × 40 cm × 30 cm) filled with 12 kg soil. The recommended fertilizers in the form of urea, nitro phosphate and potassium sulphate were applied at the rate 300, 150 and 150 kg ha^{-1}. Whole phosphorous, potash, and 25% urea fertilizers were applied at the timing of pot filling and remaining urea was applied at 4-6 and 8-10 leaf stage in two equal splits. Different experimental units were arranged in completely randomised design under factorial arrangement and each treatment was repeated three times. Two maize hybrid viz. ICI-9091 and Pioneer-1543 and four water deficit along with SA application viz. Control, Water deficit with 0.1% SA, Water deficit with 1% SA and Full irrigation with 1% SA were applied. Twenty days after sowing, thinning of the plants was done and five

plants were maintained in each pot. Manually eradication of weeds was done, while spray of Imidacloprid was done to avoid maize stem borer.

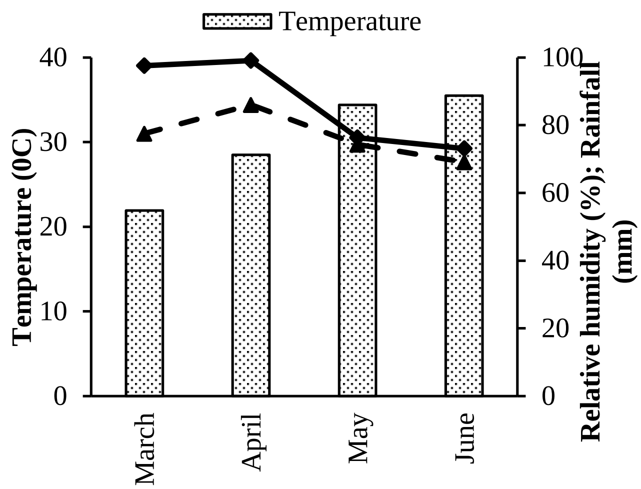

Figure-1: Meteorological data at experimental site during growing season 2016.

Deficit irrigation was applied to 50 days' older crop (10-12 leaf stage) by skipping the irrigation at that stage. After one weak of imposition of irrigation deficit, SA was applied as foliar spray on the foliage of 57 days' older plants. For the preparation of 1% SA solution, 1 g SA weighted by digital balance and mixed in 1000 ml distilled water and the solution was stirred with a magnetic stirrer, and then heated at 150 °C for 5 minutes.

The following data were recorded after 7 days of SA application. Six plants from each pot were randomly selected for growth, yield and biochemical attributes before and after harvesting the plants. Plant height (cm) was recorded at maturity with meter rod. Stem diameter (cm) was recorded from bottom, middle and top of the plant with Vernier caliper (Truper, CALDI-6MP) and then averaged. Cob length (cm) was measured with scale, which was selected randomly from each plot and measured the cob length from base to tip of the cob. Randomly selected ten number of cobs from each pot were taken; number of rows per cob and grains per row of each cob were counted and averaged. The 1000-grain weight, total dry matter per plant (g), biological yield (t ha^{-1}) and grain yield was recorded using an analytical balance (Sartorius, BL3100) on pot basis and converted into ton per hectare.

Gravimetric method was applied for the determination of leaf relative water contents (RWC). For this purpose, fresh leaves (0.5 g) (W_f) were rinsed in a test tube until their turgidity achieved and were weighed with electric balance (Ws). Then air dried and placed in oven for 24 h at 80 ºC and weighed (W_d). RWC were calculated by following formula:

RWC = (W_f - W_d)/ (W_S - W_d) × 100%

To measure the chlorophyll contents, three leaves were randomly chosen from each plant and leaf chlorophyll contents were observed by chlorophyll meter (SPAD 502 plus Minolta, Japan).

Proline was determined by using the Bates method (Bates et al., 1973). Fresh leaf of 1 g was crushed by mortar and pestle and then homogenized with 5 ml of 3% sulfo SA. The homogenate was centrifuged at 6000 rpm for 15 min. 1 ml of ninhydrin and acetic acid were added respectively into 1 ml of the supernatant. The mixture was heated in water bath for 1 h and then incubated in ice for 5 min. A solution of 2 ml was taken and extracted with 2 ml of toluene and quickly shaken with a vortex until chromoporm was formed. The upper phase of the chromoporm was taken and the absorbance was measured with a spectrophotometer at 520 nm. A standard curve was prepared for determination of proline content and was expressed in μmol g^{-1}.

For soluble sugar, ear leaves were taken at silking stage, and sugars were determined by using Anthrone method (Irigoyen et al., 1992). Fresh leaf of 0.5 g was crushed in a mortar and added 5 ml of 80% hot alcohol in it. Then mixture was centrifuged at 9000 g for 15 min (6000 rpm) and supernatant was taken into a separate test tube then 12.5 ml of 80% alcohol was added to it. 1 ml of the solution was taken and 1 ml of 0.2% anthrone was added. The mixture was heated in a water bath at 100 °C for 10 min. The incubation of the mixture was done on ice for 5 min and reaction was terminated. Total soluble sugar content was determined using a spectrophotometer at 620 nm. Total soluble sugar was calculated by creating a standard curve using a standard glucose and was expressed in μg/g fresh weight (μg/g FW). For the estimation of seed protein content, nitrogen contents of grains were determined by using the automatic crude machine. The nitrogen contents so determined was multiplied by 6.25 to have grain protein contents.

Statistical analysis

Data were statistically analyzed using Fisher's ANOVA technique, and variation among the treatment means were compared using LSD at 5% probability level (Steel et al., 1997).

Results and Discussion

Exogenous application of SA has significant effect on maize growth, yield and biochemical content under deficit irrigation conditions (Table 1, 2, 3 and 4). The application of 1% SA with full irrigation produced 24% taller plants than water deficit with 0% SA. From both cultivars, Pioneer-1543 produced 2.4% taller plants in water deficit than ICI-9091 (Table 1). Moreover, Pioneer-1543 with full irrigation with 1% SA produced 26.5% higher plant height than ICI-9091 with 0% SA and other treatments. Plant height of Pioneer-1543 and ICI-9091 with control was statistically not different (Table 1). The application of SA showed that full irrigation with 1% SA produced 39% more chlorophyll content than water deficit without SA (Table 1). Moreover, Pioneer-1543 in full irrigation with 1% SA produced 45% more chlorophyll contents than ICI-9091 without SA and other treatments. Chlorophyll contents of Pioneer-1543 with control and ICI-9091 with water deficit with 1% SA were statistically similar (Table 1). Of the cultivars, Pioneer-1543 expressed 9.6% more chlorophyll contents than ICI-9091 (Table 1). Likewise, Pioneer-1543 produced 10.6% higher relative water contents than ICI-9091 while full irrigation with 1% SA showed 70.5% more relative water content than water deficit without SA. Moreover, Pioneer-1543 with 1% SA under full irrigation produced 73.3% higher relative water contents than ICI-9091 with water deficit with 0.1% SA. Stem diameter of ICI-9091 was 2.4% more under water deficit than Pioneer-1543 (Table 1). The application of SA under water deficit showed that full irrigation with 1% SA produced 29% higher stem diameter than water deficit with 0% SA. In case of interaction, ICI-9091 with full irrigation with 1% SA produced 31.8% and 30.8% higher stem diameter than Pioneer-1543 with water deficit with 0.1% SA and ICI-9091 with water deficit with 0.1% SA respectively (Table 1). Exogenous application of SA has a regulatory effect on growth and development through activating biochemical pathways, which enhances the tolerance mechanisms in plants under water deficit (Najafian et al., 2009). Different growth parameters like plant height, stem diameter, chlorophyll contents, relative water contents of both maize hybrids were improved by SA application (Table 1 to 4). Salicylic acid diminished destructive effect of drought through ameliorating the physiological characteristics like antioxidant compounds, augmenting the antioxidant enzymes movement and developing the synthesis of new proteins (Saruhan et al., 2012). In drought condition, SA has inducing effect on plant height of maize (Zamaninejad et al., 2013). Salicylic acid has regulatory effects on different physiological and biochemical processes within plants like ion uptake, cell division, differentiation, elongation, sink/source relationship, enzyme activities, synthesis of protein, photosynthetic activity and upsurge the antioxidant capacity of plants (El-Tayeb, 2005). Exogenous applications of SA improved plant height against normal and drought conditions. Concerning the stimulatory effect of SA on seed yield and yield components may be attributed to the effect of SA on many biochemical and physiological processes that were reflected on improving vegetative growth and active translocation of the photosynthesis products from source to sink. This improvement might be cumulative oxygen ratio and reducing the abscisic acid in plant (Hayat and Ahmed, 2007). Salicylic acid caused significant increase in photosynthetic pigments (Table, 1). The enhancing effects of SA on photosynthetic capacity could be attributed to its stimulatory effects on Rubisco activity and pigment contents (Khodary, 2004) as well as increased CO_2 assimilation, photosynthetic rate and increased mineral uptake by the plant (Szepesi et al., 2005). Moreover, SA acts as one of antioxidant substances concentrated in the chloroplast and protect the photosynthetic apparatus when a plant is subjected to stress, by scavenging the excessively reactive oxygen species known as free radicals. Such effects might be due to protecting the endogenous anti-oxidant systems often correlated with increased resistance to oxidative stress and/or controlling the level of free radicals within plant tissues (El-Tayeb and Ahmed 2010). Experimental results depicted that SA enhanced the relative water content of maize under irrigation deficit (Table 1). A reason for improvement is described as an increase in leaf diffusive resistance that minimized the transpiration rates (Szepesi et al., 2005). Hussain et al. (2009) also found that foliar application of SA augmented the water status in plant body by osmotic adjustment, which occurred due to the deposit of compatible solutes that resulted in increased of osmoregulation proficiency in crops.

The trend of SA application under water deficit showed that full irrigation with 1% SA produced 48% more cob length than water deficit without SA.

Table-1: Influence of exogenous applied salicylic acid on plant height, chlorophyll, relative water contents and stem diameter of maize under different irrigations

Treatments	Plant height (cm)			Chlorophyll contents (SPAD)			Relative water contents (%)			Stem diameter (cm)		
	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean
Control	174.60 e	176.13 e	175.3 C	38.32d	42.78 c	40.5 C	54.63d	61.76c	58.1B	1.61d	1.56d	1.5C
Irrigation Deficit	148.37 g	153.80 f	151.0 D	29.65 f	31.87 e	30.7D	21.16h	23.99g	22.5D	1.35e	1.33e	1.3D
Full irrigation with 1% SA	196.00 b	201.80 a	198.9 A	47.09b	53.97 a	50.5A	74.13b	79.19a	76.6A	1.95a	1.83b	1.8A
Irrigation deficit with 1% SA	180.77 d	185.17 c	182.9 B	42.80 c	46.01 b	44.4 B	35.61f	42.59e	39.0C	1.74c	1.75c	1.7B
Mean	174.90B	179.22 A		39.46B	43.66 A		46.3B	51.88A		1.66A	1.62B	
LSD at 5 %	Hybrids (H): 1.96; Treatments (T): 2.77; H x T: 3.92			Hybrids (H): 0.92; Treatments (T): 1.29; H x T: 1.83			Hybrids (H): 1.01; Treatments (T): 1.43; H x T: 2.02			Hybrids (H): 0.03; Treatments (T): 0.05; H x T: 0.07		

Table-2: Influence of exogenous applied salicylic acid on cob length and diameter, number of rows per cob and number of grain per row of maize under different irrigations

Treatments	Cob length (cm)			Cob Diameter (cm)			Number of rows per cob			Number of grain per row		
	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean
Control	16.90d	18.87c	17.89C	3.44d	3.58c	3.51B	13.33ef	14.33de	13.83C	18.33d	21.00c	19.66C
Irrigation Deficit	12.10e	11.03f	11.58D	3.14f	3.27e	3.20C	11.33g	12.00fg	11.66D	15.66e	15.00e	15.33D
Full irrigation with 1% SA	21.00b	23.13a	22.07A	3.77b	4.02a	3.89A	17.33b	19.66a	18.50A	24.33b	27.00a	25.66A
Irrigation deficit with 1% SA	18.77c	19.33c	19.05B	3.64c	3.48d	3.56B	15.66cd	16.00bc	15.83B	21.00c	21.66c	21.33B
Mean	17.19B	18.09A		3.50B	3.58A		14.42 B	15.50A		19.83B	21.17A	
LSD values	Hybrids (H): 1.96; Treatments (T): 2.77; H x T: 3.92			Hybrids (H): 0.51; Treatments (T): 0.71; H x T: 1.01			Hybrids (H): 0.04; Treatments (T): 0.06; H x T: 0.08			Hybrids (H): 0.79; Treatments (T): 1.11; H x T: 1.58		

Likewise, Pioneer-1543 with 1% SA under full irrigation produced 52% more cob length than ICI-9091 under water deficit without SA. Moreover, Pioneer-1543 with 1% SA under water deficit, Pioneer-1543 in control and ICI-9091 with 1% SA under water deficit were statistically similar with each other (Table 2). Pioneer-1543 produced 2.23 % more cob length under water deficit with SA than ICI-9091 (Table 2). Cob diameter of Pioneer-1543 was 2.3% more under water deficit than ICI-9091 (Table 2). The application of SA under water deficit showed that full irrigation with 1% SA gave 17.7% higher cob diameter than water deficit with 0% SA. In case of interaction, Pioneer-1543 with full irrigation with 1% SA produced 21.9% higher cob diameter than ICI-9091 with water deficit (Table 2). Statistically 7% maximum number of rows per cob was recorded in Pioneer-1543 under water deficit with SA concentration than ICI-9091 (Table 2). Application of 1% SA under full irrigation produced 37% more number of rows per cob than under water deficit without SA. Likewise, Pioneer-1543 with 1% SA under full irrigation produced 42% more number of rows per cob than ICI-9091 with water deficit with 0.1% SA (Table 2). Regarding number of grains per row of maize hybrids, Pioneer-1543 showed significant improvement than ICI-9091 to SA application under water deficit (Table 2). Full irrigation with 1% SA produced 40.2% higher number of grain per row than other treatments. Pioneer-1543 with full irrigation with 1% SA showed 42% higher number of grains per row than ICI-9091 with water deficit with 0.1% SA and Pioneer-1543 with water deficit with 0.1%.

Table-3: Influence of exogenous applied salicylic acid on 1000-grain weight, total biomass and grain yield of maize under different irrigations under different irrigations

Treatments	1000-Grain Weight (g)			Total Biomass (t ha^{-1})			Grain Yield (t ha^{-1})		
	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean
Control	255.67 f	259.90 e	257.78 C	17.23 d	17.40 cd	17.32 C	5.38 d	5.52 d	5.45 C
Irrigation Deficit	239.77 h	242.77 g	241.27 D	16.54 e	16.31 e	16.43 D	4.70 e	4.77 e	4.74 D
Full irrigation with 1% SA	281.90 b	288.47 a	285.18 A	18.63 b	19.79 a	19.21 A	6.11 b	6.9 a	6.51 A
Irrigation deficit with 1% SA	265.53 d	275.57 c	270.55 B	17.54 cd	17.92 c	17.73 B	5.85 c	5.82 c	5.84 B
Mean	260.72 B	266.67 A		17.49 B	17.86 A		5.51 B	5.75 A	
LSD values	Hybrids (H): 1.21; Treatments (T): 1.69; H x T: 2.41			Hybrids (H): 0.28; Treatments (T): 0.40; H x T: 0.57			Hybrids (H): 0.11; Treatments (T): 0.16; H x T: 0.23		

Regarding 1000 grain weight, application of 1% SA under full irrigation produced 15.4% heavier grains than other treatments. Pioneer-1543 with 1% SA under full irrigation produced 16.8% more 1000 grain weight than ICI-9091 with water deficit with 0.1% SA. Maize hybrids Pioneer-1543 showed 2.23% more 1000-grain weight than ICI-9091 to SA application under water deficit (Table 3). Study period showed that 2% and 4 % higher biological and grain yield in Pioneer-1543 than ICI-9091 (Table 3). Exogenous application of 1% SA under full irrigation produced 13% and 27% higher biological and grain yield than water deficit without SA (Table 3). Pioneer-1543 had 17.6% with 1% SA under full irrigation and 30.8% more biological and grain yield than under water deficit without SA in both hybrids (Table 3). In present study, SA augmented different yield related traits and grain yield of maize under water deficit condition (Table 2 and 3). Exogenous application of SA altered the assimilatory component and amended the yield. Earlier this improvement is reported in different crops e.g. foliar application of SA under water deficit improved the yield and yield component of sunflower (Hussain et al., 2008), wheat, as well as in maize (Lahmod et al., 2016). It is reported that in maize yield improvement may be due to improved sink size mostly seed numbers and seed weight (Khan et al., 2003) which is connected with increased in photosynthetic proficiency through the conservation of chlorophyll, higher construction and translocation of organic material from source to sink (Kadioglu et al., 2011). This positive improvement in yield and yield component may be the effect of numerous biochemical and physiological processes that were revealed in improving vegetative growth and active translocation of the photosynthesis harvests from source to sink (Dawood et al., 2012).

Proline contents were also affected by irrigation deficit, however, application of SA improved proline contents under irrigation deficit (Table 4). Moreover, Pioneer-1543 with 1% SA produced 49% more proline contents than ICI-9091 under water deficit or control and Pioneer-1543 with full irrigation and 1% SA (Table 4). Pioneer-1543 produced 3.5% more proline content than ICI-9091 (Table 4) while water deficit with 1% SA recorded 43.4% more proline content than full irrigation with 1% SA and control. From both cultivars, Pioneer-1543 expressed 4.7% more soluble sugar content than ICI-9091 (Table 4). Likewise, SA application under water deficit showed that full irrigation with 1% SA produced 36.7% more soluble sugar content than control. Moreover, Pioneer-1543 with full irrigation with 1% SA produced 41.7% more soluble sugar content than Pioneer-1543 and ICI-9091 in control and other treatments (Table 4). Maize hybrids showed non-significant response in case of grain protein content under water deficit along with SA application (Table 4). Full irrigation with 1% SA produced 35% maximum grain protein content than other treatments. Pioneer-1543 with full irrigation with 1% SA showed 35.6% higher grain protein content than produced by both hybrids under water deficit with 0.1% SA. (Table 4). Proline contents of maize were enhanced under irrigation deficit (Table 4), however, its concentrations further increased through application of SA (Manzoor et al., 2015). Under water deficit conditions, proline accumulation improved the resistance that differs from variety to variety (Desnigh and Kanagaraj, 2007). It is well established that plants accumulate non-toxic compounds like proline for protection of cells, damaged as result of low water potential (Krasensky and Jonak (2012).

Table-4: Influence of exogenous applied salicylic acid on proline, soluble sugar and kernel protein contents of maize under different irrigations under different irrigations

Treatments	Proline Content (µmol/g)			Soluble Sugar Content (µg/g)			Kernel Protein Content (%)		
	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean	ICI-9091	Pioneer-1543	Mean
Control	145.00 e	166.30 d	155.67 C	10.66 d	10.00 d	10.33 D	6.50 d	6.76 d	6.63 C
Irrigation Deficit	245.70 c	265.00 b	255.33 B	12.66 c	13.50 c	13.08 C	5.83 e	5.80 e	5.81 D
Full irrigation with 1% SA	165.00 d	141.33 e	153.17 C	15.50 b	17.16 a	16.33 A	8.90 ab	9.00 a	8.95 A
Irrigation deficit with 1% SA	264.30 b	277.00 a	270.67 A	15.00 b	15.83 b	15.41 B	7.60 c	7.76 bc	7.68 B
Mean	205.00 B	212.42 A		13.45 B	14.12 A		7.05	7.25	
LSD values	Hybrids (H): 1.84; Treatments (T): 2.61; H x T: 1.69			Hybrids (H): 0.58; Treatments (T): 0.82; H x T: 1.72			Hybrids (H): NS; Treatments (T): 0.41; H x T: 0.58		

It is reported by Wang et al. (2003) that there is direct association exist between proline accumulation and sugars contents, which improved the tolerance in plants in stress. However, drought degenerated the sugar concentration, which caused dryness (Farooq et al., 2012). Exogenous spray of SA improved the metabolic utilization of sugars in the formation of new cell constituents, which stimulate maize growth. Moreover, application of SA is also supposed to prevent polysaccharide-hydrolyzing enzyme system and speed up the assimilation of sugars in polysaccharides. Our results supported that SA augmented the polysaccharide level and stimulates the use of sugar metabolism by mounting osmotic pressure (Zahra et al., 2010). Moreover, among different mechanisms adapted in plants for drought resistance is the regulation of cell osmotic potential, particularly when drought stress upsurge steadily (Lisar et al., 2012). Accumulation of sugar under drought stress aids in maintaining the consistency of the membrane, preventing and protecting membrane fusion to keep protein for functional stability (Xonostle-Cazares et al., 2010). Sugar contents have significant part in the plant self-defensive mechanism of osmoregulation and energy conservation (Yadayand and Schmidhalter, 2005). Salicylic acid application hinders destructive effects of drought on sugar contents of maize (Khodary, 2004).

It is well recognized that drought stress reduce the protein concentration in plant species due to decrease in protein biosynthesis and enhancing the rate of degradation (Hussain et al., 2008). Salicylic acid application decreased the injuries of drought by growing the antioxidant compounds and improving the activity of antioxidant enzymes with promising new proteins synthesis (Saruhan et al., 2012). The improvement in protein content of seed might be the result of increased anti-stress proteins and metabolic activities or improved stored protein.

Conclusion

It is concluded from present experiment that exogenous application of 1% SA in maize hybrids improved different growth, yield related traits of maize hybrids. Furthermore, proline, soluble sugar and grain protein contents were also improved by SA application under irrigation deficit. Therefore, exogenous application of 1 % SA is helpful in coping the irrigation deficit in maize in subtropical environments.

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Rehman AU: Finalized the manuscript.
Altaf MM: Performed research and prepared first draft.
Qamar R: Statistical analysis.