Reduction of drought effect on peroxidase, catalase, chlorophyll content and yield of broad bean (*Vicia faba* L.) by proline and salicylic acid treatments

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Abstract

Drought is one of the serious abiotic environmental stresses affected the plant growth and yield. Broad bean (*Vicia faba* L.) growth and yield are drastically affected by drought stress. Proline and salicylic acid can alleviate the harmful effect of drought on many plants. The effect of proline and salicylic acid on drought examined on the broad bean. Pot experiment designed to investigate the effect of foliar treatment of proline and salicylic acid on broad bean growth and yield under drought stress conditions. Broad bean under three levels of field capacity (field condition, 25 % level of drought and 50 % level of drought) sprayed by proline or salicylic acid at vegetative and flowering stages. Water deficit decreased the relative water content, nitrogen content, potassium content, calcium content and chlorophyll content. In the same manner, yield parameters as pod number per plant, pod weight per plant, seed number per pod, seed number per plant, seed weight per one plant and weight of 100 seeds decreased under drought conditions. Plants treated with proline or salicylic acid showed an increasing in relative water content, nitrogen and potassium content, chlorophyll content, as well as all yield parameters under drought stress condition. Proline and salicylic acid increase the activity of peroxidase and catalase enzymes significantly under drought condition. Results showed the ability of both proline and salicylic acid in mitigation the negative effect of drought stress on growth and yield of broad bean plant. Proline and salicylic acid improve the yield of broad bean plant at 25 % and 50 % levels of drought.

Keywords: Drought; Broad bean; Chlorophyll; Peroxidase; Catalase; *Vicia faba* L.; Yield Proline; Salicylic acid.

INTRODUCTION

For such as, until 45% of the world agricultural lands are subject to continuous or recurrent drought, meanwhile 38% of the world human population lives [1]. The Kingdom of Saudi Arabia (KSA) has an region of about 2.25 million km². Kingdom of Saudi Arabia (KSA) is position of in a very tough natural desert environment with no rivers or lakes and a medium yearly rainfall of lower than 100 mm. The country is under extreme water reduction conditions. Plant growth, development and final yield of a crop are affected by several environmental factors. The considerable environmental constraints to crop productivity worldwide may be caused the drought, salinity, nutrient imbalances and extremes of temperature. [2]) said drought is from the most four important environmental factor limiting crop productivity in many regions of the world. Drought stress happens when the water supply to the roots is limited or when the transpiration rate is too high [3]. Drought harms the plants where leads to a significant reduction in yield and crop productivity [4] The broad bean is nutritional, economic and environmental interesting vegetable and considered to be more sensitive to water deficits than some other legumes [4,5]

Decreases of a biotic stress is highly complicated at both of the plant and cellular levels (6) may be caused to the complexity of interactions among stress factors and different molecular, biochemical and physiological phenomena affecting plant growth and become better [7]. Compatible solutes of low molecular weight are usually nontoxic at high cellular concentrations formed during stress. Generally, they keep safe of plants from stress with cellular osmotic adjustment may could be caused detoxification of reactive oxygen species, protection of membrane integrity, and establishment of enzyme proteins [8].

Exogenous application of proline plays an important role in enhancing plant tolerance to drought stress. Salicylic acid serves in the defense response to stresses in plant species [9]. Definition of salicylic acid is an endogenous regulator of phenolic nature and also it is implicated in the regulation of different physiological processes in plants [9]. Many researches also confirming a major function of salicylic acid in controlling influence on the plant response to a biotic stress including salt and water stress [10].

In this study, broad beans were grown under different soil water levels and the plant treated either with proline or salicylic acid. The objectives of this study were to determine the influence of proline and salicylic acid treatments on the RWC, enzyme activities, plant nutrients and yield under drought stress in broad bean cultivar.

MATERIALS AND METHODS

Experimental conditions

The experiment was conducted in open field, at Faculty of Science and Arts, Qilwah province (41.43° E, 19.76° N), Al-Baha region, Kingdom of Saudi Arabia in January 2018; day mean temperature, night mean temperature and humidity were 22 °C, 16 °C and 37 % respectively. Seeds of broad bean (*Vicia faba* L.) were sown in black plastic pots (33 cm in height and 28 cm in diameter), 15 beans per pot, filled with sandy loam soil with percent of 63, 18 and 20 % sand,

clay and silt respectively. The soil supplied with fertilizers was sampled and analyzed prior to cultivation at central lab at college of science in King Saud University. The soil properties are: pH 7.3, organic matter 2.4%, available N 150.5 mg kg⁻¹ (hydrolytic N, 1 N NaOH hydrolysis), available P 182.3 mg kg⁻¹ (0.5 M NaHCO₃ extraction), available K 194.5 mg kg⁻¹ (1 N CH₃COONH₄ extraction) and field water capacity 21%. According to [11], Before sowing the soil was irrigated to 80% field water capacity (FWC) (favorable soil water level for broad bean).

Experiments treatments

Nine treatments with three replicates consisting of factorial combinations of three soil water levels (field condition, 25 % level of drought and 50 % level of drought), proline and salicylic acid treatments commenced 25 and 45 days after sowing. The soil water contents were controlled by weight method. Before sowing soil water content and soil field water capacity were measured. Proline and salicylic acid applied as foliar spray by 1.15 g L⁻¹ in 0.1% Tween 20 solution [12] and 300 mg L⁻¹ in 0.1% Tween 20 solution (13). Treatments were field condition, field condition with proline, field condition with salicylic acid, 25 % level of drought, 25 % level of drought with proline, 25 % level of drought with salicylic acid, 50 % level of drought, 50 % level of drought with proline and 50 % level of drought with salicylic acid.

Measurements

The relative water content (RWC) was estimated at vegetative and flowering stages according to [14]. Plant leaf elements analyzed at vegetative, flowering and harvest stages, total nitrogen contents by Kjeldahl method [15], Potassium and calcium by atomic absorption [16]. The chlorophyll content was estimated at vegetative and flowering stages according to [17]. The catalase activity was measured according to [18], by decreasing the absorbance at 240 nm for 1min as a consequence of H₂O₂ consumption using spectrophotometer [19]. The peroxidase activity was determined according to [20] by the oxidation of guaiacol in the presence of H₂O₂. The increase in absorbance due to formation of tetra guaiacol was recorded using spectrophotometer (model 1200, no. wpi0061006055) at 470 nm [21]. Plants were harvested on 5 May. Pods number per plant, pods weight per plant, seeds number per plant, seeds number per one pod, seeds weight per plant and the weight of 100 seeds were determined at harvest.

Data analysis

Standard deviation (S.D.) of each treatment was calculated. The significance analyses of individual and interactive effect of proline and salicylic acid treatments and drought levels were performed using two-way analysis of variance (ANOVA) with replicates and *t*-test at *PB* 0.05 using SPSS BASE 10.0 (SPSS Inc., Chicago, IL) packages [22].

RESULTS

Relative water content

Water deficit decreased RWC significantly ($P < 0.05$) at vegetative and flowering stages from 85 % to 72 % & 61 % and from 86 % to 71 % & 57 % under 25 % and 50 % levels of drought respectively (Table 1). There was significant interaction between proline and salicylic acid treatments and drought levels on RWC ($P < 0.05$).

Table (1): Effect of proline and salicylic acid on relative water content (RWC) at vegetative and flowering stages of broad bean (*Vicia faba* L.) grown under three levels of water.

Treatments	RWC	
	Vegetative growth	Flowering growth
Field conditions	85.31a ± 0.53	86.45a ± 0.34
Field conditions + Proline	86.12a ± 0.52	85.23a ± 0.65
Field conditions + Salicylic acid	85.83a ± 0.62	84.74a ± 0.65
25 % level of drought	72.45b ± 0.65	71.23b ± 0.65
25 % level of drought + Proline	80.23a ± 0.23	80.75a ± 0.41
25 % level of drought + Salicylic acid	81.81a ± 0.45	81.45a ± 0.62
50 % level of drought	60.76c ± 0.34	57.16c ± 0.45
50 % level of drought + Proline	73.13b ± 0.54	75.93b ± 0.42
50 % level of drought + Salicylic acid	72.97b ± 0.34	74.14b ± 0.34

Data with in columns represents the mean of 3 replicates ± SD. Within columns, values followed by different letters are significantly ($P < 0.05$).

Plant leaf minerals

Plant leaf minerals in different combination of proline and salicylic acid treatments and water level treated plants at vegetative and flowering stages is shown in Table 2. However, soil drought had a significant negative effect ($P < 0.05$) on plant leaf nitrogen, potassium and calcium content at vegetative and flowering stages. Leaf potassium content decreased by 26 % and 45 % at vegetative stage and 47 % and 57 % at flowering stage under 25 % and 50 % drought

There was no significant effect of proline and salicylic acid treatments on plant leaf minerals at water levels. Treating with proline and salicylic acid slightly mitigated the harmful effects of drought on broad bean nitrogen contents at vegetative and flowering stages (Table 2). There was significant interaction between proline and salicylic acid treatments and water levels on leaf potassium and calcium content ($P < 0.05$).

Table (2): Effect of proline, salicylic acid on plant nutrient elements (nitrogen, potassium and calcium) mg g⁻¹ DW at vegetative and flowering stages of broad bean (*Vicia faba* L.) grown under three levels of water.

Treatments	Nitrogen (N2)		Potassium (K)		Calcium (Ca)	
	Vegetative growth	Flowering growth	Vegetative growth	Flowering growth	Vegetative growth	Flowering growth
Field conditions	20.32a ± 0.2	24.21a ± 0.2	27.09a ± 0.9	31.69a ± 0.1	11.64a ± 0.6	16.82a ± 0.6
Field conditions + Proline	20.60a ± 0.2	25.32a ± 0.6	26.82a ± 0.2	29.88a ± 0.2	12.09a ± 0.4	18.33a ± 0.1
Field conditions + Salicylic acid	20.10a ± 0.4	25.10a ± 0.2	27.18a ± 0.2	31.05a ± 0.4	12.42a ± 0.4	18.63a ± 0.4
25 % level of drought	16.22b ± 0.9	19.33b ± 0.2	20.07b ± 0.6	19.37b ± 0.4	8.23b ± 0.1	11.11b ± 0.8
25 % level of drought + Proline	17.83b ± 0.3	20.15b ± 0.5	24.04a ± 0.2	25.02c ± 0.2	9.61b ± 0.5	14.84a ± 0.1
25 % level of drought + Salicylic acid	17.14b ± 0.2	20.23b ± 0.1	25.04a ± 0.7	26.46c ± 0.1	10.89b ± 0.2	16.31a ± 0.2
50 % level of drought	11.94c ± 0.9	12.53c ± 0.4	15.12c ± 0.2	13.68d ± 0.5	6.14c ± 0.3	6.13c ± 0.6
50 % level of drought + Proline	12.91c ± 0.3	13.53c ± 0.2	18.90b ± 0.2	20.07b ± 0.2	8.90b ± 0.1	13.10b ± 0.4
50 % level of drought + Salicylic acid	13.26c ± 0.2	14.62c ± 0.4	19.08b ± 0.6	19.71b ± 0.6	9.93b ± 0.2	12.09b ± 0.1

Data with in columns represents the mean of 3 replicates ± SD. Within columns, values followed by different letters are significantly ($P < 0.05$).

Chlorophyll content

Water deficit significantly reduced the content of chlorophyll a and b under 25 % and 50 % drought levels by 38, 50, 11 and 33 % at vegetative and flowering stages respectively (Table 3). Proline and salicylic acid significantly reduced the harmful effect of drought on total chlorophyll content (Fig. 1).

Table (3): Effect of proline and salicylic acid on leaf chlorophyll contents mg g^{-1} FW at vegetative and flowering stages of broad bean (*Vicia faba* L.) grown under three levels of water.

Treatments	Chlorophyll a mg g^{-1} FW		Chlorophyll b mg g^{-1} FW	
	Vegetative growth	Flowering growth	Vegetative growth	Flowering growth
Field conditions	1.45a $\pm$ 0.2	1.33a $\pm$ 0.2	0.95a $\pm$ 0.1	0.87a $\pm$ 0.5
Field conditions + Proline	1.40a $\pm$ 0.5	1.34a $\pm$ 0.5	0.93a $\pm$ 0.8	0.85a $\pm$ 0.2
Field conditions + Salicylic acid	1.45a $\pm$ 0.1	1.36a $\pm$ 0.1	0.99a $\pm$ 0.3	0.91a $\pm$ 0.7
25 % level of drought	0.91b $\pm$ 0.2	0.81b $\pm$ 0.7	0.87a $\pm$ 0.6	0.77a $\pm$ 0.7
25 % level of drought + Proline	1.38a $\pm$ 0.9	1.24a $\pm$ 0.2	0.89a $\pm$ 0.2	0.81a $\pm$ 0.3
25 % level of drought + Salicylic acid	1.41a $\pm$ 0.6	1.21a $\pm$ 0.9	0.91a $\pm$ 0.6	0.82a $\pm$ 0.3
50 % level of drought	0.72c $\pm$ 0.4	0.66c $\pm$ 0.1	0.62b $\pm$ 0.5	0.60b $\pm$ 0.1
50 % level of drought + Proline	1.09b $\pm$ 0.2	1.08b $\pm$ 0.5	0.70b $\pm$ 0.1	0.64b $\pm$ 0.7
50 % level of drought + Salicylic acid	1.10b $\pm$ 0.4	1.09b $\pm$ 0.2	0.73b $\pm$ 0.6	0.67b $\pm$ 0.2

Data with in columns represents the mean of 3 replicates $\pm$ SD. Within columns, values followed by different letters are significantly ($P < 0.05$).

Peroxidase and Catalase enzymes

Water deficit significantly increased both peroxidase enzymes by 35 & 51 % and by 61 & 93 % at vegetative stage flowering stage at 25 % and 50 % levels of drought respectively (Table 4). Catalase was increased by 40 and 101 % under 50 % levels of drought and by 50 and 89 % under 25 % levels of drought at vegetative and flowering stages respectively (Table 4). Results in Table 4 show significant increasing in peroxidase and catalase enzymes by proline and salicylic acid treatments.

Table (4): Effect of proline, salicylic acid on antioxidant enzymes (Peroxidase and Catalase) at vegetative and flowering stages of broad bean (*Vicia faba* L.) grown under three levels of water.

Treatments	Peroxidase		Catalase	
	Vegetative growth	Flowering growth	Vegetative growth	Flowering growth
Field conditions	21.6a $\pm$ 0.2	22.4a $\pm$ 0.2	1.68a $\pm$ 0.8	1.82a $\pm$ 0.8
Field conditions + Proline	22.4a $\pm$ 0.4	21.2a $\pm$ 0.8	2.04a $\pm$ 0.2	1.92a $\pm$ 0.3
Field conditions + Salicylic acid	22.8a $\pm$ 0.1	22.6a $\pm$ 0.5	2.12a $\pm$ 0.3	2.16a $\pm$ 0.2
25 % level of drought	29.20b $\pm$ 0.3	36.15b $\pm$ 0.9	2.36b $\pm$ 0.2	2.72b $\pm$ 0.4
25 % level of drought + Proline	51.26c $\pm$ 0.7	64.21c $\pm$ 0.4	4.61b $\pm$ 0.5	5.27c $\pm$ 0.6
25 % level of drought + Salicylic acid	52.36c $\pm$ 0.3	66.23c $\pm$ 0.2	5.52c $\pm$ 0.1	5.13c $\pm$ 0.3
50 % level of drought	32.56b $\pm$ 0.2	43.2d $\pm$ 0.4	3.38b $\pm$ 0.9	3.44b $\pm$ 0.3
50 % level of drought + Proline	66.43d $\pm$ 0.5	75.2e $\pm$ 0.2	5.91c $\pm$ 0.7	6.21d $\pm$ 0.2
50 % level of drought + Salicylic acid	69.23d $\pm$ 0.3	77.26e $\pm$ 0.9	6.52c $\pm$ 0.4	6.99d $\pm$ 0.8

Data with in columns represents the mean of 3 replicates $\pm$ SD. Within columns, values followed by different letters are significantly ($P < 0.05$).

Plant yield parameters

Results in Table (5) and Fig. (2), illustrate that water deficit significantly decreased broad bean yield parameters where pod number per plant decreased by 31 & 45 %, pod weight per plant decreased by 32.15 & 57.7 %, seed number per plant by 15.73 & 40.59 seed weight per plant by 16.87 & 50.99 % while weight of 100 seeds by 16.52 & 22.67 % as plant grown under 25 and 50 % drought levels respectively. Proline and salicylic acid decrease the harmful effect of drought on all yield parameters (Fig. 2).

Table (5): Effect of proline and salicylic acid on the pod number / plant, pod weight, seed number per pod & plant, seed weight / plant and weight of 100 seeds at harvest of broad bean (*Vicia faba* L.) grown under three levels of water.

Treatments	Pods number / plant	Pods Weight (gram) / plant	Seeds number / plant	Seeds number / one pod	Seeds weight (gram) / plant	Weight of 100 seeds (gram)
Field conditions	8.52a $\pm$ 1.16	17.26a $\pm$ 0.23	17.86a $\pm$ 0.83	1.96a $\pm$ 0.06	13.04a $\pm$ 0.04	58.40a $\pm$ 2.60
Field conditions + Proline	9.60a $\pm$ 0.00	18.04a $\pm$ 0.09	18.06a $\pm$ 0.16	2.10a $\pm$ 0.01	16.16b $\pm$ 0.12	61.33a $\pm$ 0.10
Field conditions + Salicylic acid	8.62a $\pm$ 1.50	17.42a $\pm$ 0.64	16.86a $\pm$ 0.16	2.31a $\pm$ 0.16	13.40a $\pm$ 0.78	62.56a $\pm$ 7.70
25 % level of drought	5.83b $\pm$ 0.33	11.71b $\pm$ 0.38	15.05b $\pm$ 0.50	1.82ab $\pm$ 0.10	10.84c $\pm$ 0.43	48.75b $\pm$ 0.48
25 % level of drought + Proline	6.80b $\pm$ 1.16	15.29c $\pm$ 0.23	18.10a $\pm$ 0.56	2.08a $\pm$ 0.01	12.40a $\pm$ 0.10	56.00a $\pm$ 1.80
25 % level of drought + Salicylic acid	6.80b $\pm$ 1.33	14.36c $\pm$ 0.93	17.10a $\pm$ 1.50	2.00a $\pm$ 0.08	11.48c $\pm$ 0.42	55.05 a $\pm$ 1.00
50 % level of drought	4.66c $\pm$ 0.16	7.30d $\pm$ 0.91	10.61c $\pm$ 0.16	1.64b $\pm$ 0.03	6.39d $\pm$ 0.83	45.16b $\pm$ 3.97
50 % level of drought + Proline	6.70b $\pm$ 1.00	9.60e $\pm$ 0.62	13.20d $\pm$ 0.83	1.81ab $\pm$ 0.08	7.10d $\pm$ 0.57	53.16a $\pm$ 4.55
50 % level of drought + Salicylic acid	5.80b $\pm$ 1.00	8.90e $\pm$ 0.30	12.7d $\pm$ 1.00	1.70b $\pm$ 0.04	6.90d $\pm$ 0.30	51.80ab $\pm$ 3.82

Data with in columns represents the mean of 3 replicates $\pm$ SD. Within columns, values followed by different letters are significantly ($P < 0.05$).

Fig. 1. Effect of proline and salicylic acid on total chlorophyll content of broad bean (*Vicia faba* L.) leaves (a) after vegetative treatment and (b) under three levels of water; field condition, 25 % level of drought and 50 % level of drought.

Fig. 2. Effect of proline and salicylic acid on (a) the pod number / plant, (b) pod weight per plant, (c) seed number per plant, (d) seed number per one pod, (e) seed weight (in gram) per plant and (f) weight of 100 seeds (in gram) at harvest of broad bean (*Vicia faba* L.) grown under three levels of water; field capacity, 25 % level of drought and 50 % level of drought.

DISCUSSION

Drought significantly reduced the relative water content (RWC) as illustrated in table, (1) and this finding agreed with work of Lobato et al. [23] in soy bean under stress and in some tolerant plants [24,25] Results was illustrated in table, (2) show that decreasing soil water reduced the leaf nitrogen, potassium and calcium and this foundation previously showed on broad bean [26] and on wheat [27]. Drought trouble the mineral nutrient relevance to another in plants during their effects on nutrient accessibility, transport, and partitioning in plants [28]. Drought is proving firstly as osmotic stress, resulting in the disruption of

homeostasis and ion division in the cell (29) and also may be able to be reduce soil N mineralization, thus decreasing the N availability [30]. Moreover, the availability of K to the plant reduces with decreasing soil water content, caused to the lowering mobility of K under these conditions [28]. As well as Ca uptake decreased under drought conditions [28].

The results illustrated in table, (3) and Fig. (1) show that the chlorophyll content decreased significantly by reducing soil water levels and this passive effect of drought on the chlorophyll content agreed with Makbul et al. [31]. This pigment was sensitive to increasing environmental stress [31] where chlorophyll formation linked to relative water content, nitrogen and potassium contents (23). Masoumi et al. [32] reported that the degree of chlorophyll reducing in soybean leaves was connection with the force of drought treatments. Lowering in chlorophyll content in the stressed plants may be able to be caused attribute to enhanced activity of chlorophyllase, a chlorophyll-degrading enzyme [33].

The results illustrated in table, (4), clear that drought significantly increase the activity of catalase and peroxidase enzymes. Sharma et al. [34] find the same effect on catalase enzyme activity and also the increasing of peroxidase activity under drought illustrated by EL-Tayeb and Ahmed [35]. The apoplastic peroxidase activity increased under various stress conditions [36].

Water deficit significantly decreased broad bean yield parameters; pod number per plant, pod weight per plant, seed number per plant, seed weight per plant and weight of 100 seeds (Table, 5 and Fig. 1), this situation similar to work made Al-Suhaibani [37] on broad bean and Kobraei et al. (38) who works on soy bean cultivars. The reduction on yield observed previously by many works as on barley grains [39]. This effect of drought may due to disturbance in cell turgor (40).

Proline and salicylic acid alleviated the drought effect on broad bean plant under drought condition (Table, 1-5 and Fig. 1). Proline improved the growth of broad bean at drought levels, Yan et al. [41] showed that proline improved the growth and yield of broad bean under stress. The exogenous application of proline induces a biotic stress tolerance in plants [12,14] and maintain cell turgor thus increase water uptake and also act as free-radical scavengers or chemical chaperones by immediately stabilizing membranes and/or proteins [1,29,42] and acts as an osmoprotectant and has roles in osmoadjustment [43]. The efficiency of exogenous proline to preserve greater water content in roughly stressed seedlings might be attributed to its contribution to osmotic adjustment both immediately by increasing the internal proline content and indirectly by highly the internal contents of other amino acids [29]. Many reports illustrated the ability of proline to counteract water stress where spraying cotton plants grown under conditions of low soil water potential with proline solutions counteracted the effects of stress, especially at moderate and high stresses [44]. Proline has also been shown to act as a molecular chaperone involved in protection of protein integrity and enhancement of the activities of different key enzymes [45].

Also, salicylic acid ameliorated the effect of drought on broad bean growth and yield under 25 and 50 % drought. Salicylic acid has a successful role in keep safe plants versus abiotic stresses [46]. The results showed the ability of salicylic acid to counteract the harmful effect of drought on RWC, chlorophyll content, peroxidase and catalase enzymes and bean productivity. This finding agreed with Maghsoudi et al., [46] illustrated the beneficial effects of application of salicylic acid on RWC, chlorophyll content and antioxidant enzymes in wheat plants under drought stress conditions. Salicylic acid treatment improves the efficiency of plant growth under drought stress by improve osmotic adjustment and internal proline content in wheat plant [46] and in barley [26]. Singh and Gautam [47] considerable positive attachment has been observed among the enhanced concentration of intracellular proline and the ability of plants to survive under abiotic stress conditions. Therefore, it was believed that the salicylic acid induced enhanced synthesis of proline become better plant allowance versus stresses. [44,47].

Rao et al. [49] showed that salicylic acid improved the growth and yield of *Vicia faba* L. plant under water stress. Treatments with salicylic acid alleviated the harmful effect of drought on the yield parameter as weight of pods, weight of seed per plant [50]. Salicylic acid able to regulate stomatal openings and reduce transpiration water loss so enabled the plants to maintain turgor [49] and increased the production of photosynthetic apparatus that produced more photosynthesis (51). Exogenous application of salicylic acid can withstand the water stress in a variety of maize [52], barley [53], and wheat [9, 54].

CONCLUSION

Drought occurs when the amount of water absorbed by plant root is insufficient for plant growth. Drought reduced broad bean growth and yield depending on the level of soil water and the negative effect increases as the drought level increases. Recently many substances used to mitigate the harmful effect of the drought on the plant. This experiment illustrated that application of proline, salicylic acid improved the plant growth and yield under water stress condition and the effect of proline was better than salicylic acid on almost all parameters of growth and yield. According to this work, it is preferred to spray the plants either by proline or salicylic acid during vegetative and flowering stages to relief the harmful effects of drought on the plant growth and yield.

CONFLICT OF INTEREST

I have no conflicts of interest to declare

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AUTHOR CONTRIBUTIONS

This research conducted by single author; Abdulrahman A. Alzandi

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