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Full Length Article

Mitigation of Drought Stress-induced Adverse Effects on Antioxidant System of Eggplant by Exogenous Application of Alpha-Tocopherol

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Abstract

Escalating drought stress is viewed as alarming for vegetable crop production. Drought stress is posturing negatives effects on vegetable plant including Brinjal or eggplant (*Solanum melongena* L.). To fight against drought stress short-gun approaches are gaining popularity by exogenous applications of osmolytes, osmoprotectants or antioxidants. A pot study was carried out to mitigate the negative effects of drought by foliar application of α-tocopherol Two eggplant cultivars, Sultan F1 and Janak F1 were sown in plastic pots filled with soil (mixature of sand, clay and loam). There were five levels of foliar sprays (no spray, water spray, 0.25, 0.5 and 1 mM α-tocopherol) and two levels of drought (well-watered and watering at 50% field capacity) after 45 days of sowing. Findings of this study revealed that the exogenous application of α-TOC, particularly at the level of 0.5 mM, alleviated drought stress in both cultivars as depicted by improved growth (shoot and root fresh and dry weight) and yield (fruit fresh weight/plant and number of fruit/plant) which was linked to enhanced enzymatic (Catalase, POD, SOD and APX) activities and non-enzymatic systems (total phenolics, free proline and ascorbic acid) levels.

Keywords: Eggplant; α-tocopherol; Drought; Growth; Antioxidants

Introduction

Climatic changes are involved in causing arid conditions across the world, thus researchers are interested in observing plant responses to arid conditions (Ashraf, 2010). Arid environments along with high radiation and heat stress cause serious threats for optimum plant growth (Araus *et al*., 2008). Levels of water tables are deepening due to extensive use of tube wells and increased arid conditions along with increased population of humans. All these conditions will pose a serious threat to plant production mainly in third world countries like Pakistan (Backlund *et al*., 2008). Thus, it is essential to find out the effects of drought on crops to bring improvements in managing strategies in agricultural sectors and plant responses to environmental changes (Ryan *et al*., 2008; Tabassum *et al.*, 2018).

Drought stress is also posing negative effects on vegetable plant including brinjal (*Solanum melongena* L.) generally recognized as eggplant, a member of the family Solanaceae (Knapp *et al*., 2013). It is a popular and important vegetable and is cultivated in subtropical and tropical regions. But in temperate regions of the world, eggplant is grown mostly during warm season (Vijaya and Seethalakshmi, 2011). Eggplant is an economic vegetable, can be cultivated in many regions of world but its cultivation is more extensive in Asia (Vani *et al*., 2014). Eggplant is mostly grown on farms and a chief source of money for poor farmers. Due to higher concentration of phenolic content brinjal is included in top 10 vegetables which have capability to absorb oxygen radicals (Swathy *et al.,* 2016).

Various plants processes which are affected by drought include growth and development and inhibition of cell expansion and decreased biomass (Hessini *et al*., 2009). Water shortage causes metabolic alterations in plants (Chaum and Kirdmanee, 2009). Drought stress also inhibits activities of various enzymes (Ahmad *et al*., 2009). Water shortage disturbs addition of solutes (Scala *et al.,* 2008). Plants both morphologically and physiologically adapt themselves to decrease toxicities of water stress (Ahmad *et al*., 2009). Plants recognize stress via roots and transmit signals for altered metabolic processes and then to activate defensive processes (Reddy *et al*., 2004). Stomatal closure is a chief precedency of plants in moderately or severely limited supply of water (Cornic and Massacci, 1996). Reactive oxygen species (ROS) are synthesizes in plants in usual growth situations, but they are produced with greater rates in response to various stresses like drought stress.

Reactive oxygen species (ROS) are produced in various cellular parts but the common site for their generation is chloroplast. Under water deficit conditions ROS are produced due to inhibited photosynthetic activities because of imbalance in consumption of absorbed light (Reddy *et al*., 2004). The ROS are detoxified by

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antioxidative enzymes such as peroxidase, catalase, glutathione reductase, Superoxide Dismutase (SOD) and Ascorbate peroxidase (APX) and these are of primary importance (Ahmad *et al*., 2008). Under stressful conditions, plants enhance activity of these antioxidants and this in more noticeable in tolerant species (Bian and Jiang, 2009).

Among various foliar applied osmolytes and antioxidant, tocopherols are also gaining popularity. Tocopherols belonging to family of vitamin E are lipophilic antioxidants and have association with tocotrienols. Their synthesis take place from photosynthetic organisms such as algae, plants and cyanobacteria (Falk and Munne-Bosch, 2010). Common tocopherols exist in tissues of plants are alpha- and gamma-tocopherols. Alpha tocopherol is present in green leaves and gamma tocopherol in seeds, nuts and fruits (Jin and Daniell, 2014). They are synthesized in leaf plastids and they show occurrence in vacuoles and nuclei of *Hordeum vulgare* (Falk *et al*., 2004). In plants, ROS are generated in chloroplast mainly in the form of singlet oxygen (Asada, 2006). Membranous structures of chloroplast are enriched with alpha tocopherol because of its essential roles in scavenging of ROS such as $^1O_2$ and lipid peroxyl radicals. It protects photosynthetic apparatus from oxidative burst and peroxidation of lipids (Munné-Bosch, 2005). Similarly, gamma tocopherol performs significant roles in protection of polyunsaturated fatty acids from oxidative damage (Fachechi *et al*., 2007).

In view of the above account, we hypothesize that foliar spray of α-tocopherol may have implications in lessening the adverse effects of water stress by activating the antioxidative system in the leaves. In the light of extensive role of tocopherols, α-tocopherol was applied on eggplant under normal and water deficit regimes to undermine the importance and role of α-tocopherols under drought stress conditions.

Materials and Methods

The experiment was conducted in plastic pots at Old Botanical-Garden of Department of Botany, University of Agriculture, Faisalabad, Pakistan during 2016. Equal proportion of sand, clay and loam was used to fill the pots with equal weight of 8 kg dry soil in each pot. Two eggplant cultivars, Sultan F1 and Janak F1, were utilized for the investigation. The propagating material i.e. seeds of eggplant were collected from Vegetable Research Institute, Faisalabad, Pakistan. Two water stress levels (regular watering (control) and 50% FC) were started 17 day after sowing (DAS). Drought status in pots were regularly maintained and monitored, watering was performed, if essential daily until the crop maturation.

There were five treatments including three α-tocopherol levels (control, water spray, 0.25, 0.5 and 1 mM) which were used as exogenous application at vegetative growth phase i.e. 45 days after sowing. Two plants from each experimental unit were harvested after 3 weeks of foliar application. Fresh weights of root as well as shoot were recorded. After that the plant parts were dried in oven at 65° C for 72 h and recorded their dry weights. Length of root as well as shoot was also recorded.

Leaf Gas-Exchange Attributes

Stomatal-conductance (gs), transpiration-rate (E) Net-CO_2 assimiliation-rate and sub-stomatal CO_2 concentrations (C_i) on the third leaf of each plant were recorded using portable CIRAS. These characteristics were noted from 13 to 14 h.

Determination of Antioxidants

For the estimation of enzymatic antioxidants CAT as well as POD method of Chance and Maehly, 1955 was adopted. Leaf sample (0.5) was grounded in 50 mM potassium-phosphate buffer. For the estimation of POD activity, assay solution was made by blending 50 mM potassium-phosphate buffer (pH 7.0), 20 mM guaicol, 40 mM H_20_2 and 0.1 mL enzyme extract. After that the absorbance was taken at wavelength of 470 nm at 20 s intervals using spectrophotometer.

Furthermore, assay solution for CAT activity was prepared by mixing 50 mM phosphate buffer (pH7.0), 5.9 mM H_20_2 and 0.1 mL enzyme extract. Decrease in values of absorbance was recorded at wavelength of 240 nm after every 20 s. For the measurement of ascorbate peroxidase (APX) enzyme, method of Nakano and Asada (1981) was adopted. As per this method, a reaction assay was made by different quantities of enzyme extract (100 µL), ascorbate (100 µL of conc. 7.5 mM), H_2O_2 and potassium-phosphate buffer (2.7 mL) along with neutral EDTA. The absorbance reading of this assay was measured at 290 nm.

Lipid-peroxidation in leaf membranes was estimated by measuring malondialdehyde (MDA) contents by adopting method of Heath and Packer (1968) with slight modification as suggested by Zhang and Kirkham (1994). Leaf (0.25 g) was crushed in 5 mL solution of TCA (0.1%) and mixed in 4 mL of TCA (20%) comprising 0.5% TBA. Absorbance of reaction was recorded at 532 and 600 nm.

Total Phenols

Method suggested by Ainsworth and Gillespi (2007) was followed to measure total phenolic content in leaf sample. Leaf (0.2) was grounded in 0.8 mL methanol and centrifuged. Supernatant (100 µL) was mixed FC-regent (100 µL) and Na_2CO_3 (800 µL having concentration 700 mM) and absorbance was noted at 765 nm.

Free Proline Accumulation

Free proline content was recorded using method of Bates *et al*., (1973). Fresh leaf sample (0.5) was ground in 10 mL

sulfosalicylic acid. Then filtration was done to get filtrates of 2 mL which was blended with 2 mL acid-ninhydrin solution, 4 mL toluene and 2 mL glacial acetic-acid in test tube. Then absorbance of ring develops on top of solution in test tube was taken at 520 nm wavelength.

Ascorbic Acid (AsA)

Method adopted by Mukherjee and Choudhuri (1983) was used to measure AsA. Fresh sample of leaf (0.25 g) was ground in 10 mL solution of TCA, 2 mL of dinitrophenyl hydrazine (2%) and one drop of thiourea (10%). Absorbance of assay was read at 530 nm.

H_2O_2 Content

For recording H_2O_2 content method of Alexieva *et al.* (2001) was adopted. The H_2O_2 content was measured spectrophotometrically by following Alexieva *et al.* (2001). The reaction mixture contained 0.5 mL trichloroacetic acid, 100 mM K-phosphate buffer (0.5 mL) and reagent (2 mL) 1 M KI. The absorbance of reaction assay was measured at 390 nm by using spectrophotometer.

Yield Attributes

Yield traits that are number of fruits per plant and fruit fresh weight per plant in experiments were recorded. At maturity from each treatment three plants were selected from each pot and no. of fruits per plant counted manually and takes average. Plants fruit biomass was harvested from each pot to measure biological yield in kg.

Statistical Analysis

Completely randomized design (CRD) was laid out for the experiment using 4 replicates of every experimental unit. Data obtained from repeated experiments were subjected to analysis of variance (ANOVA) to observe the significance in the treatments and means were compared using LSD at 5% levels of probability.

Results

Drought stress considerably ($P \leq 0.001$) decreased the shoot fresh weights of both eggplant cultivars (Sultan F1 and Janak F1) while Janak F1 indicated a lower fresh weight as compared to the Sultan F1. Foliar applied α-tocopherol significantly ($P \leq 0.001$) increased the shoot fresh weights in both eggplant cultivars under both non-stress and drought stress conditions. The interactions between drought and α-tocopherol, cultivars and drought, cultivars and α-tocopherol were also significant (Table 1; Fig. 1). Water deficit condition remarkably lessened the root fresh weights in both eggplant cultivars. Variations among the cultivars were also prominent, since a greater decline was observed in root

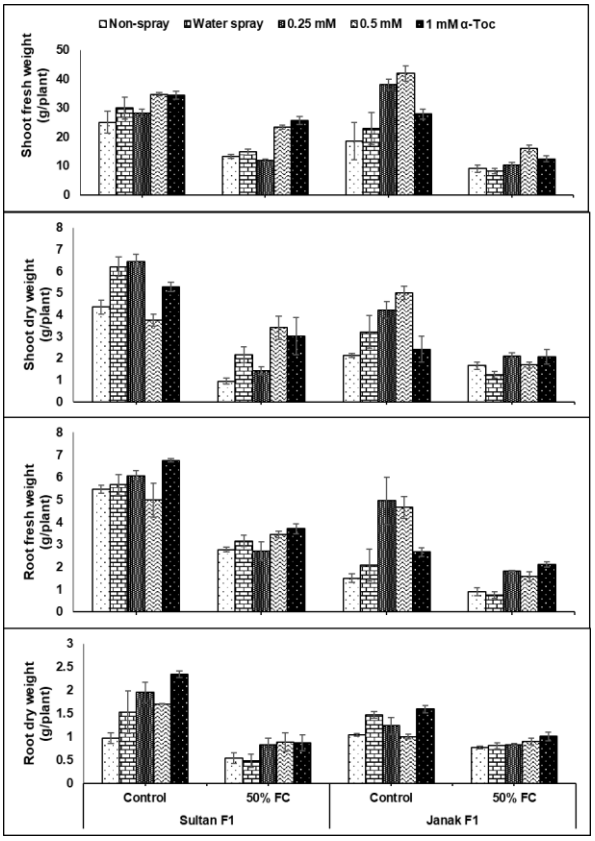

Fig. 1: Shoot and root fresh and dry weights of eggplant (*S. melongena*) cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

fresh weights of Janak F1 as compared to the Sultan F1. Foliar Spray of α-tocopherol markedly increased the root fresh weights in both eggplant cultivars under water stress condition whereas under control condition no significant effect of α-tocopherol was observed in both eggplant cultivars (Table 1; Fig. 1).

Water deficit conditions reduced the shoot dry weights in both eggplant cultivars (Sultan F1 and Janak F1). A greater decline in shoot dry weights was observed in Janak F1 as compared to the Sultan F1. Foliar applied α-tocopherol markedly increased the shoot dry weights in both eggplant cultivars under drought stress (Table 1; Fig. 1). α-tocopherol level of 0.5 mM was more prominent in enhancing shoot dry weight as compared to others levels in eggplant. A severe reduction in the root dry-weights of both the cultivars was experienced under drought stresses conditions. Variation among cultivars was also prominent. Greater decline was observed in Sultan F1 as compared to the Janak F1. Foliar applied α-tocopherol significantly increased the root dry weights of both eggplant cultivars under both non-stress and water stress conditions (Table 1; Fig. 1).

Drought stress caused significant reduction in net CO_2 assimilation rate (*A*) of both eggplant cultivars. Although,

Table 1: Mean squares from analysis of variance of data for gas exchange, growth and yield attributes of eggplant cultivars (Sultan F_1 and Janak F_1) were subjected to α-tocopherol (foliar spray) under control and water stress condition

Source	Df	*A*	*E*	g_s	Shoot fresh weight	Root fresh weight	Shoot dry weight	Root dry weight	Fruit fresh weight per plant	Number of Fruits per plant
Cultivars (C)	1	57.545***	0.7605**	0.0012*	260.75**	94.690***	25.065***	0.4047*	128.04ns	1.8ns
Drought (D)	1	1244.0***	2.9337***	0.0680***	4917.0***	95.755***	108.43***	9.5980***	208372.8***	4.05ns
α-tocopherol (α-toc)	4	7.8847**	0.3801**	0.0018***	390.88***	5.0263***	4.1130***	0.8176***	37604.8***	67.543***
C × D	1	0.0667ns	2.738***	2.645ns	178.77*	3.9444*	9.4668***	1.6102***	646.78ns	1.8ns
C × α-toc	4	8.6636**	0.1354ns	3.9857ns	125.22**	4.2326***	2.3204**	0.2765*	1934.4ns	3.0187ns
D × α-toc	4	5.8454*	0.4242***	5.1933ns	88.083*	1.6453*	3.4729***	0.3134*	1393.6ns	0.3937ns
C × D x α-toc	4	5.5363*	0.1403ns	6.1758ns	53.207ns	2.6177**	6.0877***	0.0892ns	6279.9***	0.6437ns
Error	60	2.0210	0.0798	2.6875	25.594	0.6473	0.6222	0.0925	2317.3	1.7583

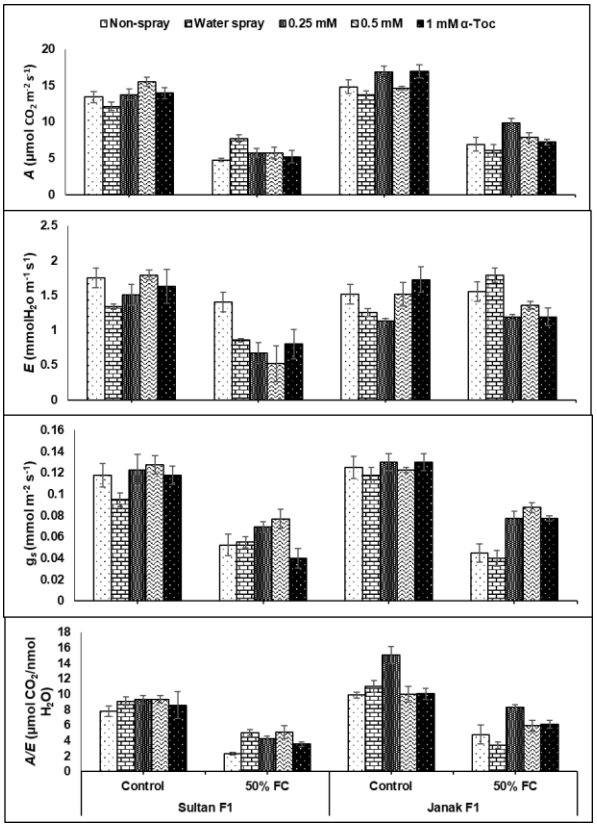

Fig. 2: Gas exchange attributes of eggplant cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

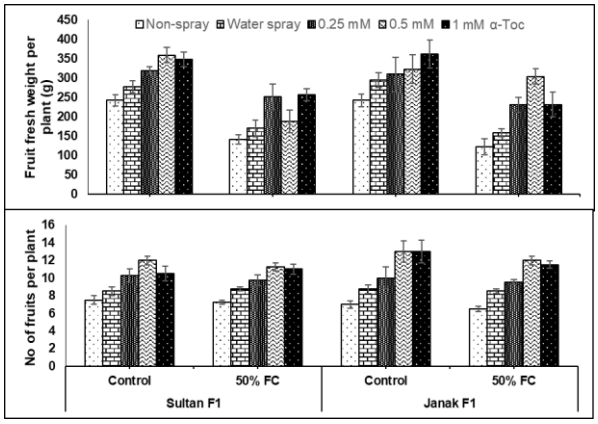

Fig. 3: Yield attributes of eggplant cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

both cultivars differed significantly in net CO_2 assimilation rate (*A*), Sultan F1 was inferior to Janak F1. Exogenous application of α-tocopherol significantly increased the net CO_2 assimilation rate (*A*) in both eggplant cultivars under non-stress and water stress conditions. The most prominent level of α-tocopherol for increase in net CO_2 assimilation rate in both eggplant cultivars was 0.5 mM under water stress conditions (Table 1; Fig. 2). Drought stress considerably decreased the transpiration rate (*E*) of both eggplant cultivars. Both cultivars differed significantly as Janak F1 was superior as compared to Sultan F1 for this parameter. Exogenous application of α-tocopherol significantly ($P \leq 0.001$) increased *E* in both eggplant cultivars under both non-stress and drought stress conditions. Foliar treatment with 0.25 mM α-tocopherol was more effective in increasing transpiration rate (*E*) in Sultan F1 and 0.5 mM in Janak F1 (Table 1; Fig. 2). Stomatal conductance (g_s) considerably decreased in both eggplant cultivars under drought stress condition. Both cultivars differed significantly in stomatal conductance (g_s) but the reduction was more prominent in Sultan F1. However, foliar application of α-tocopherol (0.25 and 0.5 mM) markedly increased the g_s in both eggplant cultivars under drought stress condition (Table 1; Fig. 2).

Fruit fresh weight per plant was markedly reduced in both eggplant cultivars under water stress condition. Although, response of both cultivars was non-significant for this yield attribute, nonetheless, foliar spray of α-tocopherol significantly increased the fruit fresh weight per plant in both eggplant cultivars. Among various α-tocopherol levels, 0.5 and 0.25 mM foliar treatments proved to be more effective in enhancing fresh weight of fruits in Janak F1 and Sultan F1, respectively under water stress conditions (Table 1; Fig. 3). A significant reduction in the number of fruits/plant was noticed in both eggplant cultivars under drought stress condition. Although, both eggplant cultivars did not differ significantly in this characteristic, exogenous

application of α-tocopherol significantly increased the number of fruits/plant in both eggplant cultivars under both non-stress and water stress conditions. In comparison, more yield was observed in Janak F1 as compared to Sultan F1. Of all levels, 0.5 mM α-tocopherol foliar treatment was more effective in enhancing the number of fruits per plant in both non-stress and water stress conditions (Table 1; Fig. 3).

Catalase (CAT) activity significantly decreased in both eggplant cultivars under water deficit conditions. Both eggplant cultivars also differed significantly in term of CAT activity. More reduction was observed in catalase activity of Sultan F1 than Janak F1. Foliar applied α-tocopherol significantly increased the CAT activity. Of various α-tocopherol levels 0.25 mM was more effective for increasing CAT activity in both cultivars under both non-stress and water stress conditions (Table 2; Fig. 4). Drought stress caused significant reduction in the peroxidase (POD) activity of both eggplant cultivars. Eggplant cultivars differed significantly in POD activity as decrease was higher in cultivar Sultan F1 as compared to Janak F1. However, foliar application of α-tocopherol significantly increased the POD activity in both eggplant cultivars under non-stress and water stress conditions. Among various levels, 0.5 mM α-tocopherol spray considerably increased the POD activity in both eggplant cultivars under drought stress condition (Table 2; Fig. 4). A considerable reduction in superoxide dismutase (SOD) activity of both eggplant cultivars was observed under drought stress condition. Variation among cultivars was also prominent Janak F1 was superior and Sultan F1 inferior in this attribute. Exogenously applied α-tocopherol significantly increased the SOD activity of both eggplant cultivars under both non-stress and water stress condition. A higher increase in SOD activity was observed in both eggplant cultivars at 0.25 mM α-tocopherol foliar treatment (Table 2; Fig. 4). Ascorbate peroxidase (APX) activity of eggplants was reduced under drought stress. Although both eggplant cultivars differed significantly in this characteristic as Janak F1 was superior to Sultan F1. However, exogenously applied α-tocopherol effectively enhanced APX activity under control and water stress condition. α-tocopherol foliar treatment @ 0.5 mM increased the APX activity in Janak F1 whereas 0.25 mM α-tocopherol foliar treatment was effective in Sultan F1 (Table 2; Fig. 4).

Drought stress considerably decreased free proline content in both eggplant cultivars. However, both cultivars did not differ significantly. Application of α-tocopherol as foliar spray significantly increased free proline contents. Of various α-tocopherol levels, 0.5 and 1 mM levels increased free proline content under water deficit condition in both eggplant cultivars (Table 2; Fig. 5). Water deficit condition reduced the leaf ascorbic acid content in both eggplant cultivars. Cultivars differed significantly in leaf ascorbic acid content. As more reduction in ascorbic acid content was recorded in Sultan F1 as compared to Janak F1. Exogenous application of α-tocopherol markedly increased

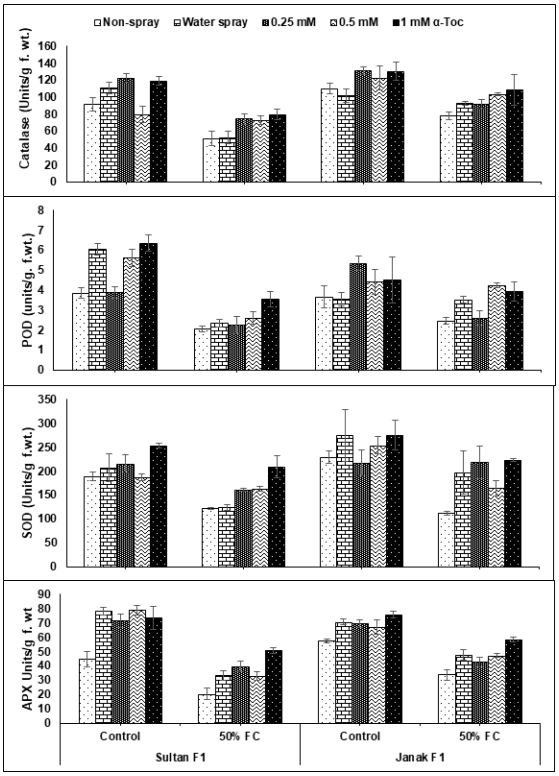

Fig 4: Enzymatic antioxidants of eggplant cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

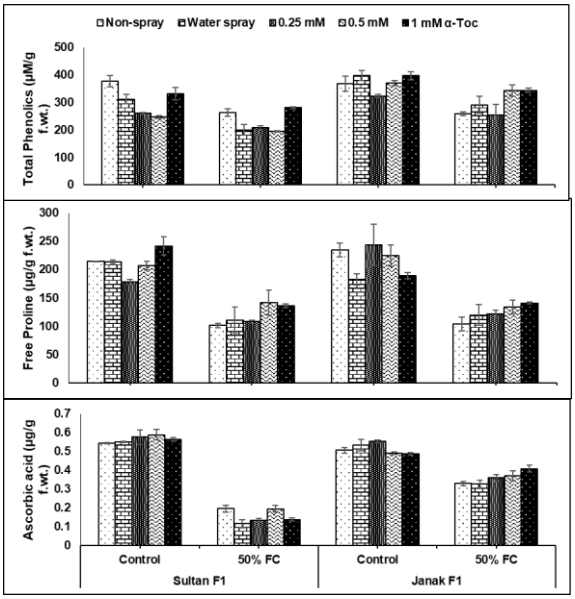

Fig. 5: Non-enzymatic antioxidants of eggplant cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

leaf ascorbic acid content in both eggplant cultivars under drought stress condition. α-tocopherol level 0.25 and 0.5

Table 2: Mean squares from analysis of variance of Reactive oxygen species, organic osmolytes and antioxidant attributes of eggplant cultivars (Sultan F_1 and Janak F_1) subjected to α-tocopherol (Foliar spray) under control and water stress condition

Source	df	Malondialdehyde	Hydrogen peroxide	Total free proline	Catalase	Peroxidase	Superoxide dismutase	Ascorbate peroxidase
Cultivars (C)	1	613.54ns	14190.2***	347.42ns	9439.5***	0.0272ns	22469.4**	432.45**
Drought (D)	1	65887.7**	156118.1***	165711.0***	19876.5***	62.254***	73998.2***	15792.2***
α-tocopherol (α-toc)	4	128347.3***	40497.4***	1337.4ns	1954.5***	5.9117***	12178.2***	1412.2***
C × D	1	49056.1*	1054.8ns	0.7716ns	1015.3ns	13.484***	801.88ns	696.2***
C × α-toc	4	9739.0ns	496.66ns	2337.5*	352.35ns	1.8990ns	1935.8ns	105.54ns
D × α-toc	4	59854.1***	4319.6***	1396.8ns	531.66ns	0.2978ns	2720.6ns	137.41ns
C × D x α-toc	4	3679.8ns	1775.5*	2128.1*	509.34ns	3.6505**	2245.6ns	127.73ns
Error	60	7840.3	520.13	810.18	263.66	0.7603	2124.4	56.016

mM was proved to be more effective in Sultan F1 and Janak F1, respectively (Table 2; Fig. 5). A significant reduction in total phenolics content of both eggplant cultivars was observed under drought stress condition. Variation among cultivars was also prominent as more reduction was recorded in Sultan F1 than Janak F1. Exogenous foliar treatment with α-tocopherol increased the phenolics content under non-stress and drought stress condition in both eggplant cultivars. Of various levels, 1 mM α-tocopherol level was more effective in increasing the total phenolics contents (Table 2; Fig. 5).

Drought stress considerably increased the malondialdehyde (MDA) content in both eggplant cultivars. Eggplant cultivars varied significantly in the accumulation of MDA content. Exogenous foliar applied α-tocopherol significantly decreased MDA content in both eggplant cultivars under non-stress and drought stress conditions. Of various α-tocopherol levels, 0.25 mM treatment reduced the MDA content of both eggplant cultivars under water stress condition (Table 2; Fig. 6). Water deficit condition remarkably increased the H_2O_2 content in both eggplant cultivars. Foliar application of α-tocopherol markedly decreased H_2O_2 content in both eggplant cultivars though, Janak F1 accumulated less H_2O_2 than Sultan F1 under drought stress condition. Of various α-tocopherol levels, 0.25 mM α-tocopherol foliar treatment proved more effective in reducing H_2O_2 content in both cultivars under water deficit condition (Table 2; Fig. 6).

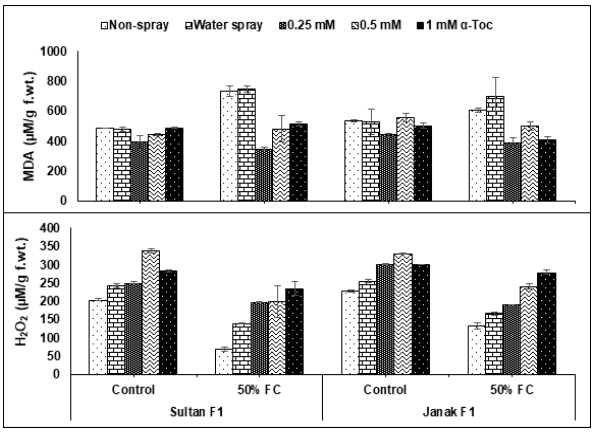

Fig. 6: Reactive oxygen species and Lipid peroxidation of eggplant cultivars (Sultan F1 and Janak F1) when plants subjected to α-tocopherol foliar treatments under control and drought stress conditions

Discussion

In the present study, foliarly applied α-tocopherol significantly alleviated severe impacts of drought on eggplants performance as determined in terms of changes in growth and yield parameters. Drought stress significantly reduced the gas-exchange attributes including, photosynthetic rate (*A*), transpiration rate (E) water-use efficiency (*A*/*E*) and stomatal-conductance (g_s) Whereas, foliar spray of alpha tocopherol in the current investigation increased all these gas exchange attributes under drought stress. These findings suggest that α-tocopherol shields photosystems from oxidative stress induced due to abiotic stresses thus, increase photosynthesis and transpiration (Bughdadi, 2013). The improvements in these attributes might be due to the induction of antioxidant activities in eggplant also depicted by results of current study. According to the conclusions of various studies and experiments (Rady *et al.,* 2013), over-production of reactive-oxygen species (ROS) i.e., superoxide and hydrogen peroxide and free radicals is the main reason behind the oxidative damage generated under water stress.

To protect against damages of ROS, many antioxidant systems operates in plants including SOD (Superoxide dismutase) act as first protective agent, against ROS (Alscher *et al.*, 2002) by converting $O_2^{\bullet-}$ radical to H_2O_2. The H_2O_2 can function as substrate for enzymes like CAT which is produced in peroxysomes where H_2O_2 concentration is high and thus it is detoxified by peroxidaces. CAT and SOD are considered as potential antioxidants to preven cellular damage (Scandalios, 1993).

In addition, APX is considered an important enzyme, which reduce H_2O_2 concentretion (Feierabend, 2005). In the current study α-TOC application amplified the activities of CAT, SOD, APX and POD under water stress condition in both eggplant cultivars. This situation is reflected in the total contents of AsA in this study. It is increased by the application of α-TOC under water stress, alleviating the buildup of $O_2\bullet-$. The AsA can directly eliminate $O_2^{\bullet-}$ and

H_2O_2 in a non-enzymatic way (Foyer *et al*., 1991).

Although some scientists have reported improvement in α-TOC contents due to foliar applied α-TOC serving as a solute for osmotic adjustment (Orabi and Abdelhamid, 2016), an important aspect of tolerance to water stress (Taie *et al.,* 2013). Furthermore, less free proline and total soluble sugars were found in this study due to foliar applied α-TOC. This suggests a vital role of α-TOC an antioxidant to mitigate harmful effects of drought. This may be attributed to the crucial role of α-TOC as an antioxidant in mitigating the deleterious drought stress effects. The antioxidant activity of α-TOC neutralizes ROS i.e. free radicals (Mehrjerdi *et al.,* 2013), which damages electron transport in PSII.

Malondialdehydes (MDA) produced under stress, is the product of degraded fatty-acids of cell membranes due to oxidative stress. Therefore, the rate of MDA production can be used as an indicator to access plant stress tolerance (Jain *et al*., 2001). Nevertheless, a significant decline in MDA has been verified as a consequence of α-TOC foliar/seed application assuring an increase in plant's defense system by scavenging different kinds of ROS produced under various stresses. Moreover, substantial decrease in the H_2O_2 was noted when α-TOC was foliarly applied on water-limited eggplants. Moreover, this was accompanied by buildup in other antioxidants such as free proline, AsA, SOD, APX, POD and CAT, which enable eggplant to enhance its ability to defend and overcome water stress by limiting negative effects of ROS.

Conclusion

Exogenous application α-TOC @ 0.5 mM improved stress-tolerance of Brinjal plants by enhancing enzymatic (Catalase, POD, SOD and APX) and non-enzymatic systems (Total phenolics, free proline and Ascorbic acid).

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