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THE EFFECT OF ABSCISIC ACID APPLICATION ON ROOT-SHOOT LENGTH AND SOME ANTIOXIDANT ENZYME ACTIVITIES OF TWO DIFFERENT TOMATO SEEDLINGS

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ABSTRACT

In this study, we determined the changes in root-shoot length, chlorophyll and carotenoid contents, and some antioxidant enzyme activities in leaf tissues of two different tomato (*Lycopersicon esculentum* Mill. cv. Aspendos and Donna) seedlings exposed to exogenous abscisic acid (ABA) 7 day intervals for a period of 28 days. Tomato seedlings were grown under controlled conditions using at seedling industry. When the seedlings had first true leaves, ABA was sprayed at 1, 10, 50 and 100 µM on upper and lower epidermis of plants. While 1 and 10 µM ABA exposure caused increases, 50 and 100 µM ABA exposure caused decreases in root and stem length of both tomato cultivars compared to control. Treatment with all ABA concentrations significantly increased the activities of superoxide dismutase (SOD, E.C. 1.15.1.1), catalase (CAT, E.C. 1.11.1.6) and peroxidase (POD, E.C. 1.11.1.7) enzymes. Root-shoot length and pigment content were positively affected by ABA application for 14 and 21 days but 28 days application caused reductions in both parameters. Results of this study revealed that application of ABA at 1 or 10 µM for 14-21 day have shown beneficial role for tomato seedlings. Additionally, we thought that these seedlings which have higher chlorophyll content and SOD, POD and CAT activity compared to controls, were more resistant against various environmental stresses.

Keywords: Abscisid acid, pigments, antioxidant enzymes, *Lycopersicon esculentum* Mill.

INTRODUCTION

Abscisic acid (ABA) plays important roles in the regulation of the plant growth and development and, is synthesized from xanthophylls (Taylor *et al*., 2000). It is a natural hormone and is synthesized by plant in low levels in the absence of the stress factors (Jiang *et al*., 2001). ABA is very important agent in the mechanisms of resistance and adaptation in plants against various abiotic stress conditions (Yurekli *et al*., 2001; 2004; Li *et al*., 2010; Bakhsh *et al.,* 2011). ABA stimulates dormancy in seeds, prevents RNA and protein synthesis and seedling growth (Garciarrubio *et al*., 2003; Chen *et al*., 2008; Zhou & Guo 2009; Li *et al*., 2010).

The endogen ABA levels increase under abiotic stress conditions like drought and salinity (Yurekli *et al*., 2001; Xiong *et al*., 2002; Yurekli *et al*., 2004) and improve the stress tolerance via conversion of environmental signals into change in gene expression (Zhang *et al*., 2005; Fediuc and Erdei, 2002; Zhao *et al*., 2009). Since ABA is the most important regulator of the plant response to abiotic stress, it is called as stress hormone (Taylor *et al*., 2000; Gonai *et al*., 2004). Abiotic stress conditions cause the increase in biosynthesis and accumulation of ABA but accumulated ABA is destroyed with the effect of long term and high level of stress (Rock, 2000).

Reactive oxygen species (ROS) including superoxide anion (O_2^-), hydrogen peroxide (H_2O_2) and hydroxyl radicals (^-OH) are metabolites of plants under normal conditions (Zhou *et al*., 2005). Exogenous application of ABA triggers increases of these metabolites, thus it stimulates of the enzymatic and non-enzymatic antioxidant defense system in plants (Jiang and Zhang, 2002; 2004). ABA application to the plant under non-stressed conditions inhibits the plant growth but its inhibitory effect appears more in high concentration. Whereas, it has stimulating effect especially in low concentrations (Sharp, 2002). ABA can increase the activities of SOD, POD and CAT enzymes due to its stimulating effects on reactive oxygen species such as $O_2^{\cdot-}$ and H_2O_2 especially in high concentrations. Therefore one mode of ABA action may be related to its role in oxidative stress (Jiang & Zhang, 2004; Xiong & Zhu, 2003; Hu *et al*., 2005). It has been reported that ABA both induce the expression of genes encoding SOD, CAT, POD and ascorbate peroxidase (APX) enzymes and cause increase in the activities of these enzymes (Hu *et al*., 2005; Roychoudhury *et al*., 2009). Jiang & Zhang (2001) reported that ABA causes oxidative stress; a rising in the capacity of oxidative stress tolerance may refer that plants need to activate both the enzymatic and non-enzymatic antioxidant defense system to resist oxidative damage in stressed plant tissues.

In spite of the fact that there are strong evidences of increases in ABA content under various environmental stresses, the information about the effects of short and long-term ABA applications on the antioxidant enzymes of the seedlings is insufficient. Seedlings are grown under controlled (light, humidity, temperature, etc.) optimum conditions in seedling cultivation enterprises. For this reason, difficulties in adaptation to the environmental conditions can be observed when seedlings are transferred to the field conditions. It is well known that ABA increases the resistance in plants to abiotic stresses under environmental stress conditions such as drought, salinity, heavy metals, etc.

In this study, the effect of different concentration and exposure times of ABA on the root and shoot length, pigment contents, activities of antioxidant enzymes such as SOD, POD and CAT and relationship between ABA and antioxidant defenses were studied in seedlings of two tomato varieties. Additionally we determined that the possibility of the use of ABA in the seedling industry to achieve seedlings with more tolerance of adverse field conditions.

MATERIALS AND METHODS

Plant Material and Growth Conditions: This study was carried out at the greenhouse of Ahi Evran University, Vocational High School, Kirsehir/Turkey. Seeds of *L. esculentum* cv. Donna and *L. esculentum* cv. Aspendos were obtained from Beta Agriculture Inc. Bursa/Turkey. During the study the average temperature and photoperiod were 19±1 (night) /23±1°C (day), 14/10 h light/dark, respectively and relative humidity varied between 60-70 %. Seedlings were grown into the standard seedling tray including 45 holes 35x35x55 mm in size. Seedling trays were filled in torph (Klasmann Portground P, Germany): perlite (2:1) mixture. Irrigation was done with water containing 20.20.20 (N.P.K.)+trace element (Maxfoli, Izotar, Turkey)). When the seedlings had first true leaf (approximately 14-17 days after sowings), 1, 10, 50 and 100 µM ABA (Sigma, (±)-cis, trans-A1049) and distilled water (control) was sprayed on the upper and lower epidermis of leaves of tomato seedlings twice a day for a period of 28 days. Plant leaves were harvested at 7^{th}, 14^{th}, 21^{st} and 28^{th} days and were stored at -80 °C for the next step of chemical analysis.

Determination of Root and Shoot Length: Randomly selected root and shoot of at least ten seedlings were harvested at 7^{th}, 14^{th}, 21^{st} and 28^{th} days and photographed with high resolution digital cam. All images transferred to PC and root and shoot length measured by AUTOCAD 2007 (Autodesk Inc., 2007).

Determination of Antioxidant Enzyme Activities: SOD: Total SOD activity was assayed by monitoring the inhibition of photochemical reduction of nitrobluetetrazolium (NBT) according to the method of Beucamp and Fridovich (1971). Leaf samples (1 g) were homogenized in 4 ml 0.05 M Na-phosphate buffer (pH: 7.8) contained 1 mM etilenediaminetetraacetic acid (EDTA)Na_2 and 2 % PVPP (pollyvinylpolypirridone), which removes phenolics and alcoloids from tissue. Homogenate was centrifuged (Hettich Micro 22R) for 15 min at 14 000 rpm at 4°C. The reaction mixture was prepared with a total volume of 3 mL 50 mM Na-phosphate buffer, 33 µM NBT, 10 mM L-methionine, 0.0033 mM riboflavin and supernatant. Light reaction was started with the addition of riboflavin and mixture was kept for 10 min under 350 µmol/photon $m^{-2}s^{-1}$. Absorbances were determined at 560 nm with a spectrophotometer (PG instruments T80). Specific enzyme activity was expressed as enzyme unit per mg protein.

POD: Leaf samples (500 mg) were homogenized in cold Na-Phosphate buffer (4 ml 0.1 M) with homogenizer (IKA). Homogenate was centrifuged (Hettich Micro 22R) at 14000 rpm at 4°C. Enzyme activity was assayed in a reaction mixture containing 15 mM guaiacol, 5 mM H_2O_2, 0.1 mM Na-Phosphate buffer and 100 µl supernatant in a final volume of 1.0 ml. The absorbance was determined at 470 nm. Enzyme activity was expressed on units/g fresh weight. One unit activity was defined as an increase of one A per min (Birecka *et al*., 1973).

CAT: CAT enzyme activity was determined by measuring the initial rate of H_2O_2 disappearance at 240 nm using the extinction coefficient (Aebi, 1984). 0.5 g leaf sample was homogenized in 4 mL K-phosphate buffer (pH:7) and centrifuged at +4 °C. The absorbance of reaction mixture contained potassium phosphate buffer, 16 mM H_2O_2 and 80 µl supernatant was determined at 240 nm and enzyme and activity was determined as a decrease in absorbance at 240 nm for 1 min following decomposition of hydrogen peroxide (H_2O_2).

Determination of Total Soluble Protein Content: Total soluble protein content was measured according to Bradford (1976) using BSA (Bovine Serum Albumin) as a protein standard. Fresh leaf samples (1 g) were homogenized with 4 ml Na-Phosphate buffer (pH:7.2) and then centrifuged at 4°C. Supernatants and dye were pipetted in spectrophotometer cuvettes and absorbances were measured using a spectrophotometer at 595 nm.

Determination of Pigment Content: Fresh leaf tissue (200 mg) was homogenized in 8 ml 80% acetone. Homogenates were centrifuged at 4°C for 15 min at 3000 rpm. Absorbances of supernatants were determined at 645, 652, 663 and 470 nm and the amounts of pigments were calculated according to the formula of Lichtenthaler (1983).

Statistical Analyses: Differences in root-shoot length and physiological parameters in seedling tissue under effect of ABA exposure were compared using one-way ANOVA with means separation by Duncan's test using SPSS 15 software at a significance level $P \leq 0.05$. Correlations between concentrations of ABA and changes morphological and physiological parameters were analyzed by bivariate correlation test with Pearson Correlation Coefficient and two-tailed test of significance parameters using SPSS 15 software at a significance level $P \leq 0.05$ and 0.001. Standardized and unstandardized parameters, R square and ANOVA table belong to the linear regressions were calculated by linear regressions module of SPSS 15 software at a significance level $P \leq 0.05$.

RESULTS AND DISCUSSION

The effect of 7-28 days application of 0, 1, 10, 50 and 100 µM ABA on root and shoot lengths in two tomato cultivars are presented in Figure 1. In both tomato cultivars, the low concentration of ABA treatment (1 and 10 µM) resulted in an increase in shoot length compared to control, except 7 days applications. On the contrary, the high concentration of ABA treatment (50 and 100 µM) drastically reduced the shoot length in both cultivars. Similar trend were observed in root length after 7-28 days treatment of 1-100 µM ABA. But reduction in the root lengths were determined lower than the shoot length in 50-100 µM ABA treatment (Figure 1). Increasing the root lengths by ABA exposure in low concentration (0.5 µM) and decreasing root lengths by 1 and 5 µM ABA exposures were reported in mutant soybean plants (Liao *et al*., 2008). Similarly, it was determined that 0.1, 10, 25 and 50 µM ABA applications decreased the root lengths in *Arabidopsis thaliana* ecotype Columbia plants in a regular trend and that the most distinctive decrease were observed in the 50 µM ABA application (Ling *et al*., 2007). Chen & Plant (1999) reported that 10^{-9} µM ABA applications was not effective in the root and hypocotyl lengths in tomato plants while 10^{-5} µM ABA applications decreased in root and stem lengths compared to control. Additionally, inhibitory effects of ABA were determined on root and stem lengths in corn (Dallmier and Stewart, 1992), soybean (Creelman *et al*., 1990), rice (Cha-um *et al*., 2007) and wheat (Zhang and Jiang, 2002) plants compared to controls.

The changes in total chlorophyll and carotenoid contents and antioxidant enzyme activities (SOD, CAT, POD) in leaf tissues of both tomato seedlings after 7-28 days treatment of 1-100 µM ABA are presented in Table 1. ABA treatments in low concentrations (1-10 µM) enhanced pigment contents in both tomato cultivars, resulting in increased total chlorophyll contents when compared to control, and also in increased carotenoid content except 14 days of 1 µM ABA treatments. 50 µM ABA treatment caused slightly increasing of pigment contents compared to control in both cultivar in 7 days applications. Total chlorophyll and carotenoid contents in both cultivars were located in same statistical group at 50 µM ABA applications (Table 1). Pigment contents of tomato seedlings were significantly reduced with longer exposure time (21-28 days) of 50 µM ABA and all exposure times of 100 µM ABA treatments when compared to control plants of both cultivars. It was reported that ABA applications to various plants resulted in both increase and decrease in pigment contents depending on the concentration. Exogenous ABA exposure to wheat plants resulted in the increases in chlorophyll and carotenoid contents compared with control (Travaglia, *et al*. 2007) while those applications caused decreases in chlorophyll contents in wheat, *Vigna radiata* and the chickpea plants (Farooq and Bano, 2006; Iqbal *et al.*, 2010).

ABA treatment increased significantly POD activity in both cultivars, it is parallel to the increase in SOD and CAT activities in treated seedlings of both cultivars when compared to control depending on ABA concentrations and exposure times (Table 1). Exogenous ABA causes increasing production of H_2O_2, O_2^- and $OH^{\cdot}$ and induces the activities of SOD, POD, CAT and glutathione reductase (GR) (Jiang and Zhang, 2001; Li *et al*., 2010). Induced antioxidant enzyme activities were reported in *Oryza sativa* (Hung and Kao, 2008), *Zea mays* (Jiang and Zhang, 2001; 2002), *Cynodon dactylon* (Lu *et al*., 2009), *Triticum aestivum* (Agarwall *et al*., 2005) by ABA applications. However, in *Picea aspartata* plants exposed to ABA, elevated SOD activity and unchanged CAT and APX activities were reported (Duan *et al*., 2007). We found that SOD, POD and CAT activities increased with depending on ABA concentration. These results show that ABA causes the induction of antioxidant enzymes in tomato plants. Jiang and Zhang (2001) showed also that high ABA concentrations caused an oxidative damage in lipids and proteins in *Zea mays*. These situations showed that exogenous ABA applications have dual role, both induction of antioxidant systems in low concentrations and causing to oxidative stress at high concentrations, in plant tissues. As seen in Table 1, increase in SOD, POD and CAT activities has been observed in all application periods and concentrations for both tomato species.

A linear regression analysis showed that the shoot length, total chlorophyll and carotenoid contents significantly decreased with increasing ABA concentrations (Figure 2). On the contrary, antioxidant activity (SOD, CAT and POD) were significantly correlated to exposure concentration of ABA according to linear trend, by strongly increasing with the increasing concentrations of ABA (Figure 2). In 10 µM ABA treatment, the correlation analysis based on physiological parameters revealed that the SOD, CAT and POD

Table 1 The effect of 7-28 days application of 0, 1, 10, 50 and 100 µM ABA concentrations on total Chl and Car contents and SOD, CAT and POD activities in two tomato cultivars

ABA		Exposure Time							
		L. esculentum cv. Aspendos				*L. esculentum* cv. Donna			
		7 days	14 days	21 days	28 days	7 days	14 days	21 days	28 days
Total Chl	Control	1.30±0.01^{c,A}	1.30±0.01^{b,A}	1.30±0.01^{b,A}	1.30±0.01^{c,A}	1.43±0.01^{c,A}	1.43±0.01^{b,A}	1.43±0.01^{c,A}	1.43±0.01^{b,A}
	1µM	1.32±0.02^{bc,B}	1.34±0.01^{b,B}	1.40±0.02^{a,A}	1.42±0.02^{a,A}	1.45±0.03^{bc,B}	1.48±0.02^{b,AB}	1.52±0.01^{b,AB}	1.54±0.03^{a,A}
	10 µM	1.39±0.02^{a,B}	1.40±0.02^{a,AB}	1.45±0.02^{a,A}	1.37±0.01^{b,B}	1.54±0.02^{a,A}	1.56±0.02^{a,A}	1.57±0.03^{a,A}	1.53±0.01^{a,A}
	50 µM	1.35±0.01^{ab,A}	1.31±0.02^{b,A}	1.25±0.01^{b,B}	1.16±0.02^{d,C}	1.49±0.02^{ab,A}	1.44±0.02^{b,A}	1.37±0.02^{c,B}	1.27±0.01^{c,C}
	100 µM	1.24±0.01^{d,A}	1.17±0.02^{c,B}	0.99±0.02^{c,C}	0.87±0.01^{e,D}	1.39±0.01^{c,A}	1.32±0.02^{c,B}	1.23±0.01^{d,C}	1.10±0.02^{d,D}
Car	Control	84.98±0.79^{bc,A}	84.98±0.79^{c,A}	84.98±0.79^{b,A}	84.98±0.79^{b,A}	90.93±1.39^{bc,A}	90.93±1.39^{b,A}	90.93±1.39^{b,A}	90.93±1.39^{bA}
	1µM	86.94±2.04^{ab,B}	92.19±0.54^{b,A}	93.40±1.74^{a,A}	94.80±0.88^{a,A}	94.46±1.90^{ab,A}	95.56±1.47^{a,A}	97.93±1.69^{a,A}	98.39±1.30^{aA}
	10 µM	91.60±1.70^{a,B}	95.51±1.26^{a,AB}	98.29±2.34^{a,A}	92.27±0.77^{a,B}	95.96±1.46^{a,A}	98.63±0.46^{a,A}	99.20±1.24^{a,A}	96.61±1.02^{aA}
	50 µM	90.28±1.30^{a,A}	83.07±0.52^{c,B}	78.49±1.37^{c,C}	70.85±1.10^{c,D}	91.73±0.46^{abc,A}	87.14±1.16^{bc,A}	81.12±2.09^{c,B}	76.23±1.86^{cB}
	100 µM	81.05±1.01^{c,A}	77.14±0.38^{d,A}	65.63±1.90^{d,B}	58.46±2.36^{d,C}	87.54±0.92^{c,A}	83.24±1.69^{c,A}	75.84±1.57^{d,B}	73.35±1.40^{cB}
SOD	Control	206.88± 1.97^{cA}	206.88± 1.97^{eA}	206.88± 1.97^{eA}	206.88± 1.97^{eA}	175.26±3.63^{cA}	175.26±3.63^{cA}	175.26±3.63^{eA}	175.26±3.63^{eA}
	1µM	207.71± 1.87^{cC}	217.63± 2.50^{dB}	226.01± 2.32^{dA}	232.11± 3.13^{dA}	174.54±3.84^{cB}	185.70±4.78^{cAB}	195.39±7.47^{dA}	200.22±4.08^{dA}
	10 µM	210.84± 2.01^{cD}	232.08± 2.79^{cC}	252.19± 2.45^{cB}	268.94± 2.20^{cA}	178.39±4.14^{bcD}	203.96±4.85^{bC}	222.98±4.37^{cB}	237.94±2.08^{cA}
	50 µM	219.09± 3.61^{bC}	252.03± 2.61^{bB}	284.32± 4.90^{bA}	292.16± 3.11^{bA}	190.79±5.25^{bC}	217.63±3.98^{bB}	248.24±4.37^{bA}	258.14±4.48^{bA}
	100 µM	232.67± 1.91^{aD}	275.02±3.79^{aC}	320.45± 3.33^{aA}	305.46± 3.55^{aB}	205.70±3.76^{aC}	243.33±5.99^{aB}	280.77±4.58^{aA}	291.24±8.40^{aA}
CAT	Control	42.13±2.81^{d,A}	42.13±2.81^{c,A}	42.13± 2.81^{dA}	42.13±2.81^{dA}	42.22±2.17^{cA}	42.22±2.17^{cA}	42.22±2.17^{dA}	42.22±2.17^{dA}
	1µM	48.33±2.16^{cd,B}	52.04±1.45^{bc,AB}	57.13±1.86^{cA}	60.74±4.01^{cA}	42.04±2.29^{cC}	48.24±2.18^{cBC}	53.61±3.79^{cAB}	60.74±2.82^{cA}
	10 µM	53.43±1.65^{bc,C}	60.46±2.57^{b,BC}	70.09±3.04^{bAB}	78.80±4.14^{bA}	48.61±2.90^{bcC}	58.70±2.35^{bB}	66.30±2.85^{bB}	78.70±2.76^{bA}
	50 µM	60.74±3.37^{ab,C}	75.09±5.06^{a,B}	95.09±2.01^{aA}	102.96±3.29^{aA}	54.07±2.65^{abD}	66.85±5.25^{abC}	80.46±3.61^{aB}	98.33±3.53^{aA}
	100 µM	67.69±2.03^{a,C}	82.69±3.50^{a,B}	102.31±4.61^{aA}	104.44±3.57^{aA}	60.46±3.18^{aD}	74.72±2.97^{aC}	88.52±3.30^{aB}	102.13±3.62^{aA}
POD	Control	52.63±4.18^{c,A}	52.63±4.18^{d,A}	52.63±4.18^{d,A}	52.63±4.18^{e,A}	38.59±5.14^{b,A}	38.59±5.14^{d,A}	38.59±5.14^{d,A}	38.59±5.14^{d,A}
	1µM	53.88±4.51^{c,B}	62.15±5.92^{d,AB}	72.80±4.60^{cd,A}	78.19±4.40^{d,A}	41.85±2.61^{b,A}	45.86±5.28^{cd,A}	48.12±4.40^{cd,A}	51.37±3.31^{d,A}
	10 µM	71.80±6.11^{c,B}	85.58±8.67^{c,AB}	97.74±9.46^{c,A}	107.39±2.71^{c,A}	48.74±5.09^{b,B}	57.26±4.88^{c,AB}	60.77±4.38^{c,AB}	72.80±6.51^{c,A}
	50 µM	109.77±5.00^{b,B}	126.56±5.46^{b,B}	159.14±6.63^{b,A}	172.18±12.67^{b,A}	67.66±5.74^{a,C}	73.43±4.64^{b,BC}	87.46±5.14^{b,AB}	98.62±7.28^{b,A}
	100 µM	146.61±9.46^{a,B}	166.66±7.72^{a,B}	238.09±18.71^{a,A}	227.06±10.42^{a,A}	78.32±4.10^{a,C}	103.38±4.97^{a,B}	124.56±8.69^{a,A}	139.09±5.74^{a,A}

* Means followed by the lower case in same columns do not differ significantly at P ≤0.05 (resulted by Oneway-ANOVA, separated by Duncan test)

activities in the tomato seedlings of cv. Aspendos and cv. Donna were not significantly correlated with the total chlorophyll contents in the same plant, respectively. However, significantly positive correlations were found between chlorophyll contents and antioxidant enzymes in both tomato cultivars at 1 µM concentration of ABA treatments. In the high concentration of ABA (50-100 µM), while the significantly negative correlations were determined for cv. Aspendos and cv. Donna between chlorophyll contents and antioxidant enzymes, SOD activities in Donna cultivars were not significantly correlated with chlorophyll contents of this seedlings (Table 2).

When the changes in pigment content, root-stem lengths and enzyme activities were evaluated together, it showed that ABA applications of low concentrations caused increase in pigment contents, root-stem length and inducing the antioxidant enzyme activities at the same time. However 50 and 100 µM ABA applications caused decrease in pigment contents and root-stem lengths in spite of the increase in the antioxidant enzyme activities. For this reason, we can say that ABA has positive effects in low concentrations, but it results in oxidative damages by excessively increasing the amounts of oxidative radicals in cases of high concentrations in plants.

Endogenous ABA levels in plants increased under various abiotic stress conditions such as water, drought, salinity and cold and, the effect of exogenous ABA application on the capacity of plants to overcome the stress has been shown under these stress conditions (Yurekli *et al*., 2001; Jiang and Zhang, 2002; Yurekli *et al*., 2004; Xiong *et al*., 2006; Kumar *et al*., 2008). The exogenous ABA applications have decreased the negative effects caused by temperature, drought, salinity and cold stresses in the plants and this effect of ABA is related to the ABA-induced antioxidant system (Zhang *et al*., 2005; Khadri *et al*., 2006; Travaglia *et al*., 2007; Yang *et al*., 2007; Zheng *et al*., 2010). Swamy & Smith (1999) reported that the endogenous ABA production under stress conditions is positively related to the stress resistance, and exogenous ABA plays an important role in the adaptation of plants to stress. All ABA concentrations caused increase of antioxidant enzymes in plants in our study. However, the effects of ABA applications for 7, 14 and 21 days on the antioxidant system continued until the sale of seedlings. Compared to control, these ABA application periods caused a statistically important increase in antioxidant enzyme activities in the samples harvested at 28th day (Table 1). We thought that exogenous ABA application at suitable doses will increase the antioxidant capacity in plants grown under controlled conditions and can make them more resistant against various stress factors that they will be exposed to at transplanting in the field.

In commercial seeding production, seedlings made resistant to environmental conditions must be around 22-25 cm in length as well as a healthy root development and high chlorophyll content. It has been determined in our study in seedlings at harvesting period that ABA applications made in low concentrations (1-10 µM) especially for periods of 14 and 21 days (Figure 1) have high chlorophyll content as well as a good stem and root development compared to the control.

Table 2 Correlation coefficients among Chl and Car, SOD, CAT, POD and shoot length in leaf tissues of two tomato cultivars

ABA Concentrations		***L. esculentum* cv. Aspendos**				
		Car	**SOD**	**CAT**	**POD**	**Soot Lenght**
1 µM	*Correlation*		**0.952**	**0.959**	**0.972**	
	Sig.		0.048	0.041	0.028	
10 µM	*Correlation*					
	Sig.	Chll				
50 µM	*Correlation*	**0.976**	**-0.992**	**-0.986**	**-0.978**	
	Sig.	0.024	0.008	0.014	0.022	
100 µM	*Correlation*	**1.000**	**-0.959**	**-0.990**	**-0.994**	**0.971**
	Sig.	0.000	0.041	0.010	0.006	0.029
ABA		***L. esculentum* cv. Donna**				
Concentrations		**Car**	**SOD**	**CAT**	**POD**	**Soot Lenght**
1 µM	*Correlation*	**0.994**	**0.961**			
	Sig.	0.006	0.039			
10 µM	*Correlation*					
	Sig.	Chll				
50 µM	*Correlation*	**0.955**	**-0.991**			**0.969**
	Sig.	0.045	0.009			0.031
100 µM	*Correlation*	**0.987**	**-0.978**		**-0.958**	
	Sig.	0.013	0.022		0.042	

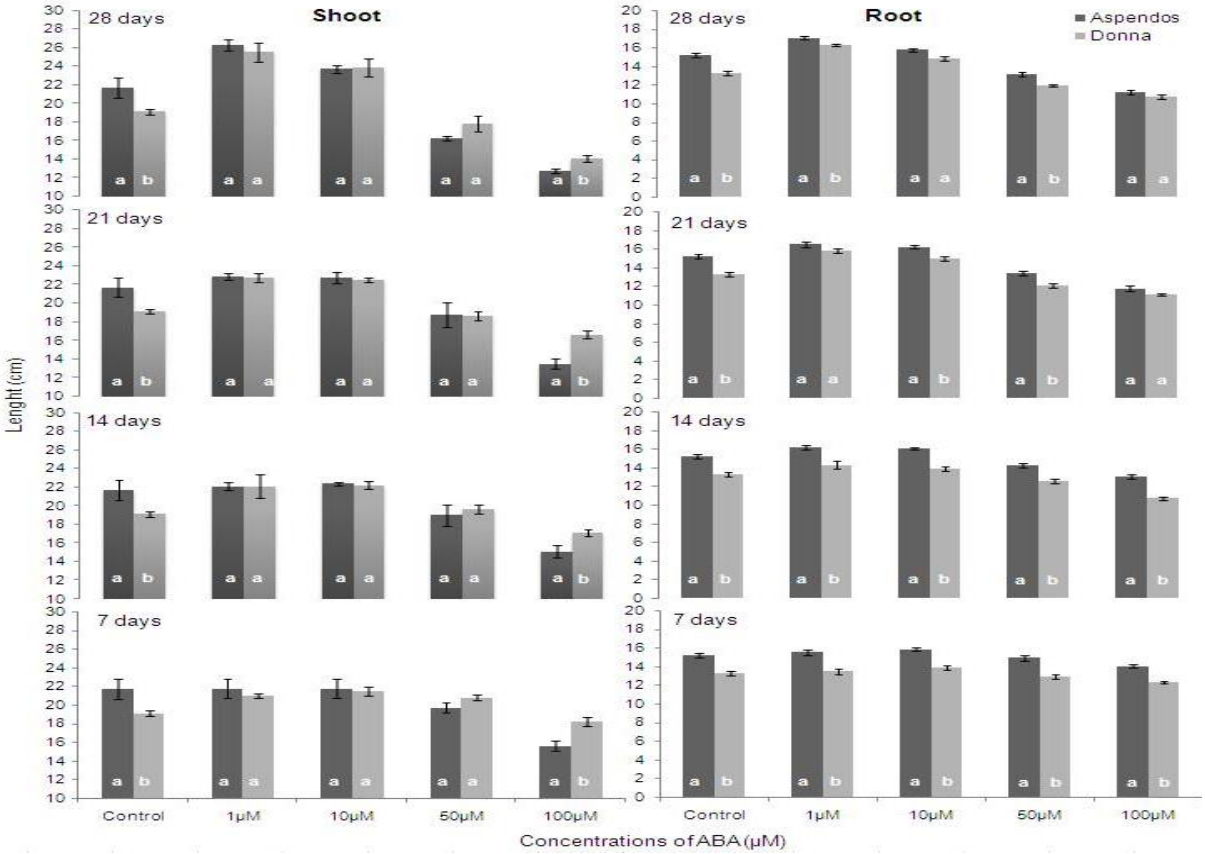

Figure 1 Effect of 7-28 days application of 0, 1, 10, 50 and 100 µM ABA on root and shoot lengths of two tomato cultivars

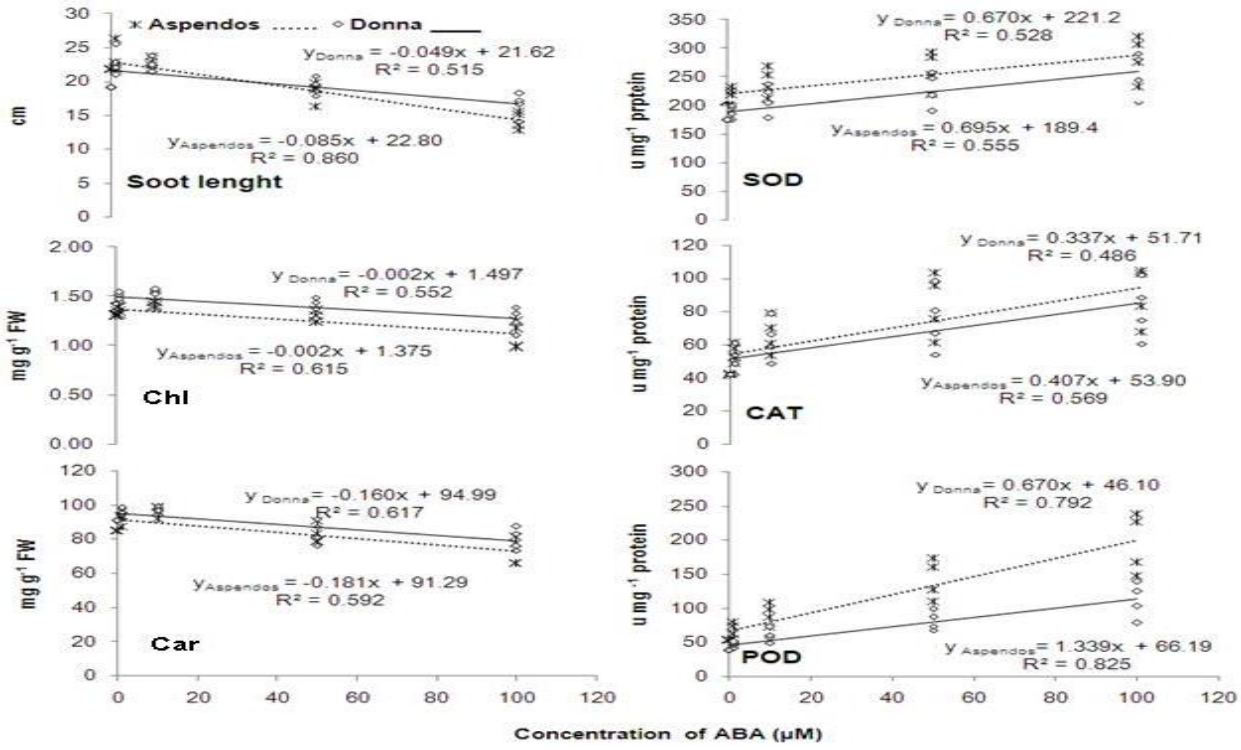

Figure 2 Regression analysis showing between ABA concentrations and shoot length, pigment content and antioxidant enzyme activities in two tomato cultivars

The use of exogenous ABA in seedling production is a new topic. Studies regarding the use of ABA in seedling production are limited to only root fringes. An important reason for this is that ABA constitutes an important input for seedling production in economical point of view. Although the application of ABA in seedling production is thought to increase costs but it should be taken into consideration that there are new developments in ABA production methods making us re-consider the use of this substance in the agricultural industry.

Consequently, in this study we have investigated through exogenous ABA applications the possibility of production of seedling having adequate root and stem lengths as well as antioxidant enzyme capacity. We have seen that 10 µM ABA applications for 14-21 day periods provide seedlings which 22-25 cm in length and better root development needed for sale (Figure 1). In addition to these, we thought that these seedlings which have higher chlorophyll content and SOD, POD and CAT activity (Table 1) compared to controls, were more resistant to various environmental stresses. The results indicated that low concentration of ABA (10 µM) for 14-21 days period may be used to produce more tolerant and acceptable seedlings in seedling industry.

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