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EFFECTS OF SALICYLIC ACID ON MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF SWEET CORN HYBRIDS UNDER WATER STRESS CONDITIONS

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ABSTRACT

To evaluate the effect of different levels of salicylic acid (SA) on yield and some morphological and physiological characteristics of sweet corn hybrids under water stress, this study was conducted in 2015 using split plots in the base of randomized complete block design with three replications. Treatments were included water stress at three levels, salicylic acid at three subplot levels and three hybrids of sweet corn (pashen, basin and chalenjer) respectively as main plot, sub plot and sub plots. The effect of SA except of catalos amount was significant on other traits. Differences among the cultivars were not significant except of chlorophyll. The interaction between water stress, salicylic acid and hybrids treatments were significant on all traits.

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The maximum forage wet and dry matter yields and also seed yield were obtained respectively 4541, 1123 and 1455 kg per hectare when the three following treatments, irrigation after drainage 50% available soil water, SA 0.5 ml molar and pashen hybrid were combined.
The results showed that the effect of water deficit stress was significant on all the traits studied. In general the results showed that application of SA relatively reduced the negative effects of water deficit stress.
Keywords: Catalase; peroxidase; chlorophyll; water deficit stress; yield.

1. INTRODUCTION

One of the most important farm management practices to achieve optimal conditions for plant growth and optimum yield is sufficient water supply to prevent water stress effects particularly in the critical stages of plant growth. Environmental stresses are the most important factors that reduce crop yield in the world. About 10 to 20 percent of yield potential in many plants is annually lost due to environmental stresses (Alizadeh, 2008).
The results of the research carried out by Rezayizad (2004) showed that drought stress, severely reduced leaf index. Daneshian *et al.* (2005) reported that water stress in different growth stages of sunflower hybrids, decreased the plant leaf area index. Haji Hassani Asl *et al.* (2008) concluded that drought stress reduced leaf area index in the sunflower and the reason for higher leaf area in the first level irrigation, was the increasing of volume and number of cells in the presence of water. Afkari bajehbaj (2009) reported that under non- stress drought condition, the leaf area index and growth rate in the sunflower increased. The pre-planting Priming with phytohormones or vitamins was found to be useful under water stress conditions (Hamada and Al-Hakimi, 2001). Khodary (2004) reported that SA is able to accelerate the growth of leaves and roots. In another study, spraying soybean and corn with acetyl salicylic acid (ASA) equivalent 3-10 mole per liter, had no effect on plant height and root length, but increased leaf area (Khan *et al.*, 2003). Application of 125 ppm SA increased the number of leaves in mulberry plants (Singh *et al.*, 2003). In contrast there were not significant differences in plant height and number of leaves of barley plants that were treated and non-treated with SA (Senartna, 2000). Maddah *et al.* (2005) reported that spraying cheek pea with SA, increased seed

protein, seed weight and yield. Soybean seedling that was treated with 0.1 micro molar of SA, was shown to increase leaf area. Alsoo an increase of five micromoles salicylic acid to roots in the soil sterile was reduced soybean root dry and shoot weight (Lian *et al.*, 2000). Hamada and Al Hakim (2001) reported that when wheat seeds were treated with 100 ppm of SA, the effect of salinity and water deficit stresses on the potato leaf area were reduced. Sakhabutdinova *et al.* (2003) claimed that wheat crop spraying with 0.5 molar SA, increased the cell division in root apical meristem and also increased plant growth. They further stated that the use of salicylic acid was increased dry matter in wheat seedlings and this event maybe due to the effect of SA in the biosynthesis of cytokinin. Stevens *et al.* (2004) reported that when plants were treated with salicylic acid under salinity stress and water deficit conditions, they produce a higher relative growth rate compared with control plants. In another study, application of Salicylic acid on melon plants had a significant effect on seedling growth and root dry weight, and the best result was obtained from the application of seed priming with 0.1 ml molar concentration of salicylic acid (Ahmet Korkmaz, 2007).

Stevens *et al*. (2006) stated that salicylic acid with affecting on plant photosynthesis and root development, causes the increase of height and growth of plant. These researchers stated that under water stress conditions, the application of salicylic acid can cause the reduction of transpiration, increase of root development, nutrient uptake and plant height which in turn give rise to more growth and yield in plant. With respect to the drought and deficit of water resources in Iran in recent years and the importance of salicylic acid in reducing the harmful effects of drought stress on crops, the objective of the current study was to evaluate the application of salicylic acid to prevent yield loss in sweet corn under drought stress conditions. Metwally et al (2003) stated that spraying barley seedlings with salicylic acid increased root dry weight and leaf. Rice plants treated with salicylic acid 100 ppm had more dry matter than no treated (Maybyngsa et al, 2001). In another trial Sanna et al (2001) reported that spraying with 2-5 micromol of salicylic acid increased the fresh and dry weight of beans (*haselus vulgaris*). Fariduddin et al (2003) states that sprayer of Canola with the minimum concentration (10- 5 mol) of salicylic acid after 60 days of growth, had more dry matter than the control plants. Spraying wheat plant with salicylic acid, increase apical meristem cell division the primary root that leads to an elongitudinal growth (Shakirova et al, 2003). Maddah et al (2007) reported that spraying pea plant with salicylic acid increases the amount of protein and increased yield, due to increased grain weight. Anatomical studies of pea plants vegetative organs showed that salicylic acid spraying (spraying with the beginning of flowering) only the leaves that are directly in contact with salicylic acid had an effect and increased the palisade tissue cells.

2. MATERIALS AND METHODS

Geographical characteristics of the region

The field experiment was conducted in 2015 under a wheat-corn cropping system located in Institute of Agricultural Science of Yasouj city in Kohgiluyeh and Boyer-Ahmad Province that is situated in 30°39'50" N and 51°35'8" E with the altitude of 1833 meters from sea level. The average annual precipitation of the region is 850 mm according to the long-term (30 years) period reports. The average annual maximum and minimum temperatures are respectively 27.2 and 7.3°C. The region for the accomplishment of experiment was considered moderate cold based on Domarten criteria. The total precipitation from planting to maturity stages of sweet corn was 44 mm. The texture of the soil was light clay loam. The soil caracterictis of the experimental location is presented in the table 1.

Table 1. The results of the soil analysis test

Texture	Absorbent phosphorus (ppm)	Absorbent phosphorus (ppm)	Total percentage of nitrogen	The percentage of neutralizing	Organic carbon percentage	Saturation	E C	pH
Clay Loamy	298	11	0.1	8	1.9	23	1.5	7

Experimental Design and management

The current survey was carried out using a split plot design in the base of randomized complete block design with three replications in 2015. Treatments were included water stress at three levels: D_1 (irrigation after draining 50% of field capacity), D_2 (irrigation after draining 60% of field capacity) and D_3 (irrigation after draining 70% of field capacity). Salicylic acid in sub-plot with three levels of S_1 (no application that was considered as control), S_2 (0.5 mm) and S_3 (1 mm) and sweet corn hybrids in three levels of H_1 (pashen), H_2 (basin) and H_3 (Challenger) were the main plot, subplot, and sub – sub plot, respectively.

Before doing the research, three samples from 0 to 30 cm of soil using a cylindrical core with 2.5 cm diameter and 30 cm length were taken from the field. The soil samples were collected using a soil sampler with three replications and were placed in plastic bags in the field. All visible roots and fresh little materials were removed from samples and processed in the laboratory. Soil analysis results are shown in Table 1. The experimental land for the research was kept as fallow during the autumn and winter. In the spring to prepare seed bed, the land was first irrigated and when the moisture of the soil reached to field capacity state, tillage practices consists of plowing and two perpendicular discs were done. Then the land was divided to plots by workers. Based on the results of soil analyses, nitrogen, phosphorus and potassium requirements were calculated. Total phosphorus and potassium fertilizers requirements that were respectively provided from superphosphate and potassium sulphate sources together with half of the nitrogen were mixed with soil in the plots before planting. Residual nitrogen was added in two rounds, 1 and 2 months after planting. Each of plots comprised of 5 planting rows with 70 cm space from each other. After disinfecting seeds with Vitawax fungicide, each three seeds were planted manually in small ditches on rows with 7o cm space apart. The 7o cm space between and on rows was aimed to have a density of 7 plants per square meter and extra plants were removed at four-leaf stage. After fourth irrigation, plots were irrigated based on the above mentioned treatments. To exert water stress treatment, soil water potential was determined and after fourth irrigation, the water stress levels were determined by sampling from 0 to 30 cm of soil depth based on the interpretation of soil water retention curve. To do this at first weight percentage of soil samples moisture were determined and then by the use of vacuum curve of soil moisture, soil water potential was determined for all plots on a daily basis. Based on the data obtained from the evaluated samples, the potential soil moisture of the stress treatment was computed in term of MPa. Subsequently irrigation was done based on stress treatments. Based On the water requirement of plant and having the formula, to determine the FC, soil moisture content percentage before irrigation, soil bulk density, the area of irrigation, root penetration depth and efficiency of irrigation, water requirement for each plot was calculated in a way that water could enter into plots using a volume counter. After the appearance of the fourth stem node and before the formation of flower organs, treatments of salicylic acid were sprayed in the afternoon at 17 to18 o'clock in a manner that the surface of the above ground plant organs became entirely wet. At the final growth stage of the plant, plant height and number of leaves per plant were measured. Shoot fresh weight was measured using digital balance. To determine the dry weight of aerial shoot fresh, they were put in the oven for 72 hour at 90 °C and were weighed using digital balance. The grain yield and protein were determined after harvesting. Chlorophyll a and b were measured by the use of spat. The amount of catalase was determined by Chance and Mahly (1995) method. Peroxidase was determined based on the Mc Adam *et al*. (1992) method. After summing up the required data, analysis of variance and means were respectively performed using SAS software and Duncan's multiple range tests. Charts were drawn using Excel software.

3. RESULTS AND DISCUSSION

Summary of the analysis of variance is shown in Table 2. Effect of water deficit stress was significant on all traits. The effect of salicylic acid on the concentration of catalase was not significant, while the difference among hybrids was significant only in terms of chlorophyll a (Table 2). The interaction of water deficit stress and application of salicylic acid on chlorophyll b and catalase were not significant. The interaction of water deficit stress and hybrid was only significant on plant height and chlorophyll a. Triple interaction of water deficit, the application of salicylic acid and hybrid were significant for all the traits studied (Table 2). Because of triple interaction among diverse sources studied were significant, therefore the mean comparisons and discussions were done on the basis of the triple interaction of the treatments. The means of the traits are shown in Tables 3 and 4 with respect to the triple interaction of the treatments.

The maximum average plant height (175 cm) was resulted from the combination of treatments: irrigation after draining 50% of field capacity, salicylic acid at a concentration of 0.5 ml molar and hybrid pashen. Conversely the lowest average plant height (97.5 cm) was obtained from the combination of the treatments: irrigation after draining 70% of field capacity, non- application of salicylic acid and hybrid pashen. Growth reduction under salinity or drought stresses could be due to interference in processes in energy production such as photosynthesis and respiration. Changes in hormonal balance, is one of the reasons for decrease of growth (Pandey *et al*., 2003). Spraying wheat plant with salicylic acid increased the cell division of the primary root apical meristem that they in turn gave rise to the longitudinal growth of the plant (Shakirova *et al*., 2003). There are some reports that show water stress significantly reduced the wheat plant height (Ashraf *et al*., 1996).

The maximum number of leaves per plant (12.2) was obtained from the combination of the treatments $D_{1,}$ S_2 and H_2 (irrigation after draining 50% of field capacity, salicylic acid 0.5 mm and hybrid basin) and the lowest number of leaves (6) was resulted from the combination of D_2, S_3 and H_3 treatments (irrigation after draining 60% of field capacity, SA acid, 1 mm and hybrid Challenger) (Table 3). The water deficit reduced canopy growth coverage with reducing growth canopy and reducing the growth of old leaves. Inhibiting or stopping the growth of leaves is the first plant response to drought stress (Chaves *et al*., 2003). Overall growth of the plant, aerial parts of the plant root growth are more sensitive to water shortages (Sharp and Davis, 1989). Deficit of moisture in the plant tissues can sometimes be determined as a useful factor, because the deficit of moisture reduces the evaporation and transpiration and is caused to maintain soil moisture (Passioura, 1982).

The maximum forage fresh weight (4541 grams) per square meter was obtained from the combination of $D_{1,}$ S_2 and H treatments (respectively irrigation after draining 50% of field capacity, salicylic acid 0.5 mm and hybrid pashen) and the lowest forage fresh weight (3543 grams) per square meter was resulted from the combination of $D_{3,}$ S_1 and H_3 treatments (respectively irrigation after draining 70% of field capacity, non- application of salicylic acid and hybrid Challenger) (Table 3). Reducing and increasing in the efficiency of photosystem (II) that result from a structural effect on photosystem (II) is one of the main factors responsible for the gradual decline in the rate of photosynthesis through the effect on the reduction in the rate of electron transfer (Netondo *et al*., 2004). This event reduces the growth and height of the plant as well as plant forage weight.

The maximum forage dry weight (1123 grams) per square meter was resulted from the combined treatments D_1, S_2 and H_1 (irrigation after draining 50% of field capacity, 0.5 mm salicylic acid and hybrid Challenger) and the lowest value (370 grams) per square meter was obtained from the combination of D_3, S_1 and H_3 treatments (irrigation after draining 70% of field capacity, non- application of salicylic acid and hybrid Challenger) (Table 3). Metwally *et al*. (2003) stated that spraying barley seedlings with salicylic acid increased root and leaf dry weight. Rice plants treated with 100 ppm of salicylic acid had more biomass than untreated plants were (Maybyngsa *et al*., 2001).

With reduction in the moisture content (RWC) of leaf that causes to reduce leaf water potential, photosynthetic rate will be reduced (Lawlor and Cornice, 2002). Deguang *et al.* (2001) stated spraying maize with 500 mg per kg acetyl salicylic acid, caused to increase tolerance of the plant to drought stress that in turn increased the yield of plant.

The maximum canned yield value (1455 grams) per square meter was obtained from the combination of the treatments D_1, S_2 and H_1 (irrigation after draining 50% of field capacity, consumption of 0.5 mm salicylic acid and hybrid pashen) whereas the minimum amount (707 grams) per square meter was resulted from combination of the treatments D_2, S_3 and H_3 (irrigation after draining 70 % of field capacity, spray of salicylic acid with a concentration of 0.5 molar and hybrid Challenger). The most important economic sector of plant is seed yield, which is the outcome of yield components and other characteristics (Evans *et al*., 1981). Water deficit stress by disrupting the uptake and transport of the nutrient elements, reduces matter supply and cause to change in yield components and also flowering, pollination and breeding of seeds that ultimately reduces grain yield. The results of this research is correspond to the results of Smith (1994) that stated water deficit stress reduces photosynthetic production and transport of nutrient materials from the leaves to the grains that at last reduces grain yield. Shafi *et al.* (1987) stated that water deficit stress reduced about 19% of the grain yield. Robertson and Guinta (1994) showed that water deficit stress at the flowering stage and after that, reduced the number of grains per spike that was caused by disorder in the pollination and pollen sterility. Leinhos. Bergmann (1995) reported that water deficit stress reduced grain yield in barley.

In another experiment, spraying canola with 5 to 10 molar salicylic acid increased plant growth, the number of capsules and seed yield about 14% in comparison to control after

60 days (Fariduddin *et al*., 2003). These results are correspond to the findings of Khan *et al* (2003) who stated that spraying salicylic acid on soybean, gave rise to increase in pods number and the yield. Zhou *et al.* (1999) stated that corn plants that were treated with salicylic acid had about 9 percent higher grain yield than untreated plants (control). Another study concluded that the use of salicylic acid on millet plant increased grain yield (Sivakumar *et al*., 2001). It seems that the higher yield is obtained from the consumption of salicylic acid is due to that the use of salicylic acid increases water hold capacity and formation of reproductive organs in the plant.

The highest amount of chlorophyll a (97 mg per gram) of fresh weight was resulted from the combination of treatments D_1, S_2 and H_1 (irrigation after draining 50% of field capacity, salicylic acid 0.5 mm and hybrid pashen) and the lowest amount (33 mg g^{-1}) of fresh weight was obtained from the combination of treatments D_3, S_2 and H_3 (irrigation after draining 70% of field capacity, salicylic acid 1 mm and hybrid Challenger) (Table 3). Increasing the growth parameters and photosynthetic pigments in response to pretreatment SA may be related to induction of antioxidant response that protects the cells from damage by oxidative stress (Hayat *et al.*, 2009; Horvath *et al.*, 2007). It is reported that chlorophyll content is increased with the use of salicylic acid (El Tayeb, 2005). Maibangsa *et al.* (2001) and Sivakumar *et al.* (2001) showed that plants were treated with 100 ppm of salicylic acid had higher chlorophyll concentration. Khodary (2004) stated that the maize plants that were sprayed with salicylic acid had higher chlorophyll a and b than the control plants under salt stress condition.

The maximum amount of chlorophyll b (135 mg g^{-1}) in the fresh weight of leaves was obtained from the combination of the treatments D_1, S_2 and H_1 (irrigation after draining 50% of field capacity, salicylic acid 0.5 mm and hybrid pashen) and the lowest amount (70 mg g^{-1}) in the fresh weight of leaves was obtained from the combination of the treatments D_3, S_1 and H_2 (irrigation after draining 70% of field capacity, non- spraying of salicylic acid and hybrid Basin). Singh and Usha (2003) stated that wheat seedlings were treated with salicylic acid had higher moisture content than untreated plants under water deficit stress conditions. The effects of salicylic acid on stomata activity, transpiration rate, and respiration airways raise this assumption that salicylic acid maybe affect other physiological functions of plant. Kumar *et al.* (2000) reported that the use of salicylic acid increased the photosynthesis rate, transpiration and stomata conductance in plants in comparison with control plants under water deficit stress conditions.

The maximum amount of catalase enzyme (57 mg protein min^{-1}) was obtained from the combination of the treatments D_1, S_2 and H_1 (irrigation after draining 50% of field capacity, salicylic acid 0.5 mm and hybrid pashen) and the lowest amount (29.4 mg protein min^{-1}) was resulted from the combination of the treatments D_3, S_1 and H_1 (irrigation after draining 70 % of field capacity, non application of salicylic acid and hybrid pashen).

It seems the current result is correspond to the findings of Neto *et al*. (2005) who stated that water deficit stress increases the amount of catalase in plant. This enzyme is effective to reduce oxidative damage in plant caused by water deficit stress through detoxification of reactive oxygen forms (ROS) such as hydrogen peroxide and to catalize it to water and oxygen. With increasing concentration of salicylic acid the amount of this enzyme was also increased. Hayat *et al*. (2005) reported that salicylic acid is able to increase the amount of antioxidant enzymes such as catalase and peroxidase under water stress conditions, and can be as a substrate that produces electron action for catalase and peroxidase to reduce water deficit stress in plants. In another study, Luna *et al*. (2005) reported that the catalase activity was increased several times under drought stress conditions, but Shim *et al*. (2003) stated that the catalase activity was significantly decreased in wheat under salt stress conditions. So, salicylic acid through increasing these enzymes can create a kind of plant response to water deficit stress which is able to reduce damage caused by water deficit stress. These results conform to the findings of Snaratna *et al*. (2000).

The maximum amount of peroxidase (144 mg protein min^{-1}) was resulted from the combination of the treatments D_1, S_1 and H_1 (irrigation after draining 50% of field capacity, non- spraying of salicylic acid and hybrid pashen), and the lowest amount (41.5 mg protein min^{-1}) was obtained from the combination of the treatments D_3, S_1 and H_1 (irrigation after draining 70% of field capacity, non- spraying of salicylic acid and hybrid pashen). Dolatabadian *et al.* (2008) stated that the amount of this enzyme was increased with increasing levels of stress and concentration of salicylic acid. It seems that increasing in concentration of the salicylic acid is itself acting as a stress and cause to increase the peroxides in plant. These results are correspond to the findings of Janda *et al*. (2000) who stated that salicylic acid increased peroxidase in maize under water deficit stress conditions. Ashraf *et al.* (1994) stated that peroxidase activity increased in wheat under drought stress. In another study increasing salinity gave rise to increasing peroxidase in leaves and roots of barley (El Tayeb, 2005).

Increasing activity of antioxidant enzymes was known as a mechanism for tolerance to stresses (Casano *et al.*, 2001). Water stress as a photosynthesis inhibitor, is known as an imbalance factor between production and light consumption (Foyer and Nestor, 2000). An imbalance between production and consumption of electrons, is caused to decrease the activity of photosystem II (PSII). This photochemical change of choloroplasma in the leaves of plants is due to the high loss of light energy in photosystem II (PSII), therefore, the production of oxygen species is dangerous under water deficit stress (-O_2، O_2، H_2O_2 ، OH) (Peltzer, 2002). The mechanism for production of these varieties of oxygen (ROS) is responsible to create toxic plants and to produce the enzymes such as superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD). The increase and activity extent of antioxidant enzymes among crop species and even between the two varieties of a crop are different under drought stress condition (Pastori *et al*, 2000). Foyer (2002) in several studies concluded that increased tolerance to drought stress is associated with excessive production of superoxide dismutase in chloroplasts. Singh and Usha (2003) reported that the superoxide dismutase content in leaves of wheat is more under drought stress conditions than plants were under water normal conditions. One of the first events that cause the cell death in plants under stress conditions is oxidative stress (McKersie *et al.*, 1988) and this harmful effect is decreased to cause increase in the activity of antioxidant enzymes that diminishes the harmful effects of stress (Dat *et al.*, 1998).

Agarwal *et al*. (2005) reported that the use of salicylic acid 1 mm had significant effect on the increase in activity of superoxide dismutase (SOD), ascorbic peroxidase (ASPO) and catalase (CAT). In another experiment, Ananieva *et al* (2004) reported that treatment only with salicylic acid alone increased the activity of superoxide dismutase, peroxidase and catalase 17, 25 and 20% respectively compared with the control treatments. While in another study, using salicylic acid on the bean did not make any change in the activity of antioxidant enzymes. In one study spraying plant with water treatment, increased the activity of catalase and peroxidase enzymes, but the activity of superoxide dismutase (SOD) enzyme did not change (Clarke *et al*., 2002). Application of salicylic acid caused to increase peroxidase activity in different plants that were under non-biotic stresses (Janda *et al*., 2000). Singh and Usha (2003) reported the maximum superoxide dismutase activity through spraying 1 and 2 ml molar salicylic acid on wheat. In a similar experiment by the application of 500 micro molar of the salicylic acid on the seedlings of barley, the activity of catalase and superoxide dismutase enzymes were observed to be increased (Popova *et al*., 2003).

Salicylic acid decreased the catalase activity in tomato (Snaratna *et al*., 2000).

Other experiments showed that the use of salicylic acid in wheat did not change the activity of the superoxide dismutase enzyme, but it decreased catalase, and increased peroxidase activity one day after spraying salicylic acid (Kang *et al*., 2003). In other research, He *et al*. (2005) reported that the application of 0.25 ml molar of salicylic acid on Kentucky blue grass plant increased the activity of superoxide dismutase and catalase. In the current study the effect of many traits were shown to be decreased in high concentration of salicylic acid. These findings are correspond to those of Xie and Chen (1999) who stated, the use of high concentrations of salicylic acid, caused it to be accumulated in the cell and in turn its inhibitory effect on some inhibitors such as ethylene, and abscisic acid was increased somehow the respiration of plant cells was decreased. Subsequently many of the physiological and morphological characteristics of the plant were badly affected and ultimately the yield was decreased noticeably.

According to the results of the current research and also findings of other researchers it can be said that the water deficit stress is the most important factor that seriously affect on plant metabolic activities and significantly reduces the yield. As well as the findings of the previous reports, it was found that salicylic acid with having phenolic compounds, has good capability to reduce the bad effects of water deficit stress in sweet corn.

Table 2. Analysis of variance for effect of salicylic acid on some morphological and physiological characteristics of sweet corn hybrids under water deficit stress

							Sources of variation	Degree of fredom		MS
		Plant heigh	Number of leaves per plant	Forage fresh weight	Forage dry weight	Canned yield	a cholorophyll	b cholorophyll	Catalaze	Peroxidase
block	2	70 ^{ns}	0.338^{ns}	34799*	6585^{ns}	230.3^{ns}	1.66^{ns}	89.65 ^{ns}	59.73^{ns}	31178**
Water deficit stress (a)	2	1338**	43.26**	1735776* *	1566048* *	447061.5* *	3720.63**	18818.26* *	2451.85**	25113**
a error	4	187	0.34	282978	6330	30.5	11.41	131.17	10.61	235
Salisylic acid (b)	2	2329**	59.9**	883784**	502604**	84694.4**	375.08**	2348.18**	230.46^{ns}	786**
a×b	4	598**	23.41**	208233**	2953**	877565.9* *	5121/52**	171.99 ^{ns}	28.34^{ns}	3791**
b error	12	38	0.316	197845	6503	28320.2	32.41	144.15	10.26	1247
Hybride (c)	2	25^{ns}	0.62^{ns}	120576 ^{ns}	3314^{ns}	71085.9**	694.3**	108.99^{ns}	1.75 ns	18^{ns}
a× c	4	13**	0.28^{ns}	22882 ^{ns}	792^{ns}	26045.2**	168.44**	1.81^{ns}	1.01^{ns}	23^{ns}
b× c	4	23**	0.017^{ns}	15272 ^{ns}	182^{ns}	12181.3**	70.27^{ns}	2.26^{ns}	3.15^{ns}	35^{ns}
a× b× c	8	27**	0.202**	13975**	510**	6281.3**	48.36**	10.66**	3.21**	42**
Total error	36	33	0.698	13957	5836	160.84	39.4	101.61	25.12	38
%CV		12	9	11	10	13	10	10	12	8

Table 3. Interaction effect of salicylic acid on some morphological and physiological characteristics of sweet corn hybrids under water deficit stress

Treatments			Triats				
Water deficit stress	Salicylic acid	Hybrids	Plant heigh (cm)	Number of leaves per plant	Forage fresh weight (g/m^2)	Forage dry weight (g/m^2)	Canned yield (g/m^2)
¥ D_1	S_1	H_1	133.2	9.2	3971.4	963.2	1017.5
		H_2	138.6	8.4	3894.5	905.8	923
		H_3	139.3	8.3	3894	914.8	925.3
	S_2	H_1	175	12.1	4541	1123	1455
		H_2	171.5	12.2	4368.9	1061.6	1218.4
		H_3	161.2	11.8	4340.3	1097.5	1231
	S_3	H_1	155.8	10.8	4456.3	1036.7	1451.5
		H_2	159.5	10	4311.2	1033.7	1221
		H_3	155.3	10.2	4070	1037.1	1216
D_2	S_1	H_1	121.1	7.2	3789.5	544.2	813.1
		H_2	121	6.9	3784.2	531.8	818.1
		H_3	120.4	7.2	3793	538.5	816
	S_2	H_1	123.2	10.8	4055.1	844.9	1454
		H_2	121.3	10.1	3879	845.4	1225.1
		H_3	122.9	10.3	3882	823.7	1210
	S_3	H_1	123.6	6.2	3565.4	739.5	720.5
		H_2	123	6.3	3569.1	718.5	717
		H_3	123.2	6	3560.5	722.5	707
D_3	S_1	H_1	97.9	10	3569	385.4	1227.3
		H_2	100.1	10.2	3571.4	375.4	1229
		H_3	97.5	10.1	3543	369.9	1228
	S_2	H_1	116.5	9.1	3968	735.7	709.9
		H_2	118.4	9.2	3974.3	728.1	708.7

		H_3	115.8	9.1	3981	719.7	707.9
	S_3	H_1	119.5	6.3	3879	544.2	1025.4
		H_2	118.7	6.3	3881	538.7	1023.3
		H_3	119.5	6	3537.3	527.9	1026.5
$LSD_{1\%}$			1	1	1	1	1

¥: D_1, D_2 and D_3 are respectively irrigation after draining 50% of field capacity, irrigation after draining 60% of field capacity and irrigation after draining 70% of field capacity. S_1, S_2 and S_3 are respectively non-spraying of salicylic acid, spray of salicylic acid with concentration of 0.5 ml molar and spray of salicylic acid with concentration of 1 ml molar and H_1, H_2 and H_3 are respectively hybrids pashen, basin and Challenger.

Table 4. Interaction effect of salicylic acid on some morphological and physiological characteristics of sweet corn hybrids under water deficit stress

Treatments			Triats			
Water deficit stress	Salicylic acid	Hybrids	a cholorophyll (mg per gram of fresh weight)	b cholorophyll (mg per gram of fresh weight)	Catalaze (mg protein per minute)	Peroxidase (mg protein per minute)
¥ D_1	S_1	H_1	67.1	119.2	47	144
		H_2	55.5	115	45.5	141.5
		H_3	55.3	113	48	138.1
	S_2	H_1	98	135	57	101.7
		H_2	78.4	131	55.3	98.6
		H_3	76	133	55.2	96.9
	S_3	H_1	94	130	53	93.6
		H_2	78	130.4	53.3	93.6
		H_3	73.5	126	51.1	92.4
D_2	S_1	H_1	47.1	75.2	35.3	57.2

		H_2	47	72	36	56.1
		H_3	47	71	35.5	55.9
		H_1	94	98.1	38.4	79.5
	S_2	H_2	73.3	96	37.5	80.1
		H_3	73	92.4	37.1	77.2
		H_1	34	90	38.5	71.9
	S_3	H_2	33.1	86	37.5	69.5
		H_3	33.1	87.3	37.5	67.7
		H_1	74.5	72.1	29.4	41.5
	S_1	H_2	72.7	70	31	43.02
		H_3	72.1	70.3	30.9	43
		H_1	34	88.7	35.4	55
D_3	S_2	H_2	33.5	87.6	37	68.1
		H_3	33	83.1	35.8	68.3
		H_1	64.3	72.3	36.2	55.3
	S_3	H_2	63	71	33.5	48.5
		H_3	59	70.2	35.1	47.3
$LSD_{1\%}$			1	1	1	1

¥: D_1, D_2 and D_3 are respectively irrigation after draining 50% of field capacity, irrigation after draining 60% of field capacity and irrigation after draining 70% of field capacity. S_1, S_2 and S_3 are respectively non-spraying of salicylic acid, spray of salicylic acid with concentration of 0.5 ml molar and spray of salicylic acid with a concentration of 1 ml molar and H_1, H_2 and H_3 are respectively hybrids pashen, basin and Challenger.

4. REFERENCES

[1] Ahmet Korkmaz. M. Uzunlu. A. Demirkiran., 2007. Treatment with acetyl salicylic acid protectsmuskmelon seedlings against drought stress. Plant Physiol 29: 503-508.

[2] Alizadeh, A. 2008. Relationships of water and soil and plant. Astan Quds Press.

[3] Afkari Bajehbaj, A., N. Qasimov and M. Yarnia. 2009., Effects of drought stress and potassium on some of the physiological and morphological traits of sunflower cultivars. J. of food, Agriculture & Environment Vol. 7(3-4): 448-451.

[4] Agarwal, S., K. R. Sairam, G. C. Srivastava, T. Aruna and C. R. Meena. 2005., Role of ABA, Salicylic acid, calcium and hydrogen peroxide on antioxidant enzyme induction in wheat seedlings. Plant Sci: 169: Pp. 559-570.

[5] Ananieva, A. E., K. N. Christov and L. P. Popova. 2004. Exogenous treatment with salicylic acid leads to increased antioxidant capacity in leaves of barley plants exposed to paraquat.

[6] Ashraf, M. Y., A. R. Azmi, A. H. Khan and S. A. Ala. 1994. Effect of water stress on total phenols, Peroxidase activity and chlorophyll content in wheat (Triticum aestivum L.). Acta Physiologiac Plantarum. 16 (3): Pp. 185-191.

[7] Ashraf, M. And J. W. Oleary. 1996., Effect of drought stress on growth, water relations and gas exchange of two lines of sunflower differing in degree of salt tolerance. Int. J. Plant Sci., 157: Pp. 729-732.

[8] Casano, L. M., M. Martin and B. Sabater. 2001., H202 mediates the induction of the chloroplasts Ndh complex under photoxidative stress in barley. Plant Physiol., 125: Pp. 1450-1458.

[9] Clarke, S. F., P. L. Guy., D. J. Burritt and P. E. Jameson. 2002., Changes in the activities of antioxidant enzymes in response to virus infection and hormone treatment. Physiology. Plant. 114 (2): Pp. 157-164.

[10] Chance, B. and Maehly, A. C. 1955. Assay of catalases and peroxidases. Methods in Enzymologist, 11: 764-755.

[11] Chaves, M. M., J. P. Morocco and J. S. Pereira, 2003. Understanding plant response to drought: from genes to the whole plant. Funct. Plant Biol., 30: Pp. 239-264.

[12] Dat, J. F., H., Lopez- Delgado., C. H. Foyer., and I. M. Scot. 1998., Parallel changes in H202 and cocktails during thermotolerance induced by salicylic acid or heat acclimation in mustard seedlings. Plant Physiol., 116:Pp. 1351-1357.

[13] Daneshian, J., M. R. Ardakani and D. Habibi. 2005., Drought stress effects on yield, quantitative characteristics of new sunflower hybrids.The2, international conference on integrated approaches to sustain and improve plant production under drought stress. Roma. Italy. P: 406.

[14] Dat, J. F., H. Lopez- Delgado., C. H. Foyer., and I. M. Scot. 1998., Parallel changes in H202 and cocktails during thermotolerance induced by salicylic acid or heat acclimation in mustard seedlings. Plant Physiol., 116:Pp. 1351-1357.

[15] Deguang, Y., S. xiuying., Z. TianHong and Y. Wench. 2001. Drought- resistant effect of exogenous oxygen remover on maize. Beijing Agricultural Sciences. 19 (5 Pp. 25-27.

[16] Doltabadyan, A., Modarres Sanavi, S., and F, Eetemadi. 2008., Effect of salicylic acid pretreatment on wheat seed germination under salt stress. Iran Biology. Vol 21: 692-702.

[17] El-Tayeb, M, A. 2005. Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regul 45: 215-224.

[18] Evans, L., T.1993. Crop evolution, Adaptation and yield. Cambridge university press. 500pp.

[19] Fariduddin, Q., S. Hayat and A. Ahmad. 2003., Salicylic acid influences the net photosynthetic rate, carboxylation efficiency, nitrate reductase activity and seed yield in Brassica juncea. Photosynthetica. 41: Pp. 281-284.

[20] Foyer C. H. and G. Nestor. 2000., Oxygen processing in photosynthesis: regulation and signaling. New Phytol., 146: Pp. 359-88.

[21] Foyer, C. H. 2002. The contribution of photosynthetic oxygen metabolism to oxidative stress in plants. In: Inze, D. and M. V. Montage, editor. Oxidative stress in plants. New York, USA: Taylor and Francis Publishers. Pp. 33-68.

[22] Haj Hassani Asl, N, Roshdi, M., Ghaffari, M, Alizadeh, A, And A, Moradi Aghdam. 2008., Effects of water stress and leaf defoliation on growth caractericties of oil sunflower. Journal of Research to Crop Science, first year, Number 1.Faculty of Agriculture, University of Gilan. Iran.

[23] Hamada, A. M. and A. M. A. Al- Hakimi. 2001. Salicylic acid versus salinity drought induced stress on wheat seedlings. Rostlinna Vyroba. 47: Pp. 444-450.

[24] Hayat, Q. Hayat S, Irfan M, Ahmad A. 2005. Effect of exogenoussalicylic acid under changing environment: a review. Environ Exp Bot. 68(1): 14-25.

[25] Hayat, S., Masood, A., Yusef, M., Fariduddin, Q., Ahmad, A. 2009., Growth of Indian Zea maiz in response to salicylic acid under hight-temperature stress. Braz Journal Plant Physiology. 21(3):187- 195.

[26] He, Y., Y. Liu, W. Cao, M. Huai, B. Xu and B. Huang. 2005., Effect of salicylic acid on heat tolerance associated with antioxidant metabolism in the Kentucky bluegrass. Crop Sci., 45: Pp. 988-995.

[27] Horvath E, Szalai G, Janda, T. 2007. Induction of abiotic stress tolerance by salicylic acid signaling. J Plant Growth Regulation. 26: 290-300.

[28] Janda T, G, Szala, and, Z, Antunovics, E, E, Hovart Paldi. 2000., Effect of benzoic acid and aspirin on chilling tolerance and photosynthesis in young mice. Plants. Mydica 45:29-33.

[29] Kang, G., C. Wang, G. Sun and Z. Wang. 2003., Salicylic acid changes activities of H2O2-metabolizing enzymes and increases the chilling tolerance of banana seedlings. Environ. Exp. Bot., 50: Pp. 9-15.

[30] Khan, W., B. Prithiviraj and D. L. Smith. 2003. Photosynthetic responses of corn and soybean to foliar application of salicylates. J. Plant Physiol., 160 (5): Pp. 485-492.

[31] Khodary, S. E. A. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. Intl. J. Agri. Biol., 6: Pp. 5-8.

[32] Kumar, P., L. N. Jyothi and V. P. Mania. 2000. Interactive effects of salicylic acid and phytohormones on photosynthesis and grain field of soybean (Glycine max L. Merrill). Plant Physiol. Plant Mol. Biol., 6: Pp. 179-186.

[33] Lawlor, D.W. And G. Cornice, 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant cell Environ. 25: Pp.275-295.

[34] Lian, B., x. Zhou, M. Miransari and D. L. Smith. 2000., Effects of Salicylic acid on the development and root nodulation of soybean seedlings. J. Agron. And Crop Sci., 185 (3): Pp.187-192.

[35] Luna, C. M., G. Pastor and S. Driscoll. 2005. Drought controls on H202 accumulation, catalase (CAT) activity and CAT gene expression in wheat J. Exp. Bot. 56 (411): Pp. 417-423.

[36] MacAdam, J. W., Nelson, C. J., Sharp, R. E. 1992., Peroxidase Activity in the Leaf

Elongation Zone of Tall Fescue. Plant physiol., 99: 872-878.

[37] Machado, E.C., Lagoa, A.M.A., and Ticelli, M. 1993. Source-sink relationships in wheat subjected to water stress during three productive stages. RevistaBrasileira de Fisiologia vegetal. 5 (2): 145-150.

[38] McKersie, B. D., T. Senaratna, M. A. Walker, E. J. Kendal and P.R. Hetherington, 1988., Deterioration of membranes during aging in plants : Evidence for free radical mediation In: Nooden, L. D. And A. C. Leopold (Eds.), Senescence and Aging in plants. Academic Press, London, Pp. 442-464.

[39] Maddah, S., Fallahian, F., Sabaghpour, S., and H, Chalbyan. 2004., Effect of salicylic acid on yield, yield components and anatomical structure of chickpea (Cicer arietinum L.). Basic Science Journal of Islamic Azad University (JSIAU), 1: 70-62.

[40] Maibangsa, S., M. Thangaraj and R. Stephen. 2000., The effect of brassinosteroid and Salicylic acid on rice (Oryza sativa L.) grown under low irradiance condition Indian J. Agric. Res., 34 (4) : Pp.258-260.

[41] Maibangsa, S., M. Thangaraj and Roy. 2001., Alleviation of low irradiance stress in rice (Oryza satioa L.) by growth regulators. Annals of plant Physiol., 13 (2): 133-142.

[42] Metwally, A., I. Finkemeier, M. George and K. Dietz. 2003., Salicylic acid alleviates the cadmium toxicity in barley seedling. Plant Physiol. 132: Pp. 272-281.

[43] Netondo G.W, Onyango J.C, Beck, E. 2004. Sorghum and Salinity: II. Gas Exchange and Chlorophyll Fluorescence of Sorghum under Salt Stress. Crop Science. 44:806–811.

[44] Neto, A.D., Gomes Filo, E. 2005. Effect of salt stress on antioxidant and lipid peroxidation in leaves and roots of salt tolerance and salt sensitive maize genotype. Indian J. Agric. Res., 39 (5): Pp.244-246.

[45] Pandey DM, Goswami, CL, Kumar, B. 2003. Physiological effects of plant hormones in cotton under drought. Biological Plant. 47(4): 535-540.

[46] Pastori, G., P. Mullineaux and C. H. Foyer. 2000., Post transcriptional regulation prevents accumulation of glutathione reductase protein and activity in the bundle sheath cells of maize. Implication on the sensitivity of maize to low temperatures. Plant Physiol., 122: Pp. 667-75.

[47] Passioura, J. B. 1988. Root signals contention in wheat seedling growing in drying soil. Aus. J. Plant Physiol., 15: Pp. 687-693.

[48] Peltzer, D., E. Dreyer and A. Poole. 2002. Temperature dependencies of antioxidative enzymes in two contrasting species. Plant Physiol Biochem., 40: Pp. 141-50.

[49] Popova, L., E. Ananieva, V. Hristova, K. Christova, K. Georgieva, V. Alexieva and Z. H. Stoinova. 2003. Salicylic acid and methyl jasmonate-induced protection on photosynthesis to paraquat oxidative stress. Bulge. J. Plant Physiol. 21: 133-152.

[50] Rezayizad, A. 2004. Effects of drought stress on yield and components of sunflower. Paper abstracts of Iran agriculture and plant breeding Congress.

[51] Robertson, M. J., and Guinta, F. 1994. Responses of spring wheat exposed to pre-anthesis water stress. Australian journal of Agricultural Research 45: 19-35.

[52] Senaratna, T., Touchell, D.,and E, Bunn., K, Dixon, 2000., Acetylsalicylic acid (Aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plant. Plant Growth Regul, 30, 157-161.

[53] Sakhabutdinova A.R, D.R, Fatkhutdinova and, M.V, Bezrukova, F.M, Shakirova. 2003., Salicylic acid prevents the damaging action of stress factors on wheat plants. Bulge J Plant Physiol 29:314-319. Special Issue.

[54] Sanna, A. M. Z., S. l. Ibrahim and H. A. M. S. Eden. 2001., The effect of naphthalene acetic acid (NAA), salicylic acid (SA) and their combination of growth, fruit setting, yield and some correlated components in dry beans (Phaseolus vulgaris L.) Annals of Agric, Sci., (Cairo). 46 (2): Pp. 451-463.

[55] Senaratna, T., Touchell, D.,and E, Bunn., K, Dixon, 2000., Acetylsalicylic acid (Aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plant. Plant Growth Regul, 30, 157-161.

[56] Shakirova, F. M., A. R. Sakhabutinova, M. V. Bezrukova, R. A. Fatkhutdinova and D. R. Fatkhutdinova, 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Sci. 164: Pp. 317-322.

[57] Sharp, R. E. and W. J. Davies. 1989., Regulation of growth and development of plants growing with a restricted supply of water. In: Jones HG, Flowers TL, Jones MB, Eds. A plant under stress: Cambridge: Cambridge University Press. Pp. 71-93.

[58] Shafi, M. N., L. Zafar, A. Ghazanfar and M. Akhtar. 1987., Response of wheat to soil moisture stress at early growth stage on high watertable soil of Faisalabad. J. Agric. Res., 20 (2): Pp. 83-86.

[59] Shim, I. S., Y. Momose, A. Yamamoto, D. W. Kim and K. Usui, 2003., Inhibition of catalase activity of oxidative stress and its relationship to salicylic acid accumulation in plants. Plant Growth Regul., 39: Pp. 285-292.

[60] Singh, H., and Usha, K. 2003. Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. Plant Growth Regul. 39: Pp. 137-141.

[61] Sivakumar, R., Kalarani, M. K., maiolica, V. And Sujatha, K. B. 2001. Effect of growth regulators on biochemical attributes, grain yield and quality in pearl millet (Pennisetum glaucum L. R. Br.) Madras Agric. J. 8: Pp. 256-259.

[62] Stevens, J., Seneratna, T., Stivasithamparam, K. 2006. Salicylic acid induces salinity tolerance in tomato (lycopersicum esculentum): associated changes in gas exchange water relations and membrane Stabilization. Plant growth Reg 49:77-83.

[63] Zhou, X. M., A. F. Mackenzie, C. A. Madramootoo and D. L. Smith. 1999., Effects of stem injected plant growth regulators, with or Without Sucrose, on grain production, biomass and Photosynthetic activity of field-grown corn plants. J. Agron. Crop Sci., 183 (2): Pp.103-110.

[64] Xie and Chen. Z. 1999. Salicylic Acid Induces Rapid Inhibition of Mitochondrial Electron Transport and Oxidative Phosphorylation in wheat cells. Plant Physiol.120 (1): 217-226.

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