## Improving Capacity of Yellow Corn Tolerance to Water Stress by Foliar Application of Ascorbic Acid and Hydrogen Peroxide

Kotb M. A., Hamada M. S., El-Sayed M. E. and M. G. Abas Agron. Dep., Fac. Agric., Suez Canal Univ., 41522 Ismailia, Egypt

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Abstract: Two field experiments were conducted in a new soil conditions in the extension field in El Qantra-West, Ismailia Governorate, Egypt (30<sup>0</sup> 58' N, 32<sup>0</sup> 23' E, and 10m above mean sea level) during 2016 and 2017 summer seasons. The study aimed to find out the effect of five exogenous application levels of AsA and  $H_2O_2$  on yellow corn hybrid 352 (three way cross) under three amounts of irrigation water (1.00. 0.80 and 0.60 of the estimated crop evapotranspiration) using surface irrigation system. A randomized complete block split-plot design with three replications was used in each season. The irrigation treatments and the levels of AsA and H<sub>2</sub>O<sub>2</sub> were randomly allocated in the main and sub-plots, respectively. The most important findings could be summarized as follows: Irrigation by 2250 m<sup>3</sup>/fad (severe water stress) instead of 3750 m<sup>3</sup>/fad (full irrigation) reduced ear leaf blade area, total chlorophyll and relative water content in both seasons. Increasing the level of AsA up to 350ppm/fad increased ear leaf blade area, total chlorophyll and relative water content followed by the highest level of H<sub>2</sub>O<sub>2</sub> (60mM H<sub>2</sub>O<sub>2</sub>). Decreasing irrigation water significantly reduced ear length, 100-grain weight and grain yield/fad. Meanwhile, ear length, 100-grain weight and grain yield/fad were significantly obtained from the highest level of AsA followed by the highest levels of  $H_2O_2$ compared with their untreated analogues. The interaction between the both studied factors showed that application of 350ppm AsA and 60mM H<sub>2</sub>O<sub>2</sub> treatments protected about 920 and 320 kg/fad grains from collapse under moderate water stress (3000 m<sup>3</sup>/fad). Meanwhile, under severe water stress, treatments by same levels of AsA and 30mM  $H_2O_2$ protected about 670 and 330kg/fad grains from lose. Application of 350ppm AsA saved approximately 750m<sup>3</sup>/fad of irrigation water without yield reduction.

Keywords: Maize, AsA, H<sub>2</sub>O<sub>2</sub>, Grain Yield, Drought, Evapotranspiration

#### INTRODUCTION

Water stress-associated with high salinity or with high temperature are often considered to be a limiting factors in maize (Zea mays L.) grown in arid and semiarid regions. About, one-third of the world's arable land is suffering from chronically inadequate supplies of water for cultivation (Massacci et al., 2008). It has been reported that maize is relatively tolerant to water stress in the vegetative stage, very sensitive during the period of tasseling, silking, and pollination, and moderately sensitive during the grain-filling stage (Shanahan and Nielsen, 1987; Abo-El-Kheir and Mekki, 2007). Irrigation SC 10 maize hybrid by 1575 m<sup>3</sup>/fad instead of 2625 m<sup>3</sup>/fad of the estimated crop evapotranspiration significantly reduced ear leaf blade area, total chlorophyll, relative water content, grain yield and irrigation water use efficiency (Kotb et al., 2009; Kotb and Elhamahmy, 2013). Drought imposed at initiation of silking was more lethal in terms of reduction in different yield and yield components including 1000grain weight, grain and biological yields (Oasim et al., 2019).

A consequence of soil water deficits is the limitation of photosynthesis which usually accompanied with the formation of reactive oxygen species (ROS) in various subcellular organelles of plant cell such as the superoxide, hydrogen peroxide and the hydroxyl radical. Increased levels of ROS cause damage to various cellular mechanisms, such as enzyme inhibition, protein degradation, DNA and RNA damage, and membrane lipid peroxidation, which ultimately culminate in cell death (Shao *et al.*, 2008).

A complex antioxidative defense system, composed of both non-enzymatic and enzymatic

\*Corresponding author e-mail: kotb\_m\_aa@yahoo.com

constituents, is present in all plant cells (Foyer *et al.*, 1994). Low-molecular weight, non-enzymatic, nutrientderived antioxidants are presented by carotenoids, tocopherols, glutathione and ascorbic acid (AsA). Apart their obvious role as enzyme substrates, they can react chemically with almost all forms of ROS. AsA is a small, water-soluble antioxidant molecule that acts as a primary substrate in the cyclical pathway for detoxification and neutralization of superoxide radicals and singlet oxygen (Foyer, 1994).

Under normal irrigation or water stress conditions, the effects of foliar application of vitamin C on many plants were indicated. Dolatabadian *et al.* (2010) found that foliar application of 150 mgl<sup>-1</sup> ascorbic acid during growing phases of corn increased grain weight. Also, foliar spray of 200ppm AsA improved leaf area, photosynthetic pigments (chl. a, chl. b and total chl.), ear length, 100-grains weight and grain yield (Abo-Marzoka *et al.*, 2016; Qasim *et al.*, 2019). Grain yield of wheat was increased by about 0.5 t/ha in AsA-treated plants under normal irrigation. Also, AsA treatments protected about 0.8-0.9 t/ha grains from collapse under water stress. Application of AsA saved approximately 852 m<sup>3</sup>/h of irrigation water without yield reduction (Kotb and Elhamahmy, 2013).

Hydrogen peroxide plays an important role as a signalling molecule such as translocation, photosynthesis, respiration, and transpiration and prevents several biotic and abiotic stresses like drought, salinity, cold and heat. It is an environment friendly compound where, it is predominantly produced in plant cell during photosynthesis and photorespiration and to a lesser extent, in respiration (Slesak *et al.*, 2007). Thus, these processes will lead to increment of crop yield. The

foliar application of H<sub>2</sub>O<sub>2</sub> during early stage of plants also had positive effect (Cavusoglu and Kabar, 2010). Khandaker et al. (2012) found that fruit growth can be enhanced by spraying the crop of wax apple with  $H_2O_2$ treatment. They showed significantly increases with the photosynthetic stomatal conductance, rates, transpiration, chlorophyll and dry matter content of the leaves. Rice seeds treated with 10 H<sub>2</sub>O<sub>2</sub> significantly protected chlorophyll chilling-induced from degradation, enhanced the activities of catalase and ascorbate peroxidase and produced quality seedlings (Afrin et al., 2019).

The objective of this study is to evaluate the effect of irrigation rates and exogenous application by ascorbic acid and hydrogen peroxide on growth and yield of yellow corn under new soil conditions.

## MATERIALS AND METHODS

Two field experiments were conducted in a new soil conditions in the extension field in El Qantra-West, Ismailia Governorate, Egypt  $(30^0 58' \text{ N}, 32^0 23' \text{ E}, \text{ and} 10\text{m}$  above mean sea level) during 2016 and 2017 summer seasons. The study aimed to find out the effect of five exogenous application levels of AsA and H<sub>2</sub>O<sub>2</sub> on yellow corn hybrid 352 (three way cross) under three amounts of irrigation water (1.00, 0.80 and 0.60 of the estimated crop evapotranspiration) using surface irrigation system. A randomized complete block splitplot design with three replications was used in each season. The irrigation treatments and the levels of AsA and H<sub>2</sub>O<sub>2</sub> were randomly allocated in the main and subplots, respectively.

Three amounts of irrigation water were calculated as 1.0 (IR1), 0.8 (IR2) and 0.6 (IR3) of the estimated crop evapotranspiration (ETc). Maize plants were given 9 irrigations at 10 days intervals starting after 25 days from sowing. In the two growing seasons, the amount of water needed for each irrigation was calculated according to the crop coefficient (Kc) and the daily reference potential evapotranspiration (ETo). The latter was determined according to the Penman-Monteith equation (Allen *et al.*, 1998) depending on the predicted climatic factors at each irrigation time and the growth stage of maize plant. The average amounts of water during the two growing seasons were 3750, 3000 and 2250 m<sup>3</sup>/fad for the irrigation treatments, respectively.

Five exogenous application levels of ascorbic acid and H<sub>2</sub>O<sub>2</sub> levels (S0: spray with tap water, S1:175 ppm AsA, S2: 350ppm AsA, S3: 30mM H<sub>2</sub>O<sub>2</sub> and 60mM H<sub>2</sub>O<sub>2</sub>) were foliar applied in 100 liter /fad after 30, 50 and 70 days from sowing. Ascorbic acid and H<sub>2</sub>O<sub>2</sub> (30%) of Elnaser Pharmaceutical Chemicals Co. Egypt were used. Before beginning of the experiment, soil samples were obtained with an auger from soil depths of 0-60 cm to determine the physical and chemical properties of the experimental field (Table 1). The soil texture at this site was predominantly loamy throughout its profile (49.3% sand, 37.2% silt and 13.5% clay). The Soil physical and chemical properties of the experimental field over the two seasons were determined following the method of Cassel and Nielsen (1986) and Grossmann and Reinsch (2002). The climate in this region is almost arid with a scarce annual rainfall of 20 mm during December to March. The temperature averages approximately 28.0°C in summer; and the relative humidity averages approximately 58.0%. The predicted monthly climatic data at Ismailia region during the growing seasons of maize are presented in Table (2).

Soil depth (cm)	EC (dS m <sup>-1</sup> )	рН	Sand (%)	Silt (%)	Clay (%)	Texture		
0-60cm	3.96	7.77	49.3	37.2	13.5	Loamy		
Soil depth (cm)	Cations (meq/l)				Anions (meq/l)			
	Ca <sup>2+</sup>	$Mg^{2+}$	Na <sup>+</sup>	$\mathbf{K}^{+}$	$CO_3^2$ -	HCO <sub>3</sub> -	СГ	SO4 <sup>2-</sup>
0-60cm	3.5	4.0	23.1	8.6	-	4.4	27.0	7.8

Table (1): Soil physical and chemical properties of the experimental field soil over the two seasons

 Table (2): The predicted monthly climatic data at Ismailia Governorate during the growing periods of corn as average from 2015 to 2019 seasons

Monthe	Ave	rage temperature	<sup>0</sup> C	Average RH	Average	
wiontins	Minimum	imum Maximum		%	Wind speed (Km/h)	
May	14	36	25.0	47.5	15.5	
June	17	39	28.0	53.0	13.5	
July	19	39	29.0	60.5	14.0	
August	21	38	29.5	63.5	12.5	
September	19	36	27.5	64.5	11.5	

Data collected from Egyptian Meteorological Authority

The sowing date was 12 May in both seasons in hills 20 cm apart. The sub-plot area was 9  $m^2$  included 5 ridges of 3 m long and 60 cm apart. The preceding crop was Egyptian clover in the two growing seasons. To ensure full germination and complete establishment of seedlings, the normal irrigation was applied to the all field area at planting up to starting the irrigation water treatments. Twenty days after sowing, maize plants were thinned to one plant/hill. The agronomic practices were done as recommended in this region.

## Sampling and Traits Studied

At 85 days from sowing, five plants were randomly taken from the  $2^{nd}$  ridge for estimating the vegetative growth characters as follows:

- 1- Ear leaf blade area (cm<sup>2</sup>).
- 2- Total chlorophyll (µMm<sup>-2</sup>)

It was determined from the youngest fully expanded leaf using the Minolta SPAD-502 chlorophyllmeter according to Markwell *et al.* (1995).

## 3- Relative water content (%)

The relative water content was determined according to Schonfeld *et al.* (1988).

## Yield measurements

At maturity (at 125 days from sowing), yield measurements were estimated from plants of the two middle ridges (the  $3^{rd}$  and  $4^{th}$  ridges) in each sub plot.

1- Ear length (cm)

2- 100-grain weight (g)

3- Grain yield (kg/fad), it was adjusted to 15.5% moisture content.

#### **Statistical Analysis**

The analysis of variance of a randomized complete block split plot design was used. The least significant difference (LSD at P  $\geq$ 0.05) was used to compare the differences among interactions means, according to Steel *et al.* (1997). Graphical presentation of data was carried out using Microsoft Excel program (Microsoft Corporation, Los Angeles, CA, USA).

## **RESULTS AND DISCUSSION**

The results and discussion were focus on the interaction effect between irrigation treatments and praying treatments with AsA or  $H_2O_2$  on measured traits as following:

## **a-** At 85 days from planting Ear leaf blade area (cm)

The interaction between irrigation treatments and exogenous application by AsA and  $H_2O_2$ , illustrated in Figures (1 and 2) showed that both of them interacted with each other significantly on ear leaf blade area in both seasons. Ear leaf blade areas were significantly and gradually increased by increasing both of irrigation water amount and levels of AsA and  $H_2O_2$  in both seasons.



Figure (1): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Ear leaf blade area (cm<sup>2</sup>) of maize at 85 days from planting in 2016 season. R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>



Figure (2): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Ear leaf blade area (cm<sup>2</sup>) of maize at 85 days from planting in 2017 season. R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

Under sever water stress treatment (0.6 of the estimated crop evapotranspiration) and spray with 350 ppm AsA/fad or 60mM H<sub>2</sub>O<sub>2</sub>/fad, the responses of ear leaf blade areas were 472.00 and 430.67  $cm^2$  in the first season and 507.00 and 465.67 cm<sup>2</sup> in second season compared with 356.33 and 390.33 cm<sup>2</sup> when the concentrations of AsA and H2O2 were decreased to zero (control treatment) in both seasons, respectively. The highest values of ear leaf blade area were obtained from 350 ppm AsA/fad or 60mM H<sub>2</sub>O<sub>2</sub>/fad under normal irrigation in both seasons. These results indicated, also, that maize plants responded to AsA and H<sub>2</sub>O<sub>2</sub> addition in both seasons under normal irrigation as well as water stress conditions. Similar results were obtained by Kotb et al. (2009), they indicated that severe water stress reduced ear leaf blade area by 40.41% and 43.93% than their unstressed maize plants in the two seasons, respectively. It has been proven that drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It effects on both cell elongation and its expansion (Shao et al., 2008). Similar results of application AsA on peanut were obtained by Kotb et al. (2014). Also, hydrogen peroxide plays an important role in stimulating the reproductive growth and promoting the expression of the flower related gene (Zhou et al., 2012). From these results, it could be concluded that exogenous AsA and H<sub>2</sub>O<sub>2</sub> application with a proper dose helped stressed maize plants to ameliorate various physiological processes, such as translocation, photosynthesis, respiration, and transpiration (Barba-Espin *et al.*, 2010) and hence had higher leaf area than their untreated analogues. Also, leaf area of maize hybrid SC.128 was significantly reduced with increasing intervals irrigation up to 25 days while ascorbic acid, particularly at 200 ppm tended to improve the adverse effect of water deficit stress by improving this trait (Abo-Marzoka *et al.*, 2016).

## **Total Chlorophyll Content**

Chlorophyll pigments have often been proposed as useful criteria for screening several plants for drought stress. Concerning to the interaction between irrigation treatments and exogenous application by AsA and  $H_2O_2$ , results in Figure (3) showed that both of them interacted with each other significantly for ear leaf blade area in the only second season (2017). Under severe water stress (0.6 of ETc), untreated plants (R3S0) significantly showed a less value of CHL content (37.83µMm<sup>-2</sup>) compared to 45.40µMm<sup>2</sup> which was obtained from treated plants by 350 ppm AsA/fad (R3S2). In the same direction, under moderate water stress (0.8 of ETc), untreated plants (R2S0) significantly gave a less value of CHL content (43.00µMm<sup>-2</sup>) compared to 50.97µMm<sup>-2</sup> which was obtained from the

highest level of AsA under the same condition. Also, under well-watered (3750 m<sup>3</sup>/fad), the maximum value of Chlorophyll (60.73µMm<sup>-2</sup>) was significantly gained from 350 ppm AsA/fad followed by 56.80 and  $56.30 \mu \text{Mm}^{-2}$  which were obtained from 60 mM  $\text{H}_2\text{O}_2$ and 175 ppm AsA/fad, respectively. Under wellwatered, the application of 350ppm AsA significantly ameliorated the content of total CHL by 7.57µMm<sup>-2</sup> than untreated plants. Also, under the same conditions, using 60mM H<sub>2</sub>O<sub>2</sub> ameliorated total CHL up to  $4.0\mu$ Mm<sup>-2</sup> than untreated plants (Figure 3). On the other hand, under severe water stress (0.6 of ETc), the increases of chlorophyll contents reached to 7.57 and 5.34  $\mu$ Mm<sup>-2</sup> by using the same levels of AsA and H<sub>2</sub>O<sub>2</sub>. Similar results were obtained by Shlemmer et al. (2005) and Premachandra et al. (2008), where they indicated that water stress reduced chlorophyll content more than

the normal irrigated maize plants. In the same direction, severe drought stress decreased the levels of chlorophyll a, b, total chlorophyll (Reddy and Rao, 1968) and produced changes in the ratio of chlorophyll 'a' and 'b' and carotenoids (Anjum et al., 2003; Farooq et al., 2009). Moreover, under drip irrigation, Kotb et al. (2009) proved that irrigation SC 10 maize hybrid by 1575 m<sup>3</sup>/fad instead of 2625 m<sup>3</sup>/fad of (ETc) significantly reduced total chlorophyll. Meanwhile, Farahat et al. (2007) confirmed that foliar application of ascorbic acid on Cupressus sempervirens cultivated in Nobaria promoted chl(a) and chl(b) specially on the high concentration of ascorbic acid. Moreover, Khandaker et al. (2012) showed that spraying wax apple trees once a week with 5 mM H2O2 significantly increased the photosynthetic rates, chlorophyll and dry matter content of the leaves.



Figure (3): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on total chlorophyll (μMm<sup>-2</sup>) of maize at 85 days from planting in 2017 season. R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

#### **Relative Water Content (%)**

Relative water content (RWC) was determined to give an indication on the plant water dehydration status during exposure drought. Concerning to the interaction between irrigation treatments and exogenous application by AsA and  $H_2O_2$ , results in Figures (4 and 5) showed that both of them interacted with each other significantly on relative water content in both seasons.

Under normal conditions, increasing the levels of AsA or  $H_2O_2$  significantly ameliorated the values of RWC. These values of RWC reached to 88.55 and 86.01% in 2016 season and 86.35 and 82.91% in 2017 season, respectively without significant differences between them (Figures 4 and 5). On the other hand,

under severe water stress, the lowest values were obtained from untreated plants or treated with 30 mM  $H_2O_2$  in both seasons. These values reached to (40.56 and 43.97%) and (37.46 and 41.17%) in 2016 and 2017 seasons, respectively without significant differences between them (Figures 4 and 5). Maize is the one of most important cereal crops which is more sensitive to water scarcity as compared to other cereal crops excluding barley (Bänziger and Araus, 2007). Increasing water stress significantly reduced relative water content, chlorophyll content, leaf water potential (Shlemmer et al., 2005; Premachandra et al., 2008). Also, under drip irrigation water, irrigation SC 10 maize hybrid by 1575 m<sup>3</sup>/fad instead of 2625 m<sup>3</sup>/fad of the estimated crop evapotranspiration significantly decreased ear leaf blade area, total chlorophyll, relative water content, (Kotb *et al.*, 2009). Meanwhile, Kotb and Elhamahmy (2013) studied the effect of three levels of AsA (0.0, 100 and 200 ppm) on the response of wheat (*Triticum asetivum*, L. cv. Sakha 94) to three surface irrigation rates (1.00. 0.80 and 0.60 of the estimated crop evapotranspiration, which represented 4260, 3408

and 2556 m<sup>3</sup>/ha, respectively. Their results indicated that, drought caused a reduction in each of leaf area index, total chlorophyll and relative water content. Application of 100-200 ppm of AsA significantly alleviated the oxidative stress damage of drought, reflected by improving leaf area index, total chlorophyll and relative water content.



Figure (4): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Relative water content (%) of maize at 85 days from planting in 2016 season. R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>



Figure (5): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Relative water content (%) of maize at 85 days from planting in 2017 season. R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

#### **b-** At harvest Ear length (cm)

The interaction between water stress and exogenous application of AsA and H<sub>2</sub>O<sub>2</sub> had a significant effect on ear length in second season (Figure 6). It is interesting to note that the values of this trait obtained from the combination of (1.0 ETc + 350 ppm AsA) and the combination of (1.0 ETc + 60 H<sub>2</sub>O<sub>2</sub>) were significantly increased by 14.25% and 15.72%, respectively, compared with the control treatment without application (R1S0). The same trend of results was obtained under moderate and severe water stress. It can be concluded that the high levels of AsA and H<sub>2</sub>O<sub>2</sub> significantly ameliorate ear length either under full irrigation or under water stress. These results are compatible with those obtained by Qasim et al. (2019), they noticed that water stress significantly diminished cob length by about 13% as compared to normal irrigation. Zhang et al. (2019) suggested that ascorbic acid could be a promising material used to reduce the harmful effect of water stress on the growth and yield of maize plants. Also, the results of Noman et

al. (2015) showed that exogenous application of ascorbic acid lowered the harmful effect of drought stress-induced reduction in growth, biomass, and photosynthetic pigments. Ascorbic acid (AsA) plays an important role in protecting plant tissues from harmful oxidative damage by acting as reductant (Anjum et al., 2016; Alamri et al., 2018). It can regulate several cellular processes such as cell division, cell differentiation and cell elongation (Alamri et al., 2018). Ear length was significantly diminished with increasing water stress while ascorbic acid, particularly at 200 ppm tended to improve the adverse effect of water deficit and ameliorate ear length of maize plants (Abo-Marzoka et al., 2016). In the other hand, hydrogen peroxide treatment also stimulated the antioxidant system that resulted in the induction of drought tolerance of maize plants in terms of higher shoot and root fresh and dry masses (Ashraf et al., 2015). H<sub>2</sub>O<sub>2</sub> have regulatory effects on growth, development and quality of plants and it plays an important role in physiological processes and in resistance to stresses (Quan et al., 2008).



Figure (6): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Ear length (cm) of maize at harvest in 2017 season.
R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

## 100-grain weight (g)

The interaction between irrigation treatments and foliar spray with antioxidants had significant effect on100-seed weight (g) in both seasons (Figures 7 and 8). Our results revealed that using high concentration of ascorbic acid with full irrigation gave significantly higher 100-seed weight (32.82 and 35.60g) in both seasons, respectively, followed by the high concentration of hydrogen peroxide with significant difference between them. Meanwhile, untreated plants under full irrigation gave 27.66 and 29.14g in 2016 and 2017 seasons, respectively. On the other hand, the lowest 100-seed weights (16.66 and 17.67g) were obtained from the interaction between severe water

stress and without antioxidants treatment. As average over the two seasons, using 350ppm AsA and 60mM  $H_2O_2$  protected approximately 6 and 5 g from collapse in weight of 100-seed, respectively, under moderate stress. Also, under severe water stress, the same levels of AsA and  $H_2O_2$  protected about 5 and 3.5g from lose in weight of 100-seed, respectively. It could be concluded that under same conditions both of foliar spray of these treatments significantly ameliorated 100seed weight compared to untreated plants (spray with tap water). These results are in a good connection with those obtained by Quan *et al.* (2008), Geros *et al.* (2012), Kotb and Elhamahmy (2013) Abo-Marzoka *et al.* (2016) and Qasim *et al.* (2019).



Figure (7): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on 100-grain weight of maize at harvest in 2016 season.
R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>



Figure (8): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on 100-grain weight (g) of maize at harvest in 2017 season.
R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

#### Grain yield (kg/fad)

The interaction effect between irrigation treatments and exogenous application treatments had significant effect on grain yield/fad in both seasons (Figures 9 and 10). When corn plants exposed to severe water stress without AsA gave the lowest averages of yield compared to the other treatments. Meanwhile, the highest averages of grain yield were obtained from the highest levels of AsA and  $H_2O_2$  under normal irrigation without significant differences between them.

As average of the two seasons, grain yields were increased by about 650 and 640 kg/fad in AsA and H<sub>2</sub>O<sub>2</sub>-treated plants under normal irrigation (Figures 9 and 10). Under normal conditions, the effects of foliar application of vitamin C were significantly ameliorated the growth and productivity in many plants (Abdel-Halim, 1995; Abd El-Aziz et al., 2007; Zhang et al., 2019). Also, 350 ppm AsA or 60 mM H<sub>2</sub>O<sub>2</sub> treatments protected about 920 and 320 kg/fad grains from collapse under moderate water stress, respectively (Figures 9 and 10). Meanwhile, under severe water stress, treatment by same level of AsA and 30 mM H<sub>2</sub>O<sub>2</sub> protected about 670 and 330 kg/fad grains from lose. Under moderate water stress, application of 350 ppm AsA saved approximately 750m<sup>3</sup>/fad of irrigation water without vield reduction compared with unstressed plants (Figures 9 and 10). The different stages of maize growth are severely affected by drought leading to extension in anthesis-silking-duration, lower chlorophyll contents, less photosynthesis and thus lower yield (Aslam et al., 2013). Also, increasing water stress significantly decreased relative water content, chlorophyll content

(Shlemmer et al., 2005; Premachandra et al., 2008), 1000-grain weight and grain yield (Muhammad et al., 2001). In the same direction, under water deficit conditions, growth traits, relative water content (RWC), chlorophyll a, total chlorophyll and carotenoids as well as grain yield decreased significantly in maize plants compared to those traits under control conditions (Kotb et al., 2009; Qasim et al., 2019; Moharramnejad et al., 2019). Meanwhile, foliar application of several concentrations of ascorbic acid on corn plants under water deficit alleviated the adverse effect of water stress and significantly improved the growth, yield and yield attributes of maize plants (Dolatabadian et al., 2010; Abo-Marzoka et al., 2016; Qasim et al., 2019). On the other hand, hydrogen peroxide plays a remarkable role as a signalling molecule and prevents several biotic and abiotic stresses like drought, salinity, cold and heat. H<sub>2</sub>O<sub>2</sub> have regulatory effects on growth, development and quality of plants and improving plant production (Zhou et al., 2012). Also, the fruit growth can be enhanced by spraying the wax apple with H<sub>2</sub>O<sub>2</sub> treatment (Khandaker et al., 2012). Results of Guler and Pehlivan (2016) suggested that low dose of H<sub>2</sub>O<sub>2</sub> pre-treatment alleviated water loss and H<sub>2</sub>O<sub>2</sub> content and increased drought stress tolerance by inducing the antioxidant system. Moreover, the treated wax apple fruit with 5 mM H<sub>2</sub>O<sub>2</sub> gave larger fruit size, increased fruit set, fruit number, fruit biomass and vield compared to the control (Khandaker et al., 2012) while, the presence of  $H_2O_2$  in the fruit could improve the process of ripening (Geros et al., 2012).



Figure (9): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Grain yield/fad of maize at harvest in 2016 season.
R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>



Figure (10): Effect of the interaction between water stress (R) and foliar spray (S) treatments by AsA and H<sub>2</sub>O<sub>2</sub> on Grain yield/fad of maize at harvest in 2017 season.
R1: well-watered (3750 m<sup>3</sup>/fad); R2: 0.8 R1, R3: 0.6 of R1. S0: untreated plants, S1: 175ppm AsA, S2: 350 ppm AsA, S3:30mM H<sub>2</sub>O<sub>2</sub>, S4: 60mM H<sub>2</sub>O<sub>2</sub>

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# تحسين قدرة الذرة الشامية على تحمل الإجهاد المائي عن طريق الرش الورقي بحمض الأسكوربيك وفوق أكسيد الهيدروجين

ماهر عبد الله قطب – محمد صبرى حمادة – محمود إبراهيم السيد – محمد جمال عباس قسم المحاصيل – كلية الزراعة – جامعة قناة السويس – ٢١٥٢ ٤ الإسماعيلية – مصر

أجريت تجريتان حقليتان تحت ظروف الأراضي الجديدة في منطقة القنطرة غرب، محافظة الإسماعيلية، مصر خلال فصلى الصيف ٢٠١٦ و ٢٠١٧. وتهدف الدراسة إلى دراسة تأثير خمسة مستويات من الرش الورقي لحامض الاسكورييك وفوق أكسيد الهيدروجين على الذرة الصفراء هجين ثلاثي ٢٥٢ تحت ثلاثة مستويات من الإجهاد المائي (٠٠.١ و ٢٠. من قيمة البخر نتح المقدر لمحصول الذرة الشامية) مستخدما نظام الري السطحي. تم استخدام تصميم القطاعات الكاملة العشوائية للقطع المنشقة مرة واحدة في ثلاث مكررات لكل موسم. تم توزيع معاملات الري ومعاملات الرش بشكل عشوائي في القطع الرئيسية والفرعية ، على التوالي. يمكن تلخيص أهم النتائج على النحو التالي: انخفاض الري إلى ٢٢٠٠ م /فدان مقارنة مع ٢٥٣٠م /فدان أدى إلى نقص معنوي لكل من مساحة نصل ورقة الكوز والكلوروفيل الكلي والمحتوى المائي النسبي في كلا الموسمين. زيادة مع ٢٥٠٥م /فدان أدى إلى نقص معنوي لكل من مساحة نصل ورقة الكوز زيادة مساحة نصل ورقة الكوز والكلوروفيل الكلي والمحتوى المائي النسبي ثم اتبعت بالمستوى الأعلى من 200 جزء مع بالنباتات غير المعاملة. نقص كمية ماء الري من ٢٣٥٠ لم /فدان مقارف في القص معنوي على طول الكوز ، ووزن ٢٠٠ حبة ، ومحصول زيادة مساحة نصل ورقة الكوز والكلوروفيل الكلي والمحتوى المائي النسبي ثم اتبعت بالمستوى الأعلى من 200 جزء مع بالنباتات غير المعاملة. نقص كمية ماء الري من ٣٧٥٠ إلى ٢٢٥٠ معرافران، أدى إلى نقص معنوي في طول الكوز ، ووزن ٢٠٠ حبة ، ومحصول الحوب/فدان. تم الحصول على أعلى القيام من طول الكوز، وزن ٢٠٠ حبة ومحصول الحوب/فدان من المعاملة بأعلى مستوى من ASA و120 تحت ظروف الإجهاد المائي المعتدل أدت إلى زيادة المحصول بحوالي ٢٠٠ و ٢٣٠ جزء في المليون من ASA أو ٢٠ مليموز من منوع با باعور من 200 الإليها للمناع لين كل من عوامل الدراسة أن معاملة ٣٠٠ جزء في المليون من ASA ولي منوع من ASA أو ٣٠ معاملة الكترول وفي المور الدواسة أن معاملة ، ٢٠ جزء في المليون من ASA أو ٢٠ ماليموز من منوع با يقوى أليون الإجهاد المائي المعتدل أدت إلى زيادة المحصول بحوالي ٢٠٠ جزء في المليون من ASA أو ٣٠ ماليموز من مولى ٣٠ معادل أدى إلى الحصول على نفس كمية المحامة الاكترول. إن الرش الورق بمعاملة الكترول وفي الوقت منوع بانوع المعتدل أدى إلى المماز عافي المحصول مل الري العادي وبدون رش حمض الاسكورييك مع الإجهاد المائي المعتدل أدى إلى المحو

*الكلمات الدالة:* الذرة الشامية، حمض الاسكوربيك، فوق أكسيد الهيدروجين، محصول الحبوب، الجفاف، النتح بخر