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THE INTERACTIVE EFFECT BETWEEN WATER STRESS AND FOLIAR SPRAYING WITH ASCORBIC ACID OR HYDROGEN PEROXIDE ON WHEAT PRODUCTIVITY

Maher A. Kotb, G.M. Yakout, Fatma S. Ali* and M.G. Abas

Agron. Dep., Fac. Agric., Suez Canal Univ., 41522 Ismailia, Egypt

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ABSTRACT: Two field experiments were carried out at a private farm at Manchat Nabhan, Fakose, Sharkia Governorate, Egypt during 2017/18 and 2018/19 winter seasons. The study aimed to find out the effect of five exogenous application levels of AsA and H_2O_2 (S0: without, S1:100 ppm AsA, S2: 200ppm AsA, S3: 30mM H_2O_2 and S4: 60mM H_2O_2) on wheat (*Triticum asetivum*, L. cv. Misr 1) under three treatments of irrigation water (4, 5 and 6 irrigations) using surface irrigation system. A randomized complete block split plot design with three replicates was used in each season. The irrigation treatments and the levels of AsA and H_2O_2 were randomly allocated in the main and sub-plots, respectively. The most important findings could be summarized as follows: At 105 days from planting, wheat plants under water stress (irrigation four times) without AsA and H_2O_2 application showed a significant decrease in leaf area index (LAI), relative water content (RWC %) and total chlorophyll in comparison to wheat plants under well watered in both seasons. In general, the highest values of these traits were significantly gained from the highest concentration of ascorbic acid (200 ppm) and H_2O_2 (60mM) in both seasons. At maturity, in both seasons, irrigations 4 times significantly resulted in lower spikes number m^{-2}, 1000-grain weight and grain yields than those in the plots irrigated 6 times. Generally, the maximum values of these traits were significantly obtained from the highest levels of ascorbic acid and H_2O_2 in both seasons. Under stressed and unstressed plants, increasing AsA and H_2O_2 levels significantly improved all these traits.

Key words: Wheat, AsA, H_2O_2, drought, Irrigations

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop and comes in first place, followed by rice and preferable than rice; due to its grain is higher in protein content. It has been reported that wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals. Egypt area of wheat is estimated by about 3.4 million faddan, with production of 8.9 million ton, while it imports 10 million tons of wheat **(FAO, STAT, 2020/21)**.

Insufficient water supply for irrigation in arid and semi-arid regions is the main yield limiting factor. Drought stress is one of the main abiotic stresses and the major causes of osmotic stress to plants under natural marginal lands **(Xiong and Zhu 2002)**. In addition, drought stress also induces oxidative stress which can cause plant death and decrease productivity at the whole-plant level. Also, exposure to drought stress can diminishes plant growth by affecting all the major plant processes, including photosynthesis, protein synthesis, respiration, translocation, ion uptake, carbohydrates synthesis energy and lipid metabolism **(Apel and Hirt, 2004; Farooq *et al*., 2008)**. Improving plant tolerance to abiotic and biotic stresses is very complex, due to the complexity of interactions between stress factors and various molecular, biochemical and physiological factors affecting plant growth,

* **Corresponding author: Tel. :**+201288901601
E-mail address: fatma_soliman.pdg@agr.suez.edu.eg

establishment, development and production **(Razmjoo *et al*., 2008)**. It has been proven that drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It affects both cell elongation and its expansion **(Shao *et al*., 2008)**. Leaf area in many species of plant was decreased under water stress conditions by slowing leaf expansion and reducing carbohydrates supply, also, both of the chlorophyll a and b and carotenoids have many essential roles and partially help the plants to withstand adversaries of drought. Getting of optimal leaf area and total chlorophylls are very important to improving photosynthesis and dry matter yield **(Farooq *et al*., 2009). Lawlor and Cornic (2002)** confirmed that the photosynthetic rate is known to be decrease as leaf water potential and the relative water content decreases under stress condition. Water stress, among other stresses, has the ability to reduce the concentrations of chlorophylls and carotenoids (**Kiani *et al*., 2008)**, primarily with the production of Reactive Oxygen Species (ROS) in the thylakoids which resulted in oxidative damage **(Reddy *et al.*, 2004**).

Decreasing the irrigation requirements (IR) of wheat from 100% to 50% significantly decreased flag leaf area and total chlorophyll, 100-grain weight, number of spikes/m^2, grain, straw and biological yields **(Abdelraouf *et al*., 2013)**. Results of **Kotb and Elhamahmy (2013), (Hammad and Ali 2014) and Mamdouh *et al*., (2018)** indicated that, drought caused a reduction in each of leaf area index, total chlorophyll, relative water content, grain and straw yields of wheat plants.

Water stress caused oxidative damage by the toxicity of ROS such as the hydroxyl radical, superoxide ($O_2^{\cdot-}$) and H_2O_2 levels must be tightly controlled. This control is accomplished through an interconnected network of antioxidants. Within this network, ascorbic acid (AsA) eliminates ROS through multiple mechanisms. AsA has the capacity to directly eliminate several different ROS including singlet oxygen, superoxide and hydroxyl radicals **(Padh, 1990).** It also indirectly eliminates H_2O_2 through the activity of AsA peroxidase (**Asada, 1992**). In addition, AsA has a major role in photoprotection as a cofactor in the xanthophyll cycle (**Rautenkranz *et al*., 1994).**

Under normal and water stress conditions, the effects of foliar application of vitamin C (AsA) on many plants were indicated. **Dolatabadian *et al.* (2010)** found that foliar application of 150 mgl^{-1} ascorbic acid during growing phases on corn increased grain weight. Also, foliar spray of 200ppm AsA on maize plants significantly improved leaf area, photosynthetic pigments (chl. a, chl. b and total chl.), 100-grains weight, grain yield and irrigation water use efficiency **(Abo-Marzoka *et al*., 2016; Qasim *et al.*, 2019).** Results of **Kotb and Elhamahmy (2013)** on wheat plants indicated that, drought caused a reduction in each of leaf area index, total chlorophyll, relative water content, grain and straw yields. Application of 100 - 200 ppm of AsA significantly alleviated the oxidative stress damage of drought, reflected by improving above parameters. 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 852m^3/h of irrigation water without yield reduction **(Kotb and Elhamahmy, 2013).** On the other hand, under water stress, increasing the level of AsA up to 350 ppm/fad., increased ear leaf blade area, total chlorophyll and relative water content, ear length, 100-grain weight and grain yield/fad of yellow corn hybrid 352 compared with their untreated analogues **(Kotb *et al*., 2021a)**.

Hydrogen peroxide with a suitable concentration in plant tissues 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_2O_2 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 rates, stomatal conductance, transpiration, chlorophyll and dry matter content of the leaves. Rice seeds treated with 10 H_2O_2 significantly protected chlorophyll from chilling-induced degradation, enhanced the activities of catalase and ascorbate peroxidase and produced quality seedlings **(Afrin *et al*., 2019)**.

Also, under water stress of maize plants, increasing the level of H_2O_2 up to 60mM H_2O_2 significantly increased ear leaf blade area, total chlorophyll and relative water content, ear length, 100-grain weight and grain yield/fad compared with their untreated analogues **(Kotb *et al*., (2021a)**.

The objective of this study is to evaluate the effect of number of irrigations and exogenous application by ascorbic acid and hydrogen peroxide in improving growth, yield and its relevant traits of wheat plants.

MATERIALS AND METHODS

Two field experiments were conducted in the extension field in Manchat Nabhan, Fakose, Sharkia Governorate, Egypt during 2017/18 and 2018/19 winter seasons. The study aimed to find out the effect of five exogenous application levels of AsA and H_2O_2 on wheat (*Triticum asetivum*, L. cv. Misr 1) under three treatments of number of irrigations (4, 5 and 6 irrigations) using surface irrigation system. A randomized complete block split plot design with three replicates was used in each season. The irrigation treatments and the levels of AsA and H_2O_2 were randomly allocated in the main and sub-plots, respectively.

Five exogenous application levels of ascorbic acid and H_2O_2 (S0: spray with tap water, S1:100 ppm AsA, S2: 200ppm AsA, S3: 30mM H_2O_2 and S4: 60mM H_2O_2) were foliar applied in 100 liter /fad. Three foliar sprays of AsA and H_2O_2 were made at the interval of 1 month, *i.e.* 35, 65 and 95 days from planting. All sprays were applied in the morning (9–10 a.m.). Ascorbic acid and H_2O_2 (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 (50.6% sand, 35.1% silt and 14.3% 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)**.

Grains of wheat were provided by the Egyptian crops Research Center, Ministry of Agriculture, Egypt. The experimental plot area was 10.5 m^2 (3 m x 3.5 m). Each plot included 15 rows, 20 cm apart with 3.5 m long. Grains were sown by drill at the rate of 120 kg/ha. Sowing was done on December 10^{th} in the two growing seasons. The agronomic practices were done as recommended in this region.

Ten days after the 3rd foliar application of AsA and H_2O_2 (at 105 days from planting), ten plants from an area of 0.25 m^2 from each plot were randomly taken to determine:

1- Leaf area index (LAI), LAI was calculated from the area of 0.25m^2 according to **Bonhomme *et al*. (1974)**.

2- Total chlorophyll content (SPAD value), 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 (RWC), it was determined according to **Schonfeld *et al.* (1988)**, where the fresh weight of twenty discs, from the youngest fully expanded leaves, was determined within 2 hours after excision. Turgid weight was obtained after soaking the discs for 16 to 18 hours in distilled water. After soaking, discs were immediately and carefully blotted dried with tissue paper prior to the determination of turgid weight. Dry weight was obtained after drying the discs sample for 72 hours at 70C^o. Relative water content was calculated using the following equation:

$$RWC = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

At maturity (at 155 days from sowing), an area of 1m^2 from each plot was harvested to determine:

4- Spikes number m^{-2}

5- 1000-grain weight (g)

6- Grain yield (t ha^{-1})

Table 1. Physical and chemical properties of the experimental field soil site over the two seasons

Soil depth (cm)	EC (dS m^{-1})	pH	Sand (%)	Silt (%)	Clay (%)	Texture		
0-60cm	**2. 61**	**7.58**	**50.6**	**35.1**	**14.3**	**Loamy**		
Soil depth (cm)		**Cations (meq/l)**				**Anions (meq/l)**		
	Ca^{2+}	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**CO_3^{2-}-**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{2-}**
0-60cm	4.2	3.3	10.1	8.9	-	5.4	9.3	11.8

Statistical Analysis

All data were analyzed using the CoStat software, version 6.311 (CoHort software, Berkeley, CA 94701). The analysis of variance of a randomized complete block split plot design was used. The least significant difference ((LSD at P ≥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

Leaf Area Index (LAI)

The interaction between irrigation treatments and exogenous application by AsA and H_2O_2, results in Figs. 1 and 2 showed that both of them interacted with each other significantly for leaf area index in both seasons. Leaf area index were significantly and gradually increased by increasing both of number of irrigations and levels of AsA and H_2O_2 in both seasons. Under water stress treatment (4 irrigations) and spray with 200 ppm AsA/fad or 60mM H_2O_2/fad., the responses of leaf area index were 3.33 and 3.21 in the first season and 3.30 and 3.19 in the second one without significant differences between them compared with 2.88 and 2.83 when the concentrations of AsA and H_2O_2 were decreased to zero, in both seasons, respectively. The highest values of LAI were obtained from 200 ppm AsA/fad., or 60mM H_2O_2/fad., under unstressed irrigation treatments (normal irrigation) in both seasons. These results indicate, also, that wheat plants responded to AsA and H_2O_2 addition in both seasons under normal irrigation as well as water stress conditions (Figs. 1 and 2).

From these results, it could be concluded that exogenous AsA and H_2O_2 application with a proper dose helped stressed wheat plants to ameliorate various physiological processes, such as translocation, photosynthesis, respiration, and transpiration **(Barba-Espin *et al.*, 2010)** and hence had higher leaf area index 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).** Increasing the level of AsA up to 350ppm/fad increased ear leaf blade area of maize, followed by the highest level of H_2O_2 (60mM H_2O_2). Also, the interaction between the both studied factors showed that application of 350ppm AsA and 60mM H_2O_2 treatments under severe water stress significantly increased ear leaf blade area compared with their untreated analogues of maize plants **(Kotb *et al.*, 2021 a).**

Total Chlorophyll Content (SPAD value)

Under water stress (4 irrigations), untreated plants (IR3S0) or treated with 30mM H_2O_2 significantly showed a less values of SPAD reading (16.81 and 15.01) compared to 22.44 which was obtained from treated plants by 200 ppm AsA/fad under the same condition in the second season (Fig. 3). In the same direction, under moderate water stress (5 irrigations), untreated plants (R2S0) or treated with 30 mM H_2O_2 significantly gave a less values of total chlorophyll content (CHL) (26.68 and 24.07) compared to 40.05 which was obtained from the highest level of AsA under the same condition. Also, under well-watered (6 irrigations), the maximum value of CHL (47.94) was significantly

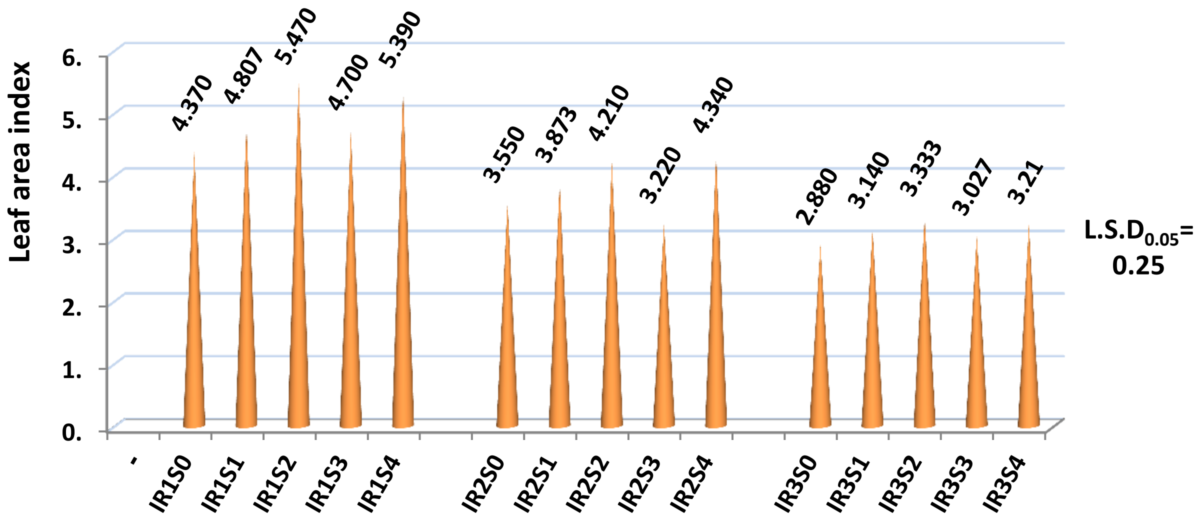

Fig. 1. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Leaf area index of wheat at 105 days from planting in 2017/18 season. IR1:well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100ppm AsA, S2: 200ppm AsA, S3 : 30 mM H_2O_2, S4: 60mM H_2O_2

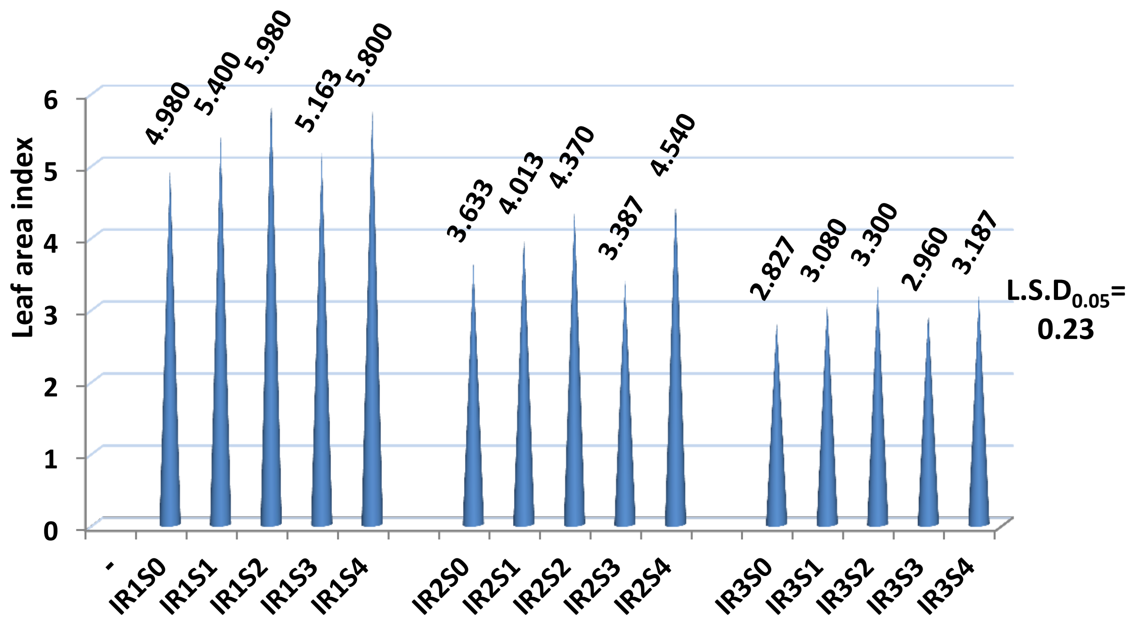

Fig. 2. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Leaf area index of wheat at 105 days from planting in 2018/19 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100ppm AsA, S2 : 200ppm AsA, S3 : 30 mM H_2O_2, S4: 60mM H_2O_2

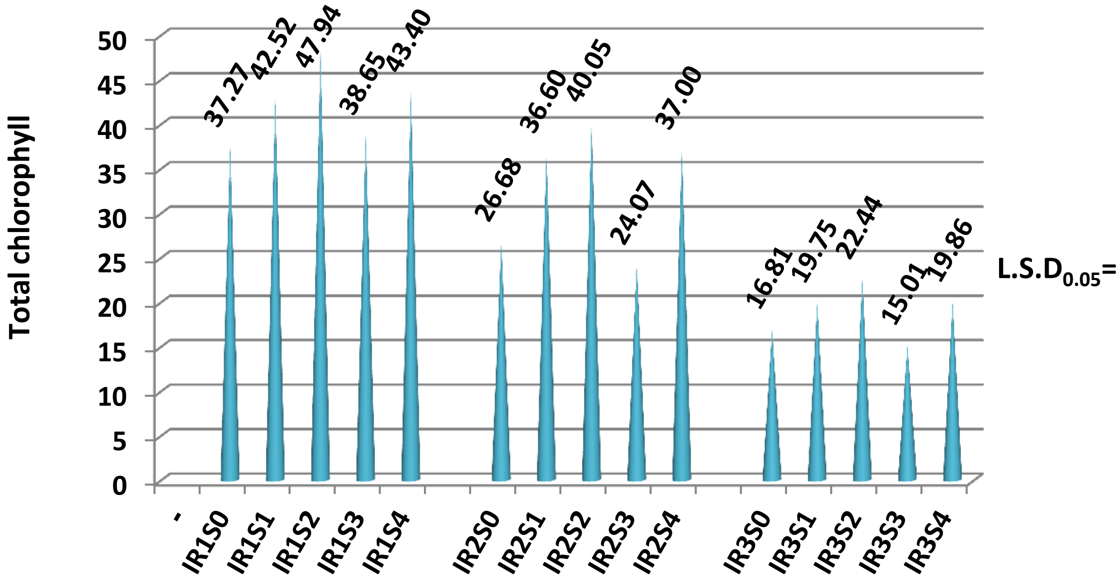

Fig. 3. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Total chlorophyll of wheat at 105 days from planting in 2018/19 season. IR1:well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2: 200ppm AsA, S3 : 30 mM H_2O_2, S4 : 60 mM H_2O_2

gained from 200 ppm AsA/ fad., followed by 43.40 and 42.52 which were obtained from 60 mM H_2O_2 and 100 ppm AsA/fad., respectively. Under well-watered, the application of 200ppm AsA significantly ameliorated the content of total CHL by 10.67 than untreated plants**.** Also, under the same conditions, using 60mM H_2O_2 ameliorated total CHL by 6.13 than untreated plants (Fig. 3). By using 4 irrigations, the increases of chlorophyll contents reached to 5.63 and 3.05 under the same levels of AsA and H_2O_2. In the same direction, **Farahat *et al.* (2007)** confirmed that foliar application of ascorbic acid on *Cupressus sempervirens* cultivated in Nobaria at concentration of (20, 40 ppm) 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 H_2O_2 significantly increased the photosynthetic rates, chlorophyll and dry matter content of the leaves. Under well watered and water stress conditions, the values of total chlorophyll of leaves of corn plants were significantly obtained from the highest level of AsA (350 ppm) followed by the highest levels of H_2O_2 (60mM H_2O_2) compared with their untreated analogues **(Kotb *et al.*, 2021a)**.

Relative Water Content (RWC %)

In the first season and under normal conditions, increasing the levels of AsA or H_2O_2 significantly ameliorated the values of RWC. These values of RWC reached to 84.36 and 83.17% compared to untreated plants (77.01%) in 2017/18 season, respectively without significant differences between them (Fig. 4). On the other hand, under water stress (4 irrigations), the lowest value was significantly obtained from treated plants with 30mM H_2O_2 in first season. This value reached to (44.61%) in 2017/18 season (Fig. 4). Also, **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^3/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. Increasing the level of

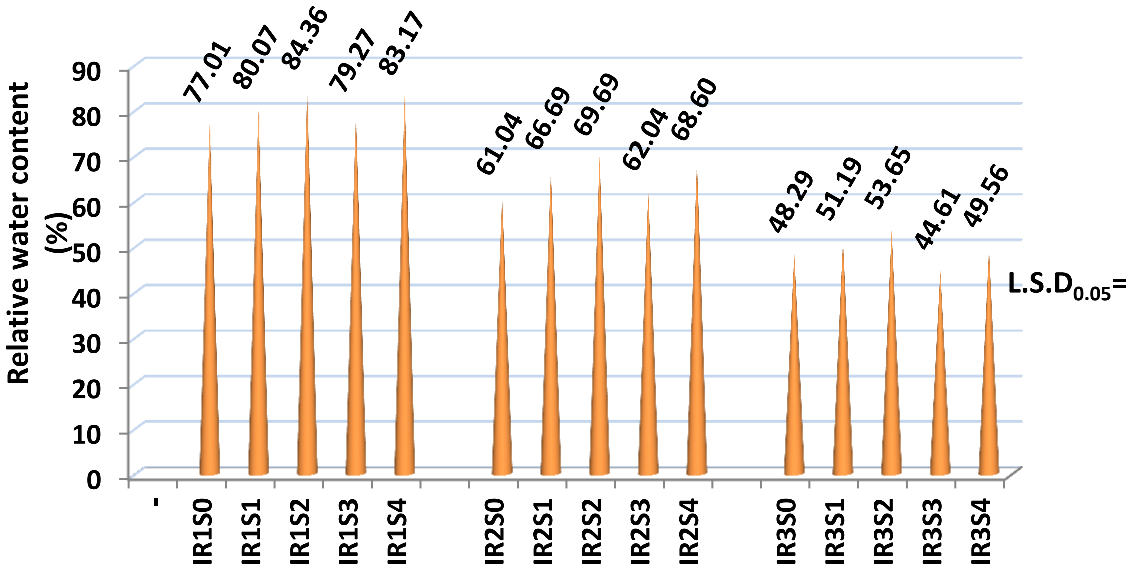

Fig. 4. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on RWC (%) of wheat at 105 days from planting in 2017/18 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100ppm AsA, S2: 200 ppm AsA, S3 : 30 mM H_2O_2, S4: 60 mM H_2O_2

AsA up to 350ppm/fad increased ear leaf blade area, total chlorophyll and relative water content followed by the highest level of H_2O_2 (60mM H_2O_2) on yellow corn hybrid 352 **(Kotb *et al.*, 2021a)**.

Spikes Number m^{-2}

Under any conditions, the interactions between water stress and foliar spray treatments presented in Figs. 5 and 6 showed that increasing H_2O_2 and AsA levels significantly improved spikes number m^{-2} in both seasons. Under well watered plants, the relative increase percentages (RIP) due to application the highest levels from these free radical (H_2O_2) and antioxidant were about 6 - 13% in comparison with untreated plants as average the two seasons, respectively. Meanwhile, under water stress condition (irrigated four times), these RIP were about 27 and 44% compared to untreated plants under the same condition as average the two seasons, respectively. From our obtained results, it is clear that the effects of antioxidants were stronger under water stress conditions compared to non-stressed plants (Figs. 5 and 6). It is suggested that ascorbic acid could be a promising material used to reduce the harmful effect of drought on the growth and productivity of wheat. On the other hand, **Abo-Marzoka *et al.* (2016)** found that 200 ppm ascorbic acid tended to alleviate the adverse effect of water stress on growth and yield attributes of maize plants. Application of 100 -200 ppm of AsA significantly alleviated the oxidative stress damage of drought, reflected by improving growth and productivity of wheat plants **(Kotb and Elhamahmy, 2013)**. Decreasing irrigation water significantly reduced growth and productivity of corn plants. Meanwhile, the highest values from these traits were significantly obtained from the highest levels of AsA followed by the highest levels of H_2O_2 compared with their untreated analogues **(Kotb *et al.*, 2021a)**.

1000-Grain Weight

Results of both seasons (Figs. 7 and 8) indicated that both of irrigation treatments and foliar spray interacted with each other significantly for 1000-grain weight (g). Our results revealed that using high levels of ascorbic acid or hydrogen peroxide with full irrigation gave significantly higher 1000-grain weight (42.43 and 40.87g) without significant difference between them in

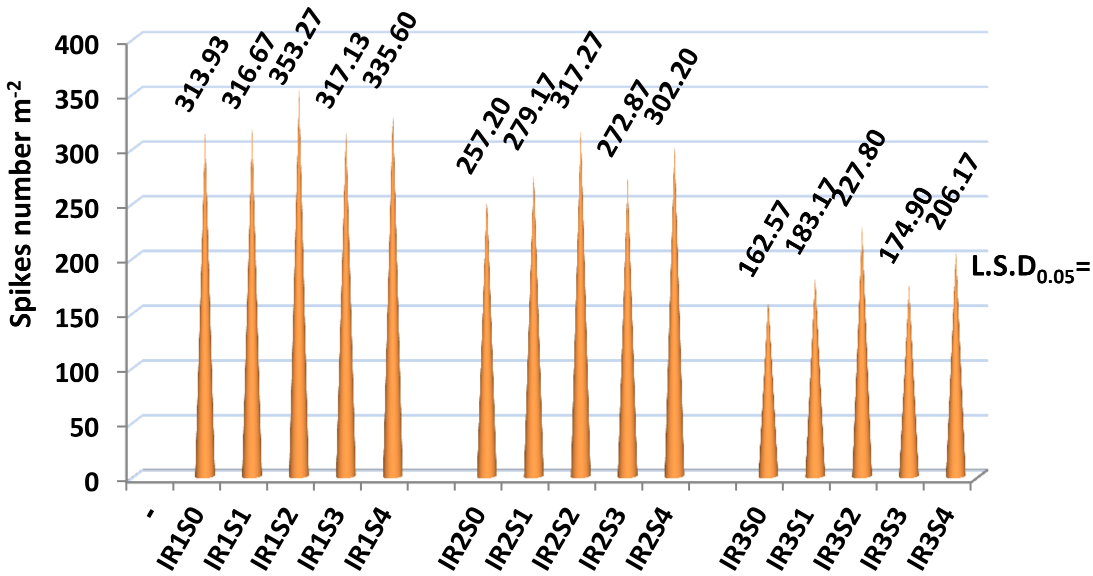

Fig. 5. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Spikes number m^{-2} of wheat at harvest in 2017/18 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2: 200 ppm AsA, S3 : 30 mM H_2O_2, S4: 60 mM H_2O_2

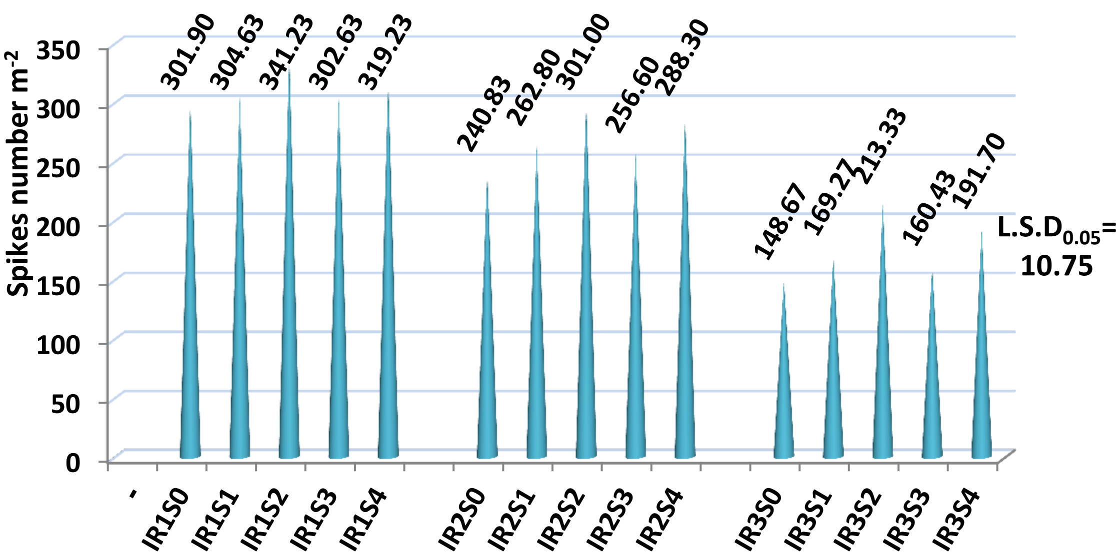

Fig. 6. Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Spikes number m^{-2} of wheat at harvest in 2018/19 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2 : 200 ppm AsA, S3 : 30 mM H_2O_2, S4: 60 mM H_2O_2

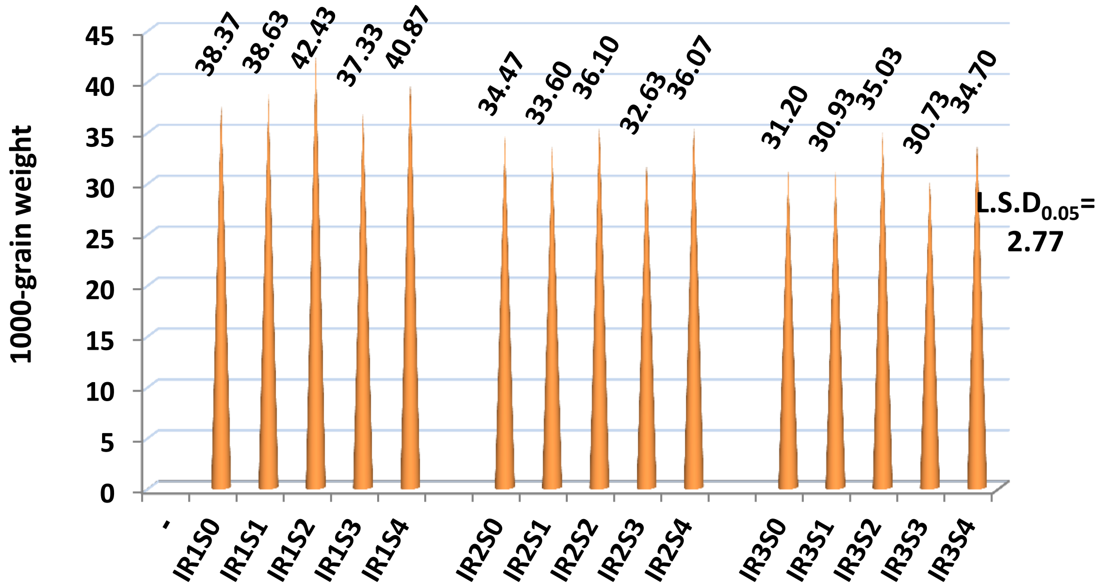

Fig. 7. **Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on 1000-grain weight (g) of wheat at harvest in 2017/18 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100ppm AsA, S2: 200ppm AsA, S3 : 30 mM H_2O_2, S4 : 60 mM H_2O_2**

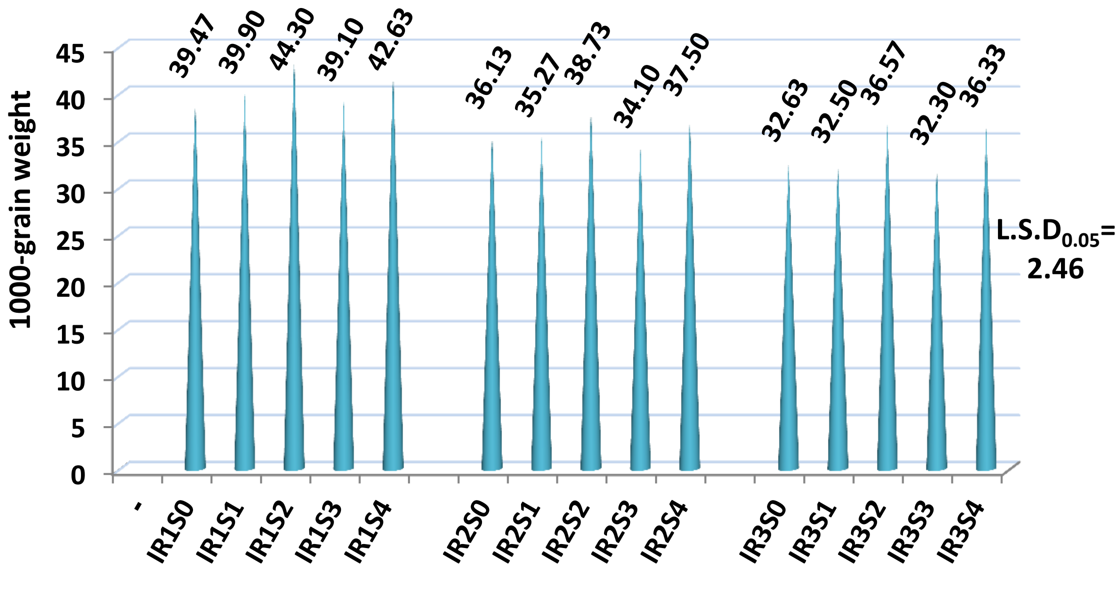

Fig. 8. **Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on 1000-grain weight (g) of wheat at harvest in 2018/19 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2 : 200 ppm AsA, S3 : 30 mM H_2O_2, S4 : 60 mM H_2O_2**

comparison with the other treatments in both seasons, respectively. On the other hand, the lowest 1000-grain weights (31.20, 30.93 and 30.73g) were obtained from the interaction between water stress (4 irrigations) and untreated plants or treated with 100ppm AsA or treated with 30mM H_2O_2 without significant differences among them in first seasons. Also, in the second season, these three interactions gave 32.63, 32.50 and 32.30g without significant differences among them. As average in both seasons, using 200ppm AsA and 60mM H_2O_2 protected approximately 4 g from collapse in weight of 1000 grain under water stress (4 irrigations). It could be concluded that under water stress conditions both of foliar spray of these treatments significantly ameliorated 1000-grain weight compared to untreated plants (spray with water). The obtained results are in agreement with those reported by **Dolatabadian *et al.* (2010), Kotb and Elhamahmy (2013), Yakout et *al*. (2013), Abo-Marzoka *et al.* (2016) and Kotb *et al.* (2021a)**.

Grain Yield (t ha^{-1})

Relative to the interaction between number of irrigations and foliar spray treatments, results of both seasons (Figs. 9 and 10) indicated that both of them interacted with each other significantly for grain yield. The results revealed that using high levels of ascorbic acid and H_2O_2 with full irrigation significantly gave the highest grain yields (6.007 and 5.896 t ha^{-1}) in first season and (6.377 and 6.249 t ha^{-1}) in second one, respectively without significant difference between them. Meanwhile, untreated plant under full irrigation gave 5.669 and 6.026 t ha^{-1} in both seasons, respectively.

In addition, the lowest values of this trait were significantly obtained from the interaction between untreated plants or treated by the lowest levels of foliar spray treatments and water stress (4 irrigations) in both seasons. Under water stress, the foliar application of the two highest levels of H_2O_2 and AsA significantly ameliorated grain yield by approximately 8 to 12% in compared with untreated plants as average the both seasons. As average the two seasons, grain yields were increased by about 345 and 225 kg ha^{-1} in 200ppm AsA and 60mM H_2O_2-treated plants under normal irrigation, respectively. Also, 200ppm AsA and 60mM H_2O_2 treatments protected about 505 and 360 kg ha^{-1} grains from collapse under water stress (irrigated 4 times), respectively (Figs. 9 and 10).

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^3/ha, respectively). Results indicated that, drought caused a reduction in grain yields. However, application of 100 - 200 ppm of AsA significantly alleviated the oxidative stress damage of drought, reflected by improving above grain yield as well as decreasing MDA and protein oxidation, but decreased activity of antioxidative enzymes by about 10-20 %. Consequently, foliar spray of AsA improved productivity and irrigation water use efficiency in wheats. Also, grain yield 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. In the same direction, also, under water deficit, foliar application of several concentrations of ascorbic acid on corn plants 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) and Kotb *et al.*, (2021b)**. 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_2O_2 have regulatory effects on growth, development and quality of plants and improving plant production (**Zhou *et al.*, 2012)**. Also, **Kotb *et al.* (2021a)** studied 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. The interaction between the both studied factors showed that application 60mM H_2O_2 treatment protected about 320 kg/fad., grains from collapse under moderate water stress (3000 m^3/fad). Meanwhile, under severe water stress, treatments by 30mM H_2O_2 protected about 330 kg/fad., grains from lose.

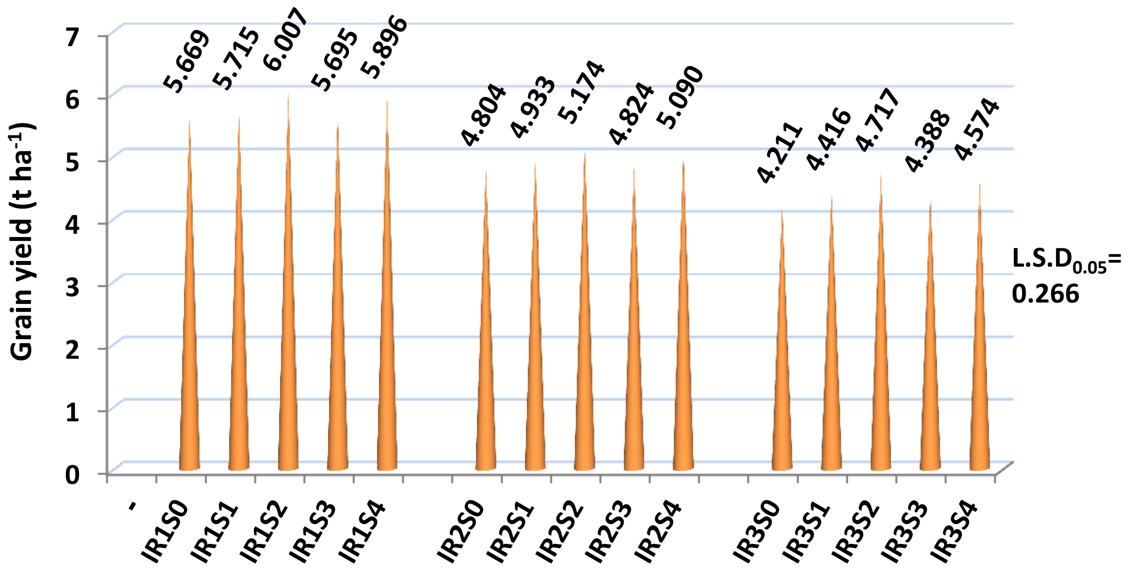

Fig. 9. **Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Grain yield (t ha^{-1}) of wheat at harvest in 2017/18 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2 : 200 ppm AsA, S3 : 30 mM H_2O_2, S4 : 60mM H_2O_2**

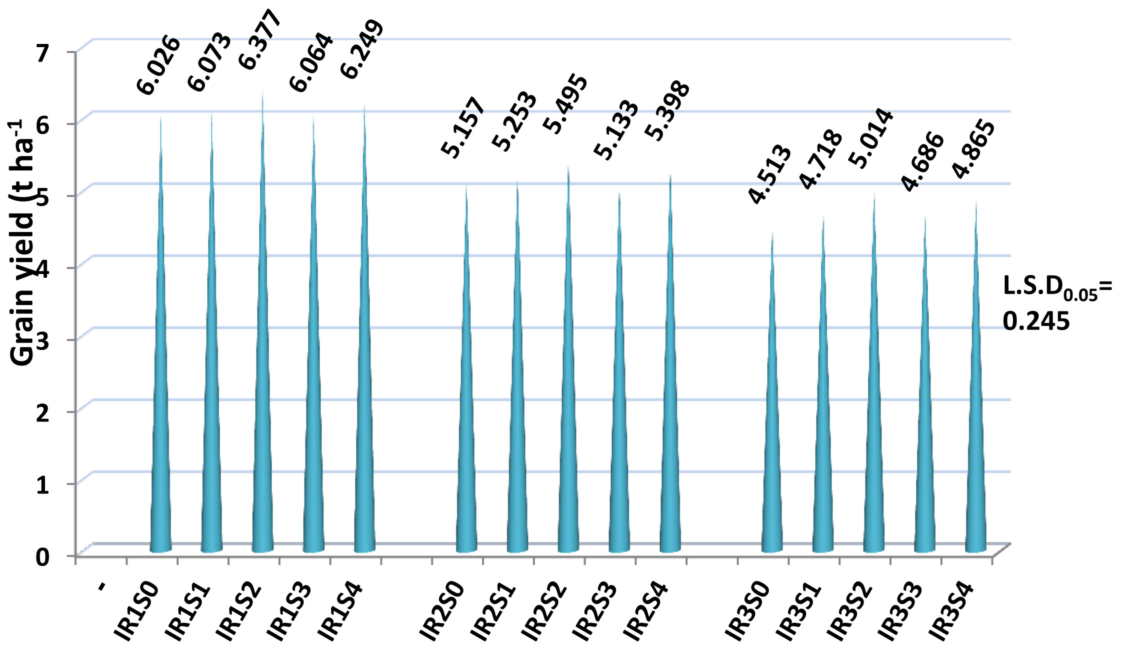

Fig. 10. **Effect of the interaction between number of irrigations (IR) and foliar spray (S) treatments by AsA and H_2O_2 on Grain yield (t ha^{-1}) of wheat at harvest in 2018/19 season. IR1: well-watered (6 irrigations); IR2: (5 irrigations), IR3: (4 irrigations). S0: untreated. Plants, S1: 100 ppm AsA, S2 : 200ppm AsA, S3 : 30 mM H_2O_2, S4 : 60 mM H_2O_2**

Conclusively, from our results, it could be concluded that water stress conditions by decreasing number of irrigations significantly diminished growth analysis and productivity of wheat plants. Meanwhile, foliar application of AsA and H_2O_2 at an appropriate level could promote the growth and increase the yield. In general, the interactions between water stress and levels of ASA and H2O2 were significant, indicating that the use of non-enzymatic antioxidants and hydrogen peroxide played an important role in reducing the harmful effect of water stress and thus improving the growth and productivity of wheat plants under water stress conditions.

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التأثير التفاعلى بين الإجهاد المائي والرش الورقى بحمض الأسكوربيك أو فوق اكسيد الهيدروجين على إنتاجية القمح

ماهر عبد الله قطب – جمال محمد ياقوت – فاطمة سليمان على – محمد جمال عباس

قسم المحاصيل – كلية الزراعة – جامعة قناة السويس –41522 الإسماعيلية – مصر

أجريت تجربتان حقليتان في مزرعة خاصة بمنطقة نبهان، فاقوس، محافظة الشرقية ، مصر خلال الموسم الشتوي لأعوام 2018/2017 و 2019/2018. بهدف دراسة تأثير خمسة مستويات من الرش الورقى لحامض الاسكوربيك وفوق اكسيد الهيدروجين (بدون، 100، 200 جزء فى المليون من حمض الاسكوربيك، 30، 60 ملى مولار من فوق اكسيد الهيدروجين) على القمح صنف مصر1 تحت ثلاثة معاملات للري (اربعة وخمسة وستة ريات) مستخدما نظام الري السطحي. تم استخدام تصميم القطاعات الكاملة العشوائية للقطع المنشقة مرة واحدة فى 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: عند 105 يوم من الزراعة ، أظهرت نباتات القمح تحت الإجهاد المائي (الري أربع مرات) دون استخدام حمض الاسكوربيك وفوق اكسيد الهيدروجين انخفاضًا معنويًا فى دليل مساحة الاوراق ، محتوى الماء النسبى للاوراق، الكلوروفيل الكلي مقارنة بنباتات القمح المروية جيدا في موسمي التجريب بصفة عامة، تم الحصول على أعلى القيم معنوياً لهذه الصفات من التركيز الاعلى لحمض الأسكوربيك (200 جزء في المليون) و 60 ملي مولار من H_2O_2 في موسمي التجريب. في ظل الظروف المجهدة وغير المجهدة للنباتات ، أدت زيادة مستويات حمض الاسكوربيك وفوق اكسيد الهيدروجين إلى تحسين معنوى لهذه الصفات. وعند النضج، في موسمي الدراسة، أدى الري 4 مرات إلى انخفاض عدد السنابل/م^2، وزن 1000 حبة ومحصول الحبوب عن النباتات النامية في الأراضي المروية 6 مرات، وعمومًا تم الحصول على أعلى القيم بمعنوية عالية لهذه الصفات من المستويات الأعلى لحمض الاسكوربيك وفوق اكسيد الهيدروجين في الموسمين. وفي ظل النباتات المجهدة وغير المجهدة، أدت زيادة مستويات حمض الاسكوربيك وفوق اكسيد الهيدروجين إلى تحسين معنوى فى الصفات المدروسة.

المحكمـــون :

1 - أ.د. السيد بيومي جـاب الله أستاذ المحاصيل – كلية التكنولوجيا والتنمية – جامعة الزقازيق.

2- أ.د. صابر عبدالحميد موافي أستاذ المحاصيل – كلية الزراعة – جامعة الزقازيق.