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Agricultural and Physiological Studies on Wheat Crop

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ABSTRACT:

Two field experiments were conducted at the farm of faculty of agriculture Kafr El-Sheikh university during 2019/20 and 2020/21 winter seasons to evaluate the role of spraying proline and abscisic acid to improve tolerance to drought for the two wheat cultivars (Sids 14 and Giza 171). Split plot design were used for each no. of irrigation in both seasons and combined over no. of irrigation and years, in three replicates. The two wheat cultivars were arranged in the main plots. Whereas, spraying treatments (spraying with proline by 10 (PPM), spraying with abscisic acid by 10 (PPM) and control treatment (spraying with distilled water) were allocated in the subplots, it was sprayed in two stages at 35 and 45 days of sowing, and readings were taken at day 55 and 70 and at harvest from the age of the plant. The results showed a significant increase in the values of the yield and yield components represented in plant height (cm), spike length, grain weight/spike, number of grains/spike, weight of 1000 grains, grain yield ton/ha, biological yield ton/ha, straw yield ton/ha and harvest index % by giving full irrigation to wheat plants followed by moderate drought stress. There were significant differences between the tested cultivars (Sids 14, Giza 171) for these traits. In addition, the effect of treatment with abscisic acid and proline in drought conditions was noted to improve the yield and yield components.

Keywords:
Abscisic acid; Drought; Wheat; Proline; Stress.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to family Poaceae. It is the one of the most important cereal crops in the worldwide and the main source of staple food in Egypt and many countries **(Abdelaal *et al.,* 2019)**. To feed the world's growing population, global wheat demand is predicted to rise by 40% by 2050 to meet food security needs. Drought, salinity, and heat stress are the key abiotic restrictions for wheat production because of global climate change, and they severely affect yield and quality through modifying physiological processes **(Yassin *et al*., 2019)**.

Drought is one of the most significant abiotic stress factors, it affects more than half of the Earth's surface area, including the great majority of agricultural land **(Hubbard *et al.,* 2010)**.Drought-related agricultural losses have a huge economic impact, which is expected to worsen as global climate change continues**(Battisti and Naylor, 2009)**. Plants vary greatly in their ability to withstand stress; some are unable to withstand stress and wilt and die (sensitive plants), while others can tolerate stress by regulate certain physiological changes in their tissues, which maintain their cell water potential and turgidity at normal levels (tolerant plants) **(Farooq *et al.,* 2009)**.

Drought stress decrease the growth and productivity of crops in all stages of growth the effects of drought stress on wheat usually stop photosynthesis, increases carbohydrates in sink, decreases grain number and yield, reduces grain filling duration and increase senescence during the flowering stage **(Mohammad *et al.,* 2017)**. Also the production of reactive oxygen species (ROS) which causes the lipid per oxidation and protein denaturation increases was increase under drought stress **(Farooq et *al.,* 2017)**.

Proline is one of the most common suitable osmolytes in drought stressed plants, proline apparently has a specific protective role in the adaptation of plant cells to water deficiency and appears to be the preferred organic osmoticum in many plants, it helps in osmotic adjustment and protection of plasma membrane integrity and acts as a sink of energy or a reducing power, as a source of carbon and nitrogen, and as a hydroxyl radical scavenger, salinity stress may increase activities of proline biosynthetic enzymes and inhibit proline dehydrogenase activity**(Manisha *et al.,* 2013)**.

Abscisic acid (ABA) is a plant hormone that plays an important role in the plant signaling system, allowing the plant to function normally under water stress conditions **(Ma *et al.,* 2008)**. ABA is involved in a variety of physiological processes, including seed dormancy, stomatal closure, storage protein and lipid synthesis, and defence against biotic factors **(Abdelaal, 2015)**. Under drought stress, guard cells produce ABA, which causes stomatal closure **(Lee and Luan, 2012)** and significantly increases the activity of antioxidant enzymes in maize under water stress **(Abdelaal, 2015)**. It was discovered that ABA increases tolerance to chilling stress by increasing superoxide dismutase and guaiacol peroxides activities, as well as related gene expression **(Guo *et al.,* 2012)**. With ABA treatment, the negative effects of drought stress on Pisum sativum are reduced **(Latif, 2014)**. ABA can be used to reduce the negative effects of drought stress and regulate many processes in plants, in addition to biotic and abiotic stress adaptation **(Lim *et al.,* 2015)**.

2. MATERIALS AND METHODS

Two field experiments were conducted at the farm of faculty of agriculture Kafr El-Sheikh University during 2019/20 and 2020/21 winter seasons to evaluate the role of spraying proline and Abscisic acid to improve tolerance to drought for the two wheat cultivars **(Sids 14 and Giza 171)**.

Two field experiments were conducted in which a two-factor randomized complete block design with split, combined over locations and years, same location but randomized each year in three replicates.

The two wheat cultivars were arranged in the main plots. Whereas, spraying treatments (spraying with proline by 10 (PPM), spraying with abscisic acid by 10 (PPM) and control treatment (spraying with distilled water) were allocated in the subplots, it was sprayed in two stages at 35 and 45 days of sowing, and readings were taken at day 55 and 70 and at harvest from the age of the plant. The sub plot size was 12 m2 (4-meter-long x 3 meter wide). The two tested wheat cultivars were planted at a rate of 60 kg/feddan on November 16, and the wheat plant preceded the corn plant in the first and second seasons, respectively. The previous crop was maize in the two seasons. Recommended NP were added at the rate of 110 kg N ha^{-1} as urea and 125 kg P_2O_5 ha^{-1} as superphosphate. Plants were harvested on 6th May 2020 (first season) and 11th May 2021 (second season).

Studied characteristics:

Ten plants were randomly selected from each plot at each growth stage to measure yield and its components features listed below: -

1- Plant height (cm).
2- Grains weight / spike.
3 -number of grain / spikes.
4 -1000 grain weight.
5 -Grains yield per ton.
6- Biological yield / ton.
7 -Harvest index.

3. RESULTS

The interaction between irrigation, cultivar and treatment had a significant effect on plant height (cm) during the combined analysis. it could be observed that, the lowest value of on plant height (cm) (100.97 cm) has resulted from cultivar Giza 171 treated with spray exogenous application proline under severe drought stress followed by without any treatment under the same conditions. At the same time, spray exogenous application abscisic acid with cultivar Sids 14 under moderate drought stress gave the highest value of plant height (cm) (112.90 cm) followed by spray exogenous application proline with cultivar Sids 14 under well water with a significant difference among them table (1).

Also, the interaction between irrigation, cultivar and treatment had not a significant effect on grains weight/spikes (g) during the combined analysis. It could be observed that the that the lowest value of grains weight/spikes (g) (3.18 g) has resulted from cultivar Sids 14 treated with spray exogenous application abscisic acid under severe drought stress whilst the cultivar Giza 171 treated with spray exogenous application proline under moderate drought stress gave the highest value (3.89 ton/ha) of grains weight/spikes (g) with did not significant differences between them as showed as in the same table.

The acquired results that are accessible in the same table demonstrated that number of grains/spikes was significantly affected by the interaction between irrigation, cultivar and treatment during the combined analysis. The second-best treatment were treating spray exogenous application abscisic acid with cultivar Sids 14 under well water (control) which recorded (58.91 grain) whilst the lowest value of number of grains/spikes (40.61 grain) has resulted from spray exogenous application proline with cultivar Giza 171 under severe drought stress followed by without any treatment with cultivar Giza 171 under the same conditions.

In addition to the data which are showed in the same table indicated that, the interaction between irrigation, cultivar and treatment had a significant effect on 1000 grains weight (g) during the combined analysis. It could be observed that the that the lowest value of 1000 grains weight (g) (61.44 g) has resulted from cultivar Giza 171 treated without any treatment under well water whilst the cultivar Giza 171 treated with spray exogenous application proline under severe drought stress gave the highest value (80.52 g) of 1000 grains weight (g) with significant differences between them.

Additionally, it could be observed from the results which are presented in the same table that, there were a significant effect on grains yield (ton/ha) due to the interaction between irrigation, cultivar and treatment during the combined analysis. the best treatment with cultivar Giza 171 was treating spray exogenous applications abscisic acid under well water conditions whereas the lowest grains yield (ton/ha) (5.45 ton/ha) resulted from without any treatment with cultivar Giza 171 under severe drought stress. It was valuable to point out that under severe drought stress conditions grains yield (ton/ha) significantly increased due to treating spray exogenous application abscisic acid and proline by (4.35 % and 9.14 %) respectively with cultivar Giza 171 and by (6.27 % and 13.69 %) respectively with cultivar Sids 14 compared to the plants without any treatment.

The data which are showed in the same table the interaction between the irrigation, cultivar and treatment during the combined analysis. Overall, the combined analysis revealed that the interaction between the irrigation, cultivar and treatment had highly significantly effect of biological yield ton/ha, the lowest biological yield ton/ha (10.65 ton/ha) resulted from treating cultivar Giza 171 treated with spray exogenous application abscisic acid under severe drought stress conditions whereas, the highest biological yield ton/ha (22.37 ton/ha) were produced from the cultivar Giza 171 without any treatment under well water conditions.

Finally, it could be observed from the results which are presented in the same table that, there were a significant effect on harvest index due to the interaction between irrigation, cultivar and treatment during the combined analysis. the best treatment with cultivar Giza 171 was treating spray exogenous applications abscisic acid under severe drought stress followed by cultivar Sids 14 under the same conditions whereas the lowest harvest index (32.31 %) resulted from without any treatment with cultivar Giza 171 under well water. It was valuable to point out that harvest index significantly increased due to treating spray exogenous application abscisic acid and proline by (56.95 % and 27.74 %) respectively with cultivar Giza 171 and by (36.08 % and 13.98 %) respectively with cultivar Sids 14 compared to the plants without any treatment.

Table 1: Means of irrigation, cultivars and treatment interaction different for wheat yield and yield components during the combined analysis

Between irrigation× Cultivars×Treatment			Plant height (cm)	Grains weight / spikes (g)	Numberof Grains /spikes	1000 Grains weight (g)	Grain yield (ton/ha)	Biological yield	Harvest index (%)
irrigation	Cultivars	Treatment							
Well water (control)	Sids 14	Control	104.80	3.85	57.48	67.38	7.37	22.14	34.60
		Proline	112.73	3.49	57.07	61.86	6.73	18.89	37.06
		Abscisic acid	108.88	3.66	58.91	62.08	7.61	17.96	43.58
	Giza 171	Control	110.53	3.69	59.95	61.44	6.73	22.37	32.31
		Proline	109.28	3.46	48.79	71.62	6.84	21.34	34.53
		Abscisic acid	108.32	3.32	50.86	67.67	6.46	19.60	35.48
Moderate drought stress	Sids 14	Control	109.48	3.82	53.30	70.75	5.72	16.73	34.22
		Proline	107.67	3.40	53.25	63.23	6.78	15.92	42.51
		Abscisic acid	112.90	3.43	54.74	63.34	6.89	14.78	46.66
	Giza 171	Control	109.20	3.55	52.49	67.39	6.36	16.52	38.48
		Proline	110.40	3.89	55.56	71.41	6.91	15.92	43.37
		Abscisic acid	109.18	3.58	46.02	73.56	6.65	13.64	48.81
Severe drought stress	Sids 14	Control	104.58	3.32	48.72	67.42	5.50	15.29	36.04
		Proline	104.62	3.39	51.67	69.07	6.25	15.25	41.07
		Abscisic acid	106.25	3.18	47.48	66.49	5.84	12.35	49.04
	Giza 171	Control	101.08	3.40	44.24	76.46	5.45	16.17	34.06
		Proline	100.97	3.33	40.61	80.52	5.94	13.89	43.50
		Abscisic acid	103.12	3.75	51.90	71.69	5.68	10.65	53.45
	F- Test		**	NS	**	**	**	**	**
	LSD 0.05		4.19	-	4.34	4.37	0.46	0.82	3.54
	LSD 0.01		5.88	-	6.09	6.12	0.65	1.15	4.96

NS, * and ** indicated not significant, significant at 0.05 and significant at 0.01 levels of probability, respectively.

4. DISCUSSION

Water deficit stress can reduce yield components by causing reduction in leaf area expansion, which in turn, will lead to reductions in all other yield components in barley **(Abdelaal *et al*., 2018b)**.The greatest reduction was observed in the severe water stress treatment. The low grain weight could have occurred due to the direct effect of water stress on carbohydrate accumulation **(Salwa and Ali, 2014)**. **(Iqbal, 2009)** indicated that water stress affected of wheat plants might lie not only in the variations in physiological processes such as accumulation of osmolytes, antioxidant capacity, stomata l conductance but also in changes in the phytohormonal balance. Yield and its components were increased when the frequency of irrigation increased **(Salwa and Ali, 2014)**. The reduction in photosynthesis under drought stress, which is the most important anabolic process in plants, resulting in reducing the efficiency of all other biological processes in plant which led to reduction of growth and yield **(Salwa and Ali, 2014)**. Delaying irrigation until soil water reached 65% or 80% depletion had the effect of decreasing grain, straw and biological yields. This could have occurred due to loss of yield components. Increasing soil moisture depletion levels decreased the grain yield. The results are in line with those reported by **(Mohammadi *et al*., 2013)**.

There was strong positive correlation of proline accumulation with grain yield and associated traits **(Farooq *et al*., 2017)**. Indeed, cytoplasmic proline accumulation reduces the toxic ion concentration and enhances the water volume in cytosol **(Cayley *et al*., 1992)**, thus causing the osmotic adjustment, which helps plants to withstand stress **(Hayat *et al*., 2012)**. Likewise, proline accumulation ameliorates the cytoplasmic acidosis and maintains the $NADP^+$/ NADPH ratios which are highly compatible with metabolism under stress conditions **(Sharma *et al*., 2011)**. Moreover, rapid proline breakdown upon relief of any stress may provide many reducing agents, which support the oxidative phosphorylation within mitochondria, and also the ATP generation **(Signorelli, 2016)**, and these interventions might be useful for plants when grown under stressful environments. Foliage applied osmoprotectants also improved the stay green of wheat plants under drought stress which was visible through improvement in chlorophyll contents. This better stay green might be due to activation of enzymes, protection of machinery of photosynthesis and metabolic regulation **(Ashraf *et al*., 2002)**, during the drought stress.

ABA, as one of the root signaling substances, played a crucial role in regulating wheat response to water stressed **(Saradadevi *et al*., 2017)**.

Soil drying can induce plant roots to produce a large amount of ABA, which can be transported to the above-ground part along with transpiration of xylem juice **(Parent *et al*., 2009)**. It was mainly responsible for regulating stomatal closure in non-hydraulic root signaling stage, and also can reduce the growth rate of plant canopy **(Ren *et al*., 2007)**.

Other results have also confirmed upward ABA can regulate stomatal guard cells and reduce plant transpiration **(Saradadevi *et al*., 2017)**.

ABA synthesized may interact with other substances in xylem sap to regulate leaf stomatal closure **(Chen *et al*., 2018)**. Exogenous applied ABA increased the leaf ABA content of wheat and promoted the production of nHRS earlier than without ABA treatment **(Kong *et al*., 2021)**. The application of ABA in root irrigation promoted the ABA content in leaves, which resulted in the early closure of stomata in leaves, and thus broadening the threshold range of soil moisture under nHRS.ABA can maintain the leaf water status by increasing the stomatal behavior of the leaves **(Kong *et al*., 2021)**.

Exogenous applied ABA further affects the sensitivity of winter wheat to leaf water content and has a long-term regulatory effect on stomatal behavior of winter wheat, and also affects stomatal response to drought especially after non-hydraulic root-sourced signal (nHRS) stimulation **(Ma *et al.*, 2015)**.Therefore, ABA, as one of the root signaling substances, played a key role in inducing stomatal closure and non-hydraulic root-sourced signal (nHRS) production in winter wheat under water deficit **(Kong et al., 2021)**.

Application of exogenous ABA increased leaf SOD, CAT and POD activities of plants, so as to enhance the ability of scavenging free radicals in plants under water-stressed **(Zhang *et al.*, 2015)**.Drenching the soil with ABA improved SOD, CAT and POD activities compared to without ABA treatment, especially when soil water content (SWC) decreased below 40% Field capacity (FC)(**Kong *et al.*, 2021)**., which inhibited the leaf H_2O_2 concentration of wheat under drought stress. Therefore, ABA can maintain the balance of ROS and antioxidant system **(Kong *et al.*, 2021)**. The results were similar to other experiments conducted in wheat under drought **(Batool *et al.*, 2019)**.

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