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Response of Bread Wheat to Abscisic Acid Under Water Stress

Abstract-*Field experiments were carried out at the Field Crops Research Station of the Agricultural Research Office - Abu Ghraib, during Seasons of 2014-2015 and 2015-2016 to study the effect of four concentrations of abscisic acid (ABA) on some of the physiological characteristics of cultivar bread wheat (Bohooth10) under water stress. The experiments were applied according to randomized complete block design (RCBD) by split plot arrangement with three replicates. Water treatments, which occupied the main plots, included four water irrigation quantities, which were irrigated when depletion 50%, 70% and 40% of available water, in addition to rainy treatment (germination irrigation + rainfed), while ABA seeds soaking concentration, which occupied the sub-plots, were 0, 0.25, 0.50 and 0.75 mg/Lt. The results showed superiority of 50% and 70% treatments in the grain yield character which gave 4.65, 4.82, 4.61 and 4.87 ton/ha for both seasons respectively, while rainy treatment has given higher of proline (5.13 and 7.39) micromole/g and peroxidase (45.77 and 49.14) absorption unit/g for both seasons respectively. Increasing of ABA concentration up to 0.75 mg/Lt lead to raise the relative water content (77.41 and 77.62%), ratio of soluble sugars (15.29 and 15.35)% and grain yield (3.61 and 3.92) ton/ha for both seasons respectively. We can conclude that there was a significant response for ABA concentrations under water stress to improve growth and yield wheat.*

Keywords- *Triticumaestivum L., tolerance, abiotic stress, ABA.*

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1. Introduction

The environmental stress affecting plants can be divided into two main groups , the first group is biotic stress which includes different microorganisms causing diseases (bacteria, fungus and viruses), the second group is called abiotic stress which includes heat, dryness, salinity and high light intensity [1], and water stress is considered the most dangerous among a biotic stress because of its effect on plants growth, development and production in many regions all over the world specially dry and semi-dry regions, as water stress causes different damages for plants such as the irregularity of cells membrane, destroying the protoplasm, dissolving of cells membrane and destroying proteins. It also causes disorder in physiological processes such as photosynthesis, respiration and absorption of water and nutrients [2]. As well, water stress can motivate oxidative stress in plants though increasing of free origins like free oxygen molecule (O^{-2}), hydrogen peroxide (H_2O_2) and hydroxyl origin (OH) which is of high toxicity to cells as they interact directly with cells content causing damage in fatty membrane, damage in nucleic acids DNA and RNA and smashing chlorophyll leading to cell death [3]. Abscisic acid is considered as one of plant growth regulators which play an important role in plants tolerance of different environmental stresses including water stress, through partially closing the gaps, which reduces water loss by transpiration and the plant preserves water content inside it [4]. The results of Boudjabi et al. [5] indicated that the exposure of some genetic installations of wheat to water stress caused a decrease in chlorophyll content. Iqbal et al. [6] confirmed that soaking wheat seeds in abscisic acid before planting in the concentration of 10-6 molar improved plant tolerance to water stress by increasing chlorophyll content. Zareian et al. [7] noted that exposure of wheat plants to water stress reduces water content from 85.44% in full irrigation treatment to 70.53% in water stress treatment. Bano et al. [8] indicated that soaking wheat seeds in abscisic acid before planting in the concentration of 10-6 molar under the effect of water stress increased the water content. In the experiment of Chachar et al. [9] found a significant increase in proline content when genetic structures of wheat exposed to water stress. The results of Yasmeen et al. [10] showed a significant increase in vitamin C content when soil moisture content decreased from 100% to 50% of field capacity. Ardakani et al. [11] noted that water stress resulted in increasing dissoluble sugars in wheat leaves in average of 29.81% in comparison with full irrigation, whereas Naderi et al. [12] found significant increase in peroxide enzyme effectiveness in percentage of 31% during exposure of wheat plants to water stress in comparison with full irrigation. This study aimed at determination of abscisic acid role in helping plants tolerance to water stress conditions and determination of its more appropriate concentration.

2. Materials And Methods

An experiment was conducted at the research station in Agricultural Research Office/Abu-Ghraib during the two winter seasons 2014-2015 and 2015-2016. The Randomized Complete Block Design (RCBD) was applied with three replications bysplit-plot arrangement. The experiment included four water treatments which were I1, I2 and I3 (irrigation when depletion of 50%, 70% and 40% of available water respectively),as well as raining treatment I4 (irrigation + rainfed). Water treatments represented the main plots, whereas treatments of seeds soaking in abscisic acid of (0, 0.25, 0.50 and 0.75) mg/Lt which was coded as C0, C1, C2, and C3 respectively represented the sub-plots. The land of the experiment was plowed and divided into plots of 2×2 m. Each plot consisted of 10 lines; the distance was 20 cm between lines. A space of 2 m was made between main plots as well as between the replications to prevent water leakage between irrigated plots. All treatments except the rainy treatment were covered with transparent polyethylene (planting nylon of 2 mm thickness) to protect them from rain during growth season. The seeds of Bohoth10 genotype were planted in the first season on 26^{th} of Nov. 2014 and planted in the second season at 24^{th} of Nov. 2015 with a seed rate of 120 kg/ha. The experiment was fertilized with urea (N 46%) by 200 kg N/ha added in four parallel installments, first one during planting, the second one after the emergence of four complete leaves, the third one at the emergence of the second node at the stem and the last one at Booting [13]. The plants were harvested when reached full maturity on 6^{th} of May 2015 for the first season and on 29^{th} of April 2016 for the second season. The soil water retention was measured by determination of the relationship between wet stress of soil sample and the moisture content volume at stress of 0, 3, 100, 500, 1000 and 1500 kilopascal, which soil water available was measured by the difference between water moisture volume content at the field capacity and permanent wilt point. Weighting method was used to measure soil moisture content by using okar to get soil samples for two depths (20 and 40 cm), saved in wet aluminum cans, then put in the microwave oven after calibrating of drying period according to the method of Zein [14] of drying samples, then the dry samples were weighted and moisture content was measured according to the formula mentioned by [15]:

$$pw \ = \left(\frac{Mw-Ms}{Ms}\right) 100 \quad (1)$$

Pw = the percentage of weighing moisture.
Mw = the wet soil mass in (g).
Ms = dry soil mass in (g).
The volumetric moisture content was measured according to the following formula:

$$\theta = Pw \times l\, b \quad (2)$$

As:
θ = the moisture content according to volume.
Pw = the moisture content according to weight.
l b = soil apparent density (mega-gram/m).

I. Irrigation Methods

The water was equipped from the well by sub-canal, the irrigation was made by plastic pipes connected to a fixed drainage pump which is equipped with a counter to measure the water added to each experimental unit by liter, equal amount of water was added to all plots during planting according to field capacity to ensure field emergence, after draining 50% of prepared water, the plants were irrigated on depths of 20 and 40 cm. The irrigation water quantities in depth of 20 cm were 78, 55 and 31 L plot for the treatments l1, l2 and l3 respectively, whereas water quantity in the depth of 40 was 156, 110 and 62 L plot for the same treatments respectively. The depth of added water was measured according to to the formula [16]:

$$d = (\theta fc - \theta w) \times D \quad (3)$$

As:
D = depth of added water (mm).
θfc = volumetric moisture at field capacity.
θw= volumetric moisture before irrigation.
D = depth of active total root (cm)

II. Preparation of abscisic acid soaking solution (ABA)

The standard solution was prepared in the laboratory of Field Crop Sciences / College of the Agriculture / University of Baghdad, by dissolving 100 mg of ABA in distilled water with adding 2.5 ml ethyl alcohol at a concentration of 50% as dissolving assistant factor. After melting, the volume was completed to one liter to get a concentration of 100 mg/Lt and prepared the needed concentrations of (0.25, 0.50 and 0.75) mg/Lt to soak seeds for 8 hours [17].

III. The studied characteristics

The following characteristics were measured at the stage of 100% flowering:

- Leaves content of chlorophyll (mg/g wet weight) according to the method of (Linchtenthaler) was mentioned by Zhang and Kirkham [18].
- Relative water content in leaves (%) according to the following formula:

$$R.W.C = \frac{FW-Dw}{TW-Dw}\, x\, 100 \qquad (4)$$

As:

R.W.C. = relative water content.

FW = wet weight (g).

Dw = dry weight (g)

Tw = full weight (g)

- Leaves content of proline (micromole/g wet weight): Proline was measured by applying the method of Bates et al. [19] by taking 0.5 g from plants green tissues (micromole/g) as wet weight.
- Vitamin C content (ascorbic acid) was measured by taking 1 g from leaves according to the method mentioned by Hussain et al. [20].
- The rate of soluble sugars in leaves was measured by taking 2.0 g from leaves according to the method of Joslyn [21].
- The efficiency of peroxidase enzyme (POD) was estimated (absorption unit/g), which was measured by taking 0.5 g from leaves [22].
- Grain yield (ton/ha)

The data was statistically analyzed by Genstat software, and the arithmetic means were compared by using the least significant deference test at a probability level of 5% [23].

3. Results and Discussion

I. Leaves content of chlorophyll

Table 1 indicated an obtained significant effect of irrigation treatments and concentration of soaking seeds in abscisic acid on leave chlorophyll content, but the interaction was not significant between them for both seasons. The irrigation treatment I1 (control) achieved the highest average in this characteristics reached 52.98 and 50.32 mg/g wet weight for the two seasons, respectively, whereas irrigation treatment I4 recorded lowest average reached 45.92 and 45.93 mg/m wet weight be for the two seasons respectively. This decrease in leaves content of chlorophyll may be due to the negative effect of water stress which causes decrease in leaves water content (Next Table 2) which reduced content of chlorophyll because of retraction of photosynthesis process in the leaves that closes its stomata as a result of water lack, which passively effects green plastids growth, thereby reducing chlorophyll. This result agreed with the results of Boudjabi et al. [5] who found a decrease in leaves chlorophyll content by increasing water stress levels on wheat. Increased concentrations of seed soaking in abscisic acid caused increase in leaves chlorophyll content, as concentration C3 gave the highest average of 50.83 and 49.93 mg/g wet weight for both seasons, whereas treatments C0 (without soaking) recorded the lowest average in this character reached 47.52 and 45.96 mg/g wet weight, this may be due to the role of abscisic acid in preserving stains stability and firmness through increasing the activity and effectiveness of antioxidant enzymes. Also, vitamin C, which increased as a result of ABA treatments, (Table 4) protects stains and photosynthesis system from oxidation danger, which happens as a result of ROS types and preserving chlorophyll. This result is consistent with the results of Iqbal et al. [6], who indicated that treating wheat plants with abscisic acid reduced the harmful effect of water stress and caused an increase in chlorophyll content.

II. Relative water content in leaves

The results of Table 2 showed significant differences in this character affected by water stress, concentrations of soaking in abscisic acid in both seasons, and a significant interaction between them for the first season only. Irrigation treatments I1 (control) gave the highest average in this character of 79.56 and 79.09% for both seasons respectively, and an increased ratio of 18.37 and 18.43% compared with irrigation treatment I4 which gave the lowest average of this character reached 67.21 and 66.87% for both seasons, respectively. The relative decrease in water content may be due to the increase of water stress in the soil which caused a lack in plants absorption ability and then reduction in water content of the tissue. These results agreed with the results of Zareian et al. [7] who noted a decrease in relative water content in wheat leaves by increase of water stress. It was found that soaking wheat seeds in abscisic acid caused significant increase in relative water content of leaves, as concentration C3 exceeded in relative water content of leaves reached 77.41 and 77.62% for both seasons respectively, while treatment C0 (without soaking) recorded lowest average of this character reached 72.99 and 72.62% for both seasons respectively. We conclude that treating with abscisic acid under the effect of water stress helps in the regulation of water content through its role in partial blockage of gaps which have a role in preserving water content in the plant by reducing transpiration average and this in turn helps in plant tolerance to water stress conditions. This result agreed with the results of Bano et al. [8] who indicated that treatment with abscisic acid increased the relative water content. A significant interaction was found between the amounts of irrigation water and concentrations of soaking in abscisic acid and the combination of I1C3 gave the highest content of relative water reached 81.08%, whereas plants in treatment I4 and non-soaking treatment C0 gave the lowest average in this character reached 63.90%.

Table 1: Effect of water stress and abscisic acid on Leaves content of chlorophyll (mg/g wet weight) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
2014-2015	I_1 50% of available water (control)	51.25	52.09	54.07	54.53	52.98
	I_2 70% of control treatment	48.20	49.05	52.14	52.58	50.49
	I_3 40% of control treatment	45.96	46.17	48.54	49.18	47.46
	I_4 rain (Germination + rainfed)	44.69	44.79	47.14	47.04	45.91
	Mean	47.52	48.02	50.47	50.83	
	$LSD_{0.05}$	Water stress 3.04		ABA Conc. 1.94		Interaction N.S
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
	I_1 50% of available water (control)	48.06	49.60	51.45	52.17	50.32
	I_2 70% of control treatment	47.26	48.70	51.22	51.93	49.78
	I_3 40% of control treatment	44.29	45.46	47.53	48.54	46.45
	I_4 rain (Germination + rainfed)	44.23	45.30	47.12	47.08	45.93
	Mean	45.96	47.26	49.33	49.93	
	$LSD_{0.05}$	Water stress 0.41		ABA Conc. 0.53		Interaction N.S

Table 2: Effect of water stress and abscisic acid on relative water content (%) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
2014-2015	I_1 50% of available water (control)	77.59	78.90	80.66	81.08	79.56
	I_2 70% of control treatment	77.38	77.77	79.95	79.78	78.72
	I_3 40% of control treatment	73.08	73.62	77.55	76.56	75.20
	I_4 rain (Germination + rainfed)	63.90	65.39	67.32	72.21	67.21
	Mean	72.99	73.92	76.37	77.41	
	$LSD_{0.05}$	Water stress 1.39		ABA Conc. 0.85		Interaction 1.88
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
	I_1 50% of available water (control)	77.18	77.67	80.16	81.37	79.09
	I_2 70% of control treatment	76.87	77.26	79.76	80.84	78.68
	I_3 40% of control treatment	73.08	74.49	77.43	78.36	75.84
	I_4 rain (Germination + rainfed)	63.37	65.03	68.82	69.91	66.78
	Mean	72.62	73.61	76.54	77.62	
	$LSD_{0.05}$	Water stress 0.90		ABA Conc. 0.67		Interaction N.S

III. Leaves content of proline

The results of Table 3 showed that there is a significant effect of irrigation treatments and concentrations of soaking in abscisic acid and the interaction between them in the leaves content of proline for both seasons. A significant increase in leaves content of proline was noted with the decrease of water irrigation amount, as plants in the rainy treatment I4 gave the highest average of proline content in leaves reached 5.13 and 7.39 micromole/g for both seasons respectively, with an increase of 37.90 and 37.61% from control treatment I1 which registered lowest average in this character reached 3.72 and 5.37 micromole/g wet weight for both seasons respectively. Under conditions of water stress plants, tissue may be unable to build protein because of increasing protein dissolves enzymes like proteinase, which causes accumulation of amino acid proline. This result agreed with the results of Chachar et al. [9] who indicated that the increase of proline content in exposed wheat leaves to water stress. The same table also showed an increase in the average of proline content in leaves during soaking of wheat seeds in abscisic acid as it increased from 3.67 and 5.78 micromole/g for treatment C0 to 5.07 and 6.70 micromole/g in treatment C3 for both seasons respectively. This is due to the role of abscisic acid in increasing proline accumulation and thus reducing the negative impact of water stress, as well as being an osmosis regulator, through working on reducing water stress value in leave cells causing water entrance and thus raising plants efficiency to tolerate water stress conditions [24]. These results were similar to the results of Iqbal [17] who indicated that soaking of wheat seeds in abscisic acid increased the accumulation of dissolve materials, especially proline, which has a protective role in wheat plant tolerance of water stress. As for interaction between irrigation and concentrations of soaking in abscisic acid, the combination of rainy treatment I4 with concentration C3 gave the highest average in the character of proline content which reached 5.96 and 7.90 micromole/g for both seasons respectively, whereas the combination I1C0 gave lowest average in this character reached 3.21 and 5.03 micromole/g for both seasons respectively.

Table 3: Effect of water stress and abscisic acid on proline content in leaves (micromole/g) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		0C_0	0.25C_1	0.50C_2	0.75C_3	
2014-2015	I_1 50% of available water (control)	3.21	3.72	3.92	4.05	3.72
	I_2 70% of control treatment	3.63	3.80	4.31	4.92	4.17
	I_3 40% of control treatment	3.78	4.19	4.86	5.36	4.55
	I_4 rain (Germination + rainfed)	4.07	4.95	5.55	5.96	5.13
	Mean	3.67	4.17	4.66	5.07	
	$LSD_{0.05}$	Water stress 0.25		ABA Conc. 0.20		Interaction 0.41
	Irrigation treatments	ABA Concentrations (mg/Lt)				
		0C_0	0.25C_1	0.50C_2	0.75C_3	
2015-2016	I_1 50% of available water (control)	5.03	5.22	5.60	5.64	5.37
	I_2 70% of control treatment	5.11	5.25	5.59	5.62	5.39
	I_3 40% of control treatment	6.21	6.48	7.59	7.62	6.97
	I_4 rain (Germination + rainfed)	6.80	6.99	7.88	7.90	7.39
	Mean	5.78	5.98	6.66	6.70	
	$LSD_{0.05}$	Water stress 0.21		ABA Conc. 0.17		Interaction 0.34

IV. Content of vitamin C in leaves

The results of Table 4 indicated that there was a significant difference in this character affected by irrigation water amounts for both seasons and concentrations of abscisic acid in the second season, while the interaction between the two factors never reached a significance level in both seasons. The content of vitamin C in leaves increased with reducing irrigation water amounts, as the two irrigation treatments I4 and I3 achieved highest average of vitamin C in leaves with insignificant difference between them by 59.99 and 59.80 mg/100 g dry matter in the first season and of 58.63 and 58.67 mg/100 g dry matter in the second season, whereas irrigation treatment I1 (control) gavethe lowest average in this character by 56.67 and 55.50 mg/100 g dry matter for both seasons respectively.

Vitamin C is considered the first protective line against non-enzyme antioxidants and it owns the ability to suppress the effective and harmful oxygen types (ROS) and the reduction of hydrogen peroxide into the water by ascorbic peroxides enzyme [25]. This result agreed with the results obtained of Yasmeen et al. [10], who indicated the increase in vitamin C content in wheat leaves under conditions of water stress. Increasing in ABA concentrations caused increasing in vitamin C concentrations in the second season, but the differences didn’t reach significance limits. ABA concentration (C3) gave the highest average of vitamin C reached to 59.24 mg/100 g dry matter, while treatment C0 (without soaking) gave lowest average in this character by 55.13 mg/100 g dry weight, indicating that treatment of soaking in abscisic acid improved tolerance of water stress through increasing vitamin C content which plays a role in eliminating of effective types of oxygen , as well as the role of abscisic acid in increasing proline content and dissolved sugars which lead to increase of vitamin C.

Table 4: Effect of water stress and abscisic acid on vitamin C content in leaves (mg/100 g) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		0C0	0.25C1	0.50C2	0.75C3	
2014-2015	I1 50% of available water (control)	56.62	56.77	56.58	56.72	56.67
	I2 70% of control treatment	56.97	57.23	56.60	57.17	56.99
	I3 40% of control treatment	59.51	59.73	60.05	59.90	59.80
	I4 rain (Germination + rainfed)	59.91	59.96	59.88	60.22	59.99
	Mean	58.25	58.42	58.28	58.50	
	$LSD_{0.05}$	Water stress 1.59		ABA Conc. N.S		Interaction N.S
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		0C0	0.25C1	0.50C2	0.75C3	
	I1 50% of available water (control)	53.56	54.22	56.61	57.62	55.50
	I2 70% of control treatment	53.93	55.48	58.07	58.67	56.54
	I3 40% of control treatment	56.57	57.49	60.30	60.35	58.67
	I4 rain (Germination + rainfed)	56.47	57.48	60.26	60.32	58.63
	Mean	55.13	56.17	58.81	59.24	
	$LSD_{0.05}$	Water stress 0.36		ABA Conc. 0.37		Interaction N.S

V. Percentage of dissolved sugars

The data of Table 5 indicated a significant effect of water stress and concentrations of soaking in abscisic acid for both seasons. Raining treatment (I4) gave the highest average in dissolve sugar percentage by 16.45 and 15.29% for both seasons respectively, whereas irrigation treatment (I1) gave the lowest average in this character by11.32 and 12.57% for both seasons. Sugar content in tissue cells is useful as considered a means for plant protective and maintaining of water balance under conditions of water stress. This result confirmed what was mentioned by Ardakani et al. [11]. Soaking of wheat seeds in abscisic acid caused increasing in dissolved sugar percentage compared with treatment C0 (without soaking), as the highest average of this character was 15.29 and 15.35% when soaking seeds at Concentrations C3 for both seasons respectively, compared with control treatment C0 (without soaking) which gave lowest average of 12.23 and 13.12% in both seasons respectively. Treatment with abscisic acid increased accumulation of dissolved sugars which in turn increased plants tolerance to water stress through its role in osmosis regulation in cells, as well as the role of abscisic acid in increasing proline acid (Table 3) considered one of the amino acids that have the ability in regulation of osmotic stress in plants tissue and increase cell adaptability for water stress by water suction. This agreed with the results of Iqbal [17], who indicated that soaking seeds in Abscisic acid increased the accumulation of dissolved sugars. The combination of irrigation treatment (I4) and ABA concentration (C3) gave the highest average of this character reached 18.47%, whereas irrigation treatment (I1) and control treatment (C0) gave the lowest average of dissolved sugars of 10.45% for the first season, while no interaction was obtained in the second season.

Table 5: Effect of water stress and abscisic acid on dissolved sugars average in leaves (%) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		0C0	0.25C1	0.50C2	0.75C3	
2014-2015	I1 50% of available water (control)	10.45	10.76	11.75	12.32	11.32
	I2 70% of control treatment	10.85	12.17	12.72	13.49	12.31
	I3 40% of control treatment	13.35	14.66	16.46	16.88	15.34
	I4 rain (Germination + rainfed)	14.28	15.12	17.95	18.47	16.45
	Mean	12.23	13.18	14.72	15.29	
	$LSD_{0.05}$	Water stress 0.64		ABA Conc. 0.50		Interaction 1.01
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		0C0	0.25C1	0.50C2	0.75C3	
	I1 50% of available water (control)	11.22	12.13	13.09	13.85	12.57
	I2 70% of control treatment	12.67	12.99	13.21	13.87	13.18
	I3 40% of control treatment	14.33	14.28	15.64	16.80	15.26
	I4 rain (Germination + rainfed)	14.28	14.32	15.69	16.88	15.29
	Mean	13.12	13.43	14.41	15.35	
	$LSD_{0.05}$	Water stress 0.42		ABA Conc. 0.54		Interaction N.S

VI. Peroxidase enzyme effectiveness

It is noted from Table 6 that water stress and concentrations of ABA showed a significant affect in peroxide enzyme effectiveness for both seasons. The rainy treatment (I4) gave the highest average in this character by 45.77 and 49.14 absorption unit/g for both seasons, respectively. Whereas control treatment (I1) gave the lowest average by 41.88 and 44.42 absorption unit/g, which didn't differ significantly from irrigation treatment (I2) in both seasons. The increase in peroxide enzyme effectiveness can be considered one of defensive means in plants during water stress due to its role in reducing the negative effect of active oxygen combinations (ROS) whose increase its levels when cells exposed to stress conditions. This agreed with what is indicated by some studies that showed increasing in peroxide enzyme effectiveness under water stress conditions [12]. Abscisic acid concentration treatment (C3) gave the highest average in this character of 45.57 and 48.46 absorption unit/g which didn't differ significantly from concentration C2 in the first season whereas the treatment C0 (without soaking) reached lowest average in this character of 40.99 and 44.61 absorption unit/g. The increase of the peroxide enzyme levels under abscisic acid treatments may be due to the reduction in the harmful effect of ROS on plants under water stress. This agreed with the results of Iqbal [17], who mentioned that soaking seeds in abscisic acid increased peroxide enzyme effectiveness under water stress conditions.

Table 6. Effect of water stress and abscisic acid on average of peroxide enzymes effectiveness (absorption unit/g) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
2014-2015	I_1 50% of available water (control)	39.47	40.87	43.27	43.90	41.88
	I_2 70% of control treatment	39.23	41.30	43.17	45.10	42.20
	I_3 40% of control treatment	42.07	44.40	45.17	45.93	44.39
	I_4 rain (Germination + rainfed)	43.20	45.27	47.27	47.33	45.77
	Mean	40.99	42.96	44.72	45.57	
	$LSD_{0.05}$	Water stress 1.22		ABA Conc. 1.77		Interaction N.S
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
	I_1 50% of available water (control)	42.28	43.10	45.84	46.45	44.42
	I_2 70% of control treatment	43.01	43.84	46.04	47.28	45.04
	I_3 40% of control treatment	45.90	46.77	48.08	49.33	47.52
	I_4 rain (Germination + rainfed)	47.25	48.44	50.10	50.76	49.14
	Mean	44.61	45.54	47.52	48.46	
	$LSD_{0.05}$	Water stress 0.90		ABA Conc. 0.81		Interaction N.S

VII. Grain yield

The data of Table 7 indicated a significant effect of water stress and concentrations of soaking in abscisic acid in grain yield character for both seasons and their interaction during the second seasons only. The effect of the two irrigation treatments I1 (control) and I2 (70% from control treatment) were similar in grain yield, that gave the highest average of grain yield by 4.65 and 4.61 ton/ha in the first season and 4.82 and 4.87 ton/ha in the second season, whereas water irrigation (I4) gave the lowest average in grain yield by 1.52 and 2.26 ton/ha for both seasons respectively. The decrease in grain yield under reduction of irrigation water amounts may be due to the decrease in one or more of yield components. These results agreed with the results of Chachar et al. [7] found a decrease in wheat grain yield when the crop is exposed to water stress. Concentration treatment C3 exceeded other concentrations in the grain yield, when it gave 3.61 and 3.92 ton/ha for both seasons, whereas control treatment (C0) recorded the lowest average in this character by 3.41 and 3.14 ton/ha for both seasons respectively. This may be due to the increase in a number of spikes and weight of 1000 grain, these results agreed with the results of Iqbal [17] who indicated that treatment with abscisic acid caused an increase in wheat grain yield. The combination of irrigation treatment I2 with soaking seeds in abscisic acid in concentration C3 gave the highest average in grain yield by 5.06 ton/ha whereas the combination of I4 and C0 gave lowest average in this character by 1.95 ton/ha in the second season. In the second season, there was no effect of interaction on grain yield.

We can conclude that soaking in abscisic acid with a concentration of 0.75 mg/Lt caused increasing in tolerance of wheat to water stress conditions through improving physiological characteristics, so we recommend soaking wheat seeds with abscisic acid at a concentration of 0.75 mg/ Lt.

Table 7: Effect of water stress and abscisic acid on grain yield average (ton/ha) for seasons 2014-2015 and 2015-2016

Season	Water stress	ABA Conc. (mg/Lt)				Means
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
2014-2015	I_1 50% of available water (control)	4.50	4.62	4.66	4.83	4.65
	I_2 70% of control treatment	4.42	4.58	4.64	4.80	4.61
	I_3 40% of control treatment	2.41	2.48	2.70	2.93	2.63
	I_4 rain (Germination + rainfed)	1.25	1.30	1.66	1.88	1.52
	Mean	3.14	3.24	3.41	3.61	
	$LSD_{0.05}$	Water stress 0.15		ABA Conc. 0.14		Interaction N.S
2015-2016	Irrigation treatments	ABA Concentrations (mg/Lt)				
		$0C_0$	$0.25C_1$	$0.50C_2$	$0.75C_3$	
	I_1 50% of available water (control)	4.60	4.74	4.94	5.00	4.82
	I_2 70% of control treatment	4.72	4.81	4.90	5.06	4.87
	I_3 40% of control treatment	2.38	2.64	2.78	3.03	2.71
	I_4 rain (Germination + rainfed)	1.93	2.15	2.38	2.60	2.26
	Mean	3.41	3.59	3.75	3.92	
	$LSD_{0.05}$	Water stress 0.06		ABA Conc. 0.07		Interaction 0.13

References

[1] C.E. Vickers, J.Gershenzon, M.T. Lerdau and F. Loreto, "A unified mechanism of action for volatile isoprenoids in plant abiotic stress," Nature Chem. Biol. 5: 283-291. 2009.

[2] S.T. Ahmad and R. Haddad, "Study of silicon effects on antioxidant enzyme activities and osmotic adjustment of wheat under drought stress," Czech J. Gen .Pl. 47, 1, 17-27. 2011.

[3] I. M. Moller, P. E. Jensen and A. Hansson, "Oxidative modifications to cellular components in plants," Ann. Rev. Plant, Bio., 58, 459-481. 2007.

[4] H.S. Al-Disooki, "Fundamentals of plant physiology," Jasirat Al-Ward Library. Al-Mansoora, The Egyptian Arabic Republic. pp 438. 2008.

[5] S. Boudjabi, M. Kribaa and H. Chenchouni, "Growth, physiology and yield of durum wheat (*Triticum durum* L.) treated with sewage sludge under water stress conditions," EXCLI J. 14: 320-334. 2015.

[6] S. Iqbal, A.Bano, and N. Ilyas, "Drought and abscisic acid (ABA) induced changes in protein and pigment contents of four wheat (*Triticumaestivum* L.) Accessions," J. Agric. Res. 48, 1, 1-13. 2010.

[7] A. Zareian, H.H.S. Abad and A. Hamidi, "Yield, yield components and some physiological traits of three wheat (*Triticumaestivum* L.) cultivars under drought stress and potassium foliar application treatments." Inter. J. Bio. 4, 5, 168-175. 2014.

[8] A. Bano, F. Ullah and A. Nosheen, "Role of abscisic acid and drought stress on the activities of antioxidant enzymes in wheat," Plant, Soil, Environ. 58, 4, 181-185. 2012.

[9] M.H. Chachar, N.A. Chachar, Q. Chachar, S.M. Mujtaba, S. C. Chachar and Z.Chachar, "Physiological characterization of six wheat genotypes for drought tolerance." Inter. J. Res. 4, 2, 184-196. 2016.

[10] A. Yasmeen, S. M. Basra, A. Wahid, F. Farooq, W. Nouman, H.Rehman and N. Hussain, "Improving drought resistance in wheat (*Triticumaestivum* L.) by exogenous application of growth enhancers." Inter. J. Agri. Bio. 15, 6, 1307-1312. 2013.

[11] M.R. Ardakani, R.A. Nejad, F. Moradi and F. Najafi, "Abscisic acid and cytokine induced osmotic and antioxidant regulation in two drought-tolerant and drought-sensitive cultivars of wheat during grain filling under water deficit in field conditions." Not. Sci. Biol. 6, 3, 354-362. 2014.

[12] R. Naderi, M. Valizadeh, M. Toorchi and M. R. Shakiba, "Antioxidant enzyme changes in response to osmotic stress in wheat (*Triticumaestivum* L.) seedling," Act. Bio. Szeg. 58, 2, 95-101. 2014.

[13] K.A. Jadoa, "Wheat facts and instructions," General Commission of Agric. Extension and Cooperation. Ministry of Agric. 1995.

[14] A.M.K. Zein, "Rapid determination of soil moisture content by the microwave oven drying method," Sud. Engi. Soc. J. 48, 40, 43-54. 2002.

[15] D. Hillel, "Application of Soil Physics," Acad. Press, Inc. New York. p. 116-126. 1980.

[16] V.A. Kovda, C. Vanden Berg and R.M. Hangun, "Drainage and Salinity," FAO. UNE Co. London. 1973.

[17] S. Iqbal, "Physiology of Wheat (*Triticumaestivum* L.) Accessions and the Role of Phytohormones under Water Stress," Ph.D. Dissertation. Faculty of Biological Sci. Qua-I-Azam Univ. Isla. pp. 210. 2009.

[18] J. Zhang and M. B. Kirkham, "Antioxidant responses to drought in sunflower and sorghum seedling," New Phytol, 132, 361- 373. 1996.

[19] L. S. Bates, R. P. Waldes and T. D. Teare, "Rapid determination of free prolin for water stress studies," Plant, Soil, 39, 205-207. 1973.

[20] I. Hussain, L. Khan, M. A. Khan, F.U. Khan, S. Ayaz and F.U. Khan, "UV Spectrophotometric analysis profile of ascorbic acid in medicinal plants of Pakistan," World Appl. Sci. J. 9, 7, 800-803. 2010.

[21] M.A. Joslyn, "Methods in Food Analysis, Physical, Chemical and Instrumental Methods of Analysis," Acad. Press, New. Lon. 1970.

[22] M. Nezih, "The proxidase enzyme activity of some vegetables and its resistance to heat," Food Agric. 36, 877-880. 1985.

[23] G.D. Steeland J.H. Torrie, "Principles and Procedures of Statistics," McGraw. Hill Book Co., Inc. New York. 1980.

[24] M.H. Idrees, "Plant Physiology," Plant Encyclopedia-Susan Mubarak Exploration Scientific Center in Cairo, Egypt .part 2. pp. 50, 2009.

[25] P.L. Gratao, A. Polle, P.J. Lea and R.A. Azevedo, "Making the life of heavy metal-stressed plants a little easier," Func. Plant. Biol. 32 481-494. 2005.