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Integrated Application of Proline or Potassium in Alleviating the Adverse Effects of Irrigation Interval on Wheat Plants

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ABSTRACT

Drought stress is one of the most harmful factors of plant growth and productivity. Two pot experiments were carried out at greenhouse of agriculture botany department, faculty of agriculture, zagazig university, Sharkya Governorate, Egypt, during two successive winter seasons (2014/2015 and 2015/2016), to study the role of proline or potassium in mitigation the harmful impact of drought stress conditions on wheat plants c.v Misr 2 grown in Egypt. Growth parameters, yield and biochemical constituents were evaluated.Results show that all plant growth characters studied (shoot dry weight, leaf area and plant height) as well as yield and its components *(*dry weight of grains /plant, number of spikes/plant, number of grains/plant, number of grains/ spike, and1000-grains weight) were decreased with increasing irrigation intervals (irrigation every 10, 20 and 30 days) during the two successive growing seasons.The most effective treatment was Irrigation every 30 days in decreasing yield and its components. Integrated application of proline or potassium at rate of 0.1 and 0.2 % alleviated these negative effects by enhancing the growth and productivity. However, these increases were less than the control treatment. Moreover, it was found that drought stress decreased RWC, ELWR, RWL, photosynthetic pigments contents, whilst increasing, total phenol, proline as well as peroxidase and catalase activities in the leaves of wheat plants during the two growing seasons. However, application of proline or potassium increased all these parameters and decreasing total phenols. Treatment of proline at rate of 0.2 % was the most effective in this respect. It is recommended that application of proline or potassium can fully or partially counteract the adverse effect of drought stress on growth, and productivity of wheat plants through their effects on biochemical constituents

Keywords : Wheat, Irrigation intervals , Adverse effcet, Proline , Potassium ,Drought stress.Abb. :RWC; Relative Water Content. ELWR; Excised Leaf water retention. RWL; Relative Water Loss

INTRODUCTION

The most important cereal crops indented to poaceae as wheat *Triticum aestivum*. It is a stable diet for the world population and contributes more calories and protein to the world diet more than other cereal crop. It is grown on roughly 200 million hectares with production average of 600 million tons (Rajaram and Braun, 2006). The cultivated area of wheat in Egypt is about 3.4 million fedan with an average production of 9.4 million tons (Anonymous, 2017).

The abiotic stress as drought, which negatively affects performances of crop plants. Under drought, many crop plants are dehydrated and died. Drought stress significantly decreased growth and crop productivity. However, in certain tolerant/ adaptable crop plants morphological and metabolic changes happen in reaction to drought stress, which participate towards adaptation to such inescapable environmental constraints (Sinha *et al*., 1982; Blum, 1996). Through crop plants, wheat (*Triticum aestivum*), is one of the most important crops to study its behavior under water stress conditions due to the presence of natural genetic differences associated with resistance to water (Loggini *et al*., 1999). Drought not only affects the water relations of the plant through limiting water content and turgor, but it also causes stomatal closure which limiting gaseous exchange, reduces transpiration and stopping, carbon assimilation (photosynthesis) rates (Razak *et al*., 2013). During limiting water conditions, photosynthesis is an important plant food making organelles that function is repressed. Decreased the availability of CO_2, change in photochemical activity, photosynthesis and metabolism (Tang *et al*., 2002, Flexas *et al*., 2004). Plants exposed to water stress in field has decreased CO_2 uptake (Chaves, 2002). Free radical processes are activated during water stress condition that has significant possibility to decline photosynthesis, proteins and other plant metabolites. Plants have inbuilt mechanism to reduce drought stress harm through diminishing plant growth (Mitchell *et al*., 1998). Drought stress positively leads to oxidative stress in the plant cell due to higher leakage of electrons towards O_2 during respiratory processes and photosynthetic leading to increase in producing of reactive oxygen species (ROS) (Asada, 1999). The ROS such as H_2O_2, O_2^- and OH radicals, can attack directly membrane lipids, inactivate metabolic enzymes and damage the nucleic acids leading to cell death (Mittler, 2002). Under normal conditions, the balance between ROS production and exhaustion is controlled by antioxidant enzymes system (Noctor and Foyer, 1998). This includes superoxide dismutase, catalase, ascorbate peroxidase, peroxidases and glutathione reductase which provides an active protection against deadly ROS in all the sub-cellular organelles of the plant cell (M¨oller, 2001). Nowadays, a few numbers of materials are used to alleviate the water stress effects in plants. Some of these products that potentially improve water stress tolerance are inorganic or organic substance. Heuer, (1994) show that in many crops under conditions of environmental stresses, proline accumulate as compatible solutes, it plays an important role in osmotic adjustment. Proline plays a major role in osmotic adjustment in many different organisms including higher plants (Hasegawa *et al*., 2000) to enhanced their drought tolerance. Therefore, to increased plant productivity under water stress condition there is an alternative or additional approach which is exogenous application of Proline (Makale *et al*., 1996). Potassium has role in enhancing resistance of drought to harmful environmental conditions. Potassium (K) deficiency is important to soil fertility constraints in increasing world food production. (Srinivasarao *et al.,* 2009).

Maathuis and Sanders, (1996) reported that the major plant macro-nutrient as potassium plays role of stomatal behavior, activity of enzymes, osmoregulation, cell expansion (Elumalai *et al*., 2002). Toxicity of Na^+

due to its ability to compete with K^+ for binding site essential for cellular function (Bhandal and Malik, 1988). Also, high Na^+/K^+ ratios and/or high levels of Na^+ can damage many reactions of enzymes in the cytoplasm (Blaha *et al*., 2000). In fact, for many species high K^+/Na^+ ratio is important than simply maintaining some low levels of Na^+ and related to stress resistance (Cuin *et al*., 2003). Application of potassium decreased the adverse effect of water stress through its role in plants as stomatal movement and closure, photosynthesis, protein synthesis, and water relations *i.e.* turgor regulation and osmotic adjustment (Marschner 1995).

Therefore, this study aimed to investigate the adverse effect of water stress on growth, physio-biochemical traits, water relations, endogenous proline, enzymatic antioxidants and yield and its components of wheat plants c.v. Misr 2 and to clarify the ameliorative effects of exogenously application whether proline or potassium on these criteria.

MATRIALS AND METHODS

Two pot experiments were conducted during the two successive winter seasons (2014/2015 and 2015/2016) at agriculture botany department, faculty of agriculture, zagazig university, Sharkya Governorate, Egypt.

1. Growth conditions, experimental design and treatments:

Healthy wheat (*Triticum aestivum* L., cv. Misr 2) grains were obtained from Wheat Research Section, Agronomy Research Institute, Agriculture Research Centre, Giza, Egypt. The grains were sterilized by using 1% (v/v) sodium hypochlorite for 2 minutes washed with distilled water, and sown on the 20th of November for both seasons. In plastic pots (30 cm inner diameter and filled with 10 kg of air dried clayey soil. Physical and chemical properties of the tested soil were determined according to Page *et al*. (1982) and presented in Table (1).

Table 1. Physical and chemical properties of the investigated soil

Mechanical analyses			Chemical analyses										
Coarse Sand%	Silt %	Clay %	Cations mg/100g soil				Anions mg/100g soil				E. Ca^+ 25c ds/m (mmhos/cm)	PH Soil Reaction	WHC
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO3^-$	$HCO3^-$	Cl^-	$SO4^{--}$			
44.60	27.32	28.08	2.78	1.65	2.45	0.1	0.00	0.5	1.20	5.36	2.91	7.31	33.56

Three levels of water stress as irrigation intervals were examined, including irrigation every 10 days as a control, and two irrigation every 20 days and 30 days. Proline or potassium (Solupotasse K_2O 50.9% from products of the Belgian company Sndrolo) each at rate of 0.1 and 0.2 % was applied as foliar spray treatments. Ten grains per pot were sown. Two weeks after sowing, seedlings were thinned to three plants per pot. Nitrogen was added as ammonium sulphate (20.5% N) at a rate of 50 mg kg^{-1} soil in three equal doses. The first addition was done before the 1st irrigation, while the second and third doses were after 30 and 40 days later. The doses recommended by ministry of agriculture, Egypt, for all experimental treatments of phosphorus and potassium were added as ordinary super phosphate (6.5% P) and potassium sulphate (41.0% K), respectively at rates of 15 mg P and 40 mg K kg^{-1} soil before sowing. The amount of potassium found in Solupotasse was calculated and added as a foliar spray for plants. The experiments were arranged in a factorial system design. Spraying till dripping with took place three times at 25,40 and 55 days from sowing using hand atomizer and with few drops of Tween- 20 as a wetting agent" (0.05 %).

2. Growth characteristics measurements:

Sample was taken at random at 65 days old (botting stage) during each growing season to record growth parameters and physiological properties. Plant height (cm) and leaf area (cm^2) were measured. Shoot samples for dry weight were dried on 70°C for 48 h or till a constant weight and weighted.

3. Physiological characters:

Relative Water Content (RWC) as described by Barrs and Weatherley (1962) was estimated by using the following formula.

$$\mathbf{RWC = [\ (FW - DW)/\ (TW - DW)]\ x\ 100.}$$

where, DW: dry weight at 80 °C, FW: fresh weight, TW, turgid weight.

Four new leaves were collected and weighed (FW) then left for 4 h to wilt at 25°C and reweighed (WW4h). Excised Leaf water retention (ELWR) was calculated using the following formula according to Farshadfar *et al*. (2002).

$$\mathbf{ELWR = [1 - (FW - WW4h)/FW] \times 100}$$

Relative Water Loss (RWL was calculated using the following equation according to Gavuzzi *et al*. (1997).

$$\mathbf{RWL = [(FW - WW4h)/\ (FW - DW)]\ x\ 100.}$$

Chlorophyll a, b and carotenoids were extracted from fresh leaf sample (Fadeel, 1962). and estimated using the formula adapted by (Wettestein 1957).

Photochemical activity in fresh leaves of wheat plants were determined according to Jagendorf (1956) and modified by Avron (1960) using Ferricyanide.

Estimation of Free, bound and total phenols in fresh leaves by using the colorimetric method described by Snell and Snell (1953).

As for antioxidant enzymes measurements:

Thomas *et al.* (1982) method was used to estimate the activity of peroxidase (POD). Catalase (CAT) was assayed spectro-photo-chemically according to Chance and Maehly (1955).

Proline concentration was estimated according to the method given by Bates *et al*. (1973).

4. Yield and its components:

At harvesting, number of spikes/plant, number of grains/ spike, number of grains/plant, dry weight of grains /plant (g) and1000-grain weight (g) was determined.

Statistical analysis:

The data of all experiments were analysed statistically using analysis of variance according to Gomez and Gomez, (1984). Combined analysis of data of the two seasons (2014/2015 and 2015/2016) was conducted, the treatment means were compared using the least significant differences (LSD)

RESULTS AND DISCUSSION

Growth characters and water relations:

Table (2) shows control plants had highest values of plant height (cm), leaf area (cm^2), shoot dry weight (g), RWC, ELWR and RWL during botting stage comparing to the other two water irrigation intervals (every 20 days and 30 days). Drought stress significantly reduced the plant height, leaf area, dry weight of shoot. These results hold true at both two seasons. The reduction of dry weight due to water stress might be attributed with the reduction in plant height as well as No. of leaves and tillers. In present study, Relative water content (RWC) was determined to give indication on the plant water status under drought condition. RWC was reduce by water stress applied at botting stage of wheat cultivar Misr 2. The highest RWC was reduced in the plant grown under normal condition (10 days) and the minimum was detected in sever condition (30 days). Excised leaf water retention (ELWR) and relative water loss (RWL) significantly reduced an increase in water irrigation intervals.

These observations are in full agreement with the finding of Mirbahar *et.al.,* (2009) who found that water stress significantly reduced growth characters and cell division. Several changes inside the cell, including synthesis of molecular chaperones, changes in levels of gene expression, and enzymic activity involved in the production and removal of ROS as a consequence of drought stress (Mahajan and Tuteja, 2005). Siddique *et al.* (2000) reported that plants lose their turgor and thus cell expansion and growth are reduced, under water stress conditions, there was a positive relation between photosynthetic rate and RWC. In this connection, Akram, (2011) indicated that increasing yield and yield components were associated with high value of RWC. Progressively, Leaf size, stems extension and root proliferation, water-use efficiency reduces, and plant water relations disturbs by drought stress. (Anjum, *et. Al.* 2011). (Hussain *et al.,* 2008) added that drought caused weakened mitosis; cell elongation and expansion

Table 2. Effect of water irrigation intervals and potassium or proline as well as their interactions on water relations measurements and growth parameters of wheat plant during the two growing seasons 2014 /2015 and 2015/2016.

Characters		Plant height (cm)		Leaf area (cm^2)		Dry weight of shoot (g)		RWC		ELWR		RWL	
Treatments		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Effect of water irrigation intervals													
10 days(cont.)		75.00	72.37	31.00	29.22	5.46	5.15	75.43	75.84	76.15	75.22	93.37	90.62
20 days		66.27	62.50	23.48	24.71	4.09	4.05	69.07	68.25	68.62	72.10	76.94	79.59
30 days		58.90	59.53	17.40	17.84	3.15	3.00	62.61	57.55	50.99	56.05	59.94	54.57
L.S.D. (0.05)		6.44	3.82	3.60	5.45	0.58	0.83	8.54	5.49	4.98	3.74	14.54	15.20
Effect of foliar spray with Potassium or Proline													
Distilled water		59.72	58.72	22.18	20.98	3.81	3.75	66.98	62.13	57.01	61.87	67.02	69.33
Potassium 0.1%		63.67	62.72	23.15	22.19	4.02	3.92	67.63	65.86	62.87	65.16	71.42	73.01
Potassium 0.2%		65.94	63.78	23.61	24.34	4.14	4.12	68.59	67.29	65.74	69.25	77.61	76.37
Proline 0.1%		71.50	68.44	24.52	24.53	4.52	4.15	70.33	69.98	68.29	71.20	81.18	77.57
Proline 0.2%		72.78	70.33	26.33	27.57	4.68	4.38	71.67	70.80	72.38	71.47	86.52	78.38
L.S.D. (0.05)		5.09	4.55	3.36	4.10	1.00	1.21	6.41	4.31	6.71	4.20	12.18	11.67
irrigation intervals	Foliar spray						Interaction Effect						
10 days (cont.)	Distilled water	71.83	70.33	28.73	24.61	4.87	5.08	72.55	74.32	73.62	74.02	86.70	84.68
	K 0.1%	70.17	70.17	29.71	26.20	5.39	5.12	73.69	74.87	75.11	74.04	87.40	85.76
	K 0.2%	72.00	70.67	30.54	30.61	5.50	5.12	74.20	75.02	75.75	74.16	95.36	92.56
	Pr 0.1%	80.17	73.67	31.46	31.09	5.72	5.17	78.18	77.14	77.16	76.66	98.11	94.10
	Pr 0.2%	80.83	77.00	34.54	33.58	5.82	5.23	78.55	77.85	79.13	77.19	99.26	96.01
20 days	Distilled water	55.33	54.50	22.42	22.32	3.70	3.59	67.35	62.24	65.22	67.41	62.57	77.39
	K 0.1%	67.50	60.50	23.04	24.01	3.76	3.94	67.71	65.19	65.61	71.95	73.79	79.65
	K 0.2%	67.00	62.83	23.65	24.30	3.86	4.06	68.43	67.53	68.22	73.57	80.82	79.72
	Pr 0.1%	70.67	67.00	24.09	24.35	4.55	4.25	69.64	72.47	70.54	73.66	81.14	80.51
	Pr 0.2%	70.83	67.67	24.18	28.55	4.59	4.39	72.24	73.84	73.52	73.93	86.38	80.70
30 days	Distilled water	52.00	51.33	15.40	16.02	2.85	2.58	61.04	49.84	32.19	44.18	51.79	45.91
	K 0.1%	53.33	57.50	16.71	16.37	2.90	2.70	61.48	57.52	47.88	49.50	53.07	53.61
	K 0.2%	58.83	57.83	16.63	18.10	3.07	3.17	63.15	59.32	53.23	60.02	56.65	56.82
	Pr 0.1%	63.67	64.67	18.00	18.14	3.29	3.02	63.17	60.33	57.16	63.27	64.29	58.09
	Pr 0.2%	66.67	66.33	20.27	20.59	3.62	3.52	64.21	60.72	64.48	63.30	73.92	58.43
L.S.D. (0.05)		10.09	7.96	6.27	8.28	1.65	2.04	12.97	8.56	11.47	7.45	23.60	23.39

RWC: Relative Water Content, ELWR: Leaf water retention, RWL: Relative Water Loss

Concerning the effect of proline or potassium on plant growth characters, the results in Table (2) show significant increases in plant height, leaf area, shoot dry weight , RWC, ELWR and RWL as a result of spraying wheat plants with proline or potassium (at rate of 0.1 and 0.2 %), the trend was true for wheat plant c.v. Misr 2 during botting stage in the two growing seasons. Under drought stress conditions, the critical roles of proline have been actively researched to understand the tolerance of plants to dehydration. (Reddy *et al.,* 2004).

Proline is an amino acid and compatible solutes and plays a crucial major role in osmoregulation and osmotolerance (Helaly *et al.* 2017). They added that it protects membranes and proteins against the destabilizing effects of dehydration and under stress conditions, it has some ability to scavenge free radicals generated (Ashraf and Foolad 2007). Potassium as plant macro-nutrient plays an important role related to decline the harmful effect of drought stress through its role of cell expansion, closure, behavior and movement of stomata. (Elumalai *et al.,* 2002) and water relations as osmotic adjustment and turgor regulation in plants (Marschner 1995). K-fed plants maintained higher leaf water potential, lower osmotic potential and RWC and turgor potential as compared to untreated plants of wheat (Pier and Berkowitz 1987). Cackmark (2002) showed that production of oxygen radicals generates by the activity of NADPH oxidase, could alleviated by K supply. He suggested that potassium is a very important cation for multiple roles in plant growth and metabolism. In various physiological processes, potassium plays a vital role such as meristematic growth, cation/anion balance, osmoregulation and stomatal movement (Epstein and Bloom, 2005).

In conclusion, the adverse effects of water deficit condition irrigation intervals on the growth criteria and water relations measurements of wheat plants *c.v.* Misr2 can be partially mitigated by foliar sprayed of proline or potassium.

Photochemical activity:

In table (3) data show the effect of proline or potassium as foliar application on photosynthetic pigments and photochemical activity in fresh leaves of wheat plants c.v. Misr 2 grown under different levels of irrigation intervals. Different irrigation intervals treatments decreased significantly the photosynthetic pigments *i.e.* chlorophyll a, b, carotenoids and photochemical activity in the homogenate leaves in the two growing seasons. The severe drought stress treatment (irrigation every 30 days) was the most effective treatment in this result compared with the control. These results are in agreement with those obtained by Reddy, *et al.,* (2004) who reported that, photosynthetic pigments synthesis and CO_2 assimilation rates decreased due to drought stress as a result of reduction in stomatal conductance. They added that drought stress leads to a reduction in the contents and activities of photosynthetic carbon reduction cycle enzymes. Water stress induced by irrigation intervals decreased the chl. a, chl., b and carotenoids. This reduction in the photosynthetic pigments and photochemical activity under water stress observed here is in agreement with the results of Huseynova *et al*., (2007) who reported that wheat plants grown under normal water supply and severe water deficit showed the intensive fluorescence at 740 nm and higher photochemical activity of PS II which decreased under water deficit condition. Farooq, *et al*., (2009) noticed that, under drought stress condition, photosynthetic pigments were decreased and produced changes in the ratio of chlorophyll 'a' and 'b' and carotenoids. Abdul Jaleel, *et al.,* (2009) showed that synthesis of photosynthetic pigments were reduced by water deficit. The foliar photosynthetic rate of higher plants is known to decrease the relative water content (RWC) and leaf water potential. However, the debate continues as to whether drought mainly limits photosynthesis through metabolic impairment or stomatal closure (Lawson, *et al.,* 2003). Under drought stress, plants generally display many physiological responses such as decreased / stopped photosynthetic activity (Secenji, *et al.,* 2005). Photosynthetic pigments disrupt and the gas exchange reduces by drought stress leading to a reduction in plant growth and productivity. (Anjum, *et. al.* 2011).

Concerning the applied proline or potassium, data in the same table show that, each of proline or potassium (0.1 %& 0.2%) increased photosynthetic pigments content and photochemical activity in the leaves during the two growing seasons. Proline at 0.2% level was the most effective in this respect. As for the interaction effects, it could be shown that all application of proline or potassium at rate 0.1 % & 0.2% enhanced the contents of photosynthetic pigments and photochemical activity under drought stress levels (irrigation every 20, 30 days). Applied proline or potassium can partially mitigate the harmful effect of drought stress on photosynthetic pigments and photochemical activity in wheat plants. Stomatal closure is related with K transport and high proline content of the plant parts (Reddy, *et al.,* 2004). By the excess K in the leaf can be partial protected photosynthesis from the harmful effects of drought stress. Through the mechanism of a K/H antiport system, the protective impact appears by extra choloroplantic K in the plant cells, possibly acting on chloroplast photosynthesis. (Srinivasarao *et.al.,* 2009). Potassium plays a vital role in various physiological processes, such as photosynthesis, osmoregulation, and protein synthesis (Epstein and Bloom, 2005). Increase in photosynthetic rate due to foliar application of K might have been due to stomatal or non-stomatal limitations, major controlling factors of photosynthetic rate (Dubey, 2005).

Phenols, proline, as well as activities of peroxidase and Catalase:

Data presented in Table (4) show the changes of total phenols (free and bound phenols), proline, catalase (CAT) and peroxidase (PX) activities in the leaves of wheat plants as affected by water irrigation intervals and integrated applied of proline or potassium. Data indicated that total phenol, proline, peroxidase and catalase activities an increased gradually with increase in drought stress in the shoot of wheat plants during the two growing seasons. The obtained results are in agreement with those obtained by Mallick *et al.,* (2011) who showed that superoxide dismutase, catalase and peroxidase activities in leaves increased under water stress. On the contrary, POD activities and MDA contents greatly increased in response to water stress (Helaly *et al*. 2017). It is well known that the proline contents in leaves of many plants get enhanced by several stresses including drought stress. Higher proline content in wheat plants after water stress has been reported by Errabii *et al*. (2006). Relative water content (RWC) decreased and proline content increased under drought stress (Mahajan and Tuteja, 2005) and Hura *et al.,* (2008) reported that during drought stress, phenolics change optical properties of leaves and have possibility to protect photosynthetic apparatus. Drought stress cause increase of phenolics compound in leaf tissue (D'souza and Devaraj 2011). The increase of proline and soluble phenols were much higher in pea and wheat plants, due to drought stress alone Alexieva *et al.,* (2001).

As for the effect of proline or potassium at the same data show that they promoted the synthesis and accumulation of proline and peroxidase and catalase activities under drought stress levels. Proline 0.2% treatment and irrigation every 30 days were most effective in this respect. But each of the potassium or proline decreased total phenols. For the interaction, data also show that, the application of potassium or proline gave similar response to enhance the contents of proline, promote the enzymatic activity of peroxidase and catalase but reduced total phenols, under drought stress during the two growing seasons. It can also be inferred that proline acts as a free radical scavenger and may be more important in overcoming stress than in acting as a simple osmolyte proline accumulation caused by drought stress in maize plant does not seem to be an indication of drought stress resistance, but rather a symptom of it. For this accumulation to take place it seems that fully organized chloroplasts are required as well as the systemic development of the plant. Caballero *et al* (2008). Elumalai *et al.,* (2002) reported that the major plant macro-nutrient as potassium plays role of stomatal behavior, activity of enzymes, osmoregulation, cell expansion Osmolytes as proline play a major role in osmotic adjustment and protect the cells by scavenging ROS (Helaly *et al*., 2017). Proline involved in reducing the photodamage in the thylakoid membranes by scavenging and/or reducing the production of $^1O_2$. (Pinhero *et al.,* 2001). Proline accumulation in plants is caused, by the activation of proline biosynthesis, and the inactivation of proline degradation. Secenji *et al.* (2005) reported that the accumulation of proline is one of the most studied phenomenon as an osmoprotectant. Under water deficit, proline biosynthesis is increased and due to increased expression of the key enzyme.

Table 3. Effect of water irrigation intervals and potassium or proline as well as their interactions on photosynthetic pigments (mg. /g. F. Wt.) and photochemical activity (µmol /mgchl. per10min.) of fresh leaves of wheat plant during the two growing seasons 2014 /2015 and 2015/2016.

Characters		Chl. a		Chl. b		Chl. (a+b)		Carotenoids		Photochemical activity	
Treatments		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Effect of water irrigation intervals											
10 days(cont.)		1.76	1.28	0.74	0.67	2.50	1.95	0.76	0.70	162.51	160.95
20 days		1.56	1.21	0.62	0.59	2.19	1.80	0.76	0.62	154.37	152.33
30 days		1.25	1.06	0.50	0.42	1.74	1.48	0.71	0.62	131.64	128.90
L.S.D. (0.05)		0.058	0.054	0.145	0.141	0.185	0.193	0.003	0.013	1.36	1.62
Effect of foliar spray with Potassium or Proline											
Distilled water		1.43	1.11	0.56	0.51	1.98	1.62	0.73	0.63	144.20	141.84
Potassium 0.1%		1.52	1.17	0.57	0.53	2.09	1.69	0.74	0.64	147.76	145.48
Potassium 0.2%		1.54	1.19	0.62	0.56	2.16	1.75	0.75	0.65	149.86	147.76
Proline 0.1%		1.54	1.23	0.66	0.58	2.21	1.81	0.75	0.65	151.66	149.71
Proline 0.2%		1.59	1.23	0.68	0.61	2.28	1.84	0.75	0.65	154.06	152.18
L.S.D. (0.05)		0.115	0.070	0.066	0.105	0.139	0.132	0.004	0.011	2.23	2.26
irrigation intervals	Foliar spray	Interaction Effect									
10 days (cont.)	Distilled water	1.682	1.248	0.684	0.657	2.365	1.905	0.760	0.671	158.22	156.51
	K 0.1%	1.746	1.271	0.705	0.662	2.451	1.933	0.761	0.676	159.22	157.59
	K 0.2%	1.767	1.298	0.710	0.663	2.477	1.961	0.762	0.715	161.87	160.31
	Pr 0.1%	1.771	1.302	0.785	0.666	2.555	1.968	0.762	0.716	164.40	162.90
	Pr 0.2%	1.833	1.302	0.805	0.704	2.638	2.006	0.775	0.722	168.86	167.43
20 days	Distilled water	1.483	1.190	0.601	0.501	2.084	1.691	0.744	0.621	148.67	146.42
	K 0.1%	1.545	1.190	0.611	0.533	2.156	1.723	0.755	0.621	153.27	151.09
	K 0.2%	1.569	1.193	0.618	0.616	2.186	1.809	0.759	0.621	155.00	152.86
	Pr 0.1%	1.576	1.246	0.629	0.638	2.205	1.884	0.759	0.621	157.29	155.41
	Pr 0.2%	1.646	1.246	0.661	0.646	2.307	1.892	0.760	0.622	157.64	155.84
30 days	Distilled water	1.121	0.895	0.381	0.382	1.502	1.277	0.697	0.606	125.73	122.59
	K 0.1%	1.268	1.035	0.399	0.383	1.667	1.417	0.715	0.615	130.79	127.76
	K 0.2%	1.270	1.082	0.542	0.409	1.812	1.491	0.715	0.617	132.70	130.10
	Pr 0.1%	1.277	1.134	0.579	0.447	1.856	1.580	0.715	0.619	133.30	130.80
	Pr 0.2%	1.300	1.153	0.583	0.477	1.882	1.630	0.716	0.619	135.69	133.25
L.S.D. (0.05)		0.187	0.121	0.175	0.214	0.281	0.278	0.006	0.021	3.62	3.84

Table 4. Effect of water irrigation intervals and potassium or proline as well as their interactions on total phenols, proline, catalase and peroxidase activities of leaves of wheat plant during the two growing seasons 2014 /2015 and 2015/2016.

Characters Treatments		Catalase µmol H_2O_2/mg protein/min		Peroxidase µmol H_2O_2/mg protein/min		Proline µmoles proline /gm F. wt.		Free phenols		Bound phenols		Total phenols mg/gm F.Wt.	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Effect of water irrigation intervals													
10 days(cont.)		376.92	375.66	0.53	0.49	9.67	8.42	1.13	1.15	0.61	0.66	1.74	1.82
20 days		439.29	438.04	0.65	0.61	13.16	12.58	1.22	1.24	0.69	0.74	1.91	1.98
30 days		486.65	485.39	1.05	1.02	18.35	16.95	1.33	1.37	0.77	0.73	2.10	2.10
L.S.D. (0.05)		64.25	64.25	0.18	0.18	0.63	0.88	0.03	0.07	0.09	0.09	0.09	0.06
Effect of foliar spray with Potassium or Proline													
Distilled water		407.17	405.91	0.65	0.61	12.23	11.55	1.27	1.32	0.79	0.77	2.06	2.09
Potassium 0.1%		414.26	413.00	0.69	0.65	13.04	11.95	1.25	1.27	0.69	0.72	1.94	1.99
Potassium 0.2%		435.23	433.97	0.74	0.70	13.73	12.62	1.23	1.26	0.70	0.70	1.93	1.96
Proline 0.1%		446.57	445.32	0.78	0.75	14.21	13.33	1.21	1.24	0.65	0.70	1.86	1.94
Proline 0.2%		468.21	466.96	0.85	0.81	15.43	13.80	1.16	1.19	0.63	0.66	1.79	1.85
L.S.D. (0.05)		51.97	51.97	0.25	0.25	0.79	0.84	0.04	0.03	0.09	0.10	0.08	0.10
Water irrigation intervals	Foliar spray	Interaction Effect											
10 days (cont.)	Distilled water	344.30	343.04	0.442	0.404	8.43	7.40	1.17	1.19	0.66	0.74	1.83	1.93
	K 0.1%	351.05	349.79	0.509	0.472	9.38	8.23	1.17	1.19	0.63	0.70	1.80	1.89
	K 0.2%	382.69	381.43	0.554	0.517	9.86	8.35	1.16	1.18	0.64	0.67	1.79	1.85
	Pr 0.1%	399.73	398.48	0.555	0.518	10.23	8.87	1.13	1.16	0.58	0.69	1.72	1.85
	Pr 0.2%	406.83	405.57	0.576	0.539	10.42	9.26	1.02	1.05	0.53	0.52	1.55	1.57
20 days	Distilled water	420.17	418.92	0.579	0.541	11.14	11.42	1.27	1.33	0.72	0.68	1.99	2.01
	K 0.1%	427.27	426.01	0.599	0.562	12.49	11.56	1.22	1.26	0.75	0.74	1.98	2.00
	K 0.2%	442.50	441.25	0.667	0.629	12.75	11.90	1.22	1.24	0.73	0.74	1.94	1.98
	Pr 0.1%	449.93	448.67	0.666	0.629	13.51	13.84	1.19	1.21	0.64	0.76	1.83	1.96
	Pr 0.2%	456.60	455.35	0.727	0.689	15.90	14.16	1.18	1.19	0.63	0.77	1.81	1.96
30 days	Distilled water	457.03	455.77	0.933	0.896	17.11	15.84	1.37	1.44	0.98	0.88	2.35	2.32
	K 0.1%	464.45	463.20	0.967	0.929	17.24	16.05	1.37	1.36	0.69	0.72	2.05	2.07
	K 0.2%	480.50	479.25	1.000	0.963	18.57	16.93	1.31	1.36	0.73	0.69	2.04	2.04
	Pr 0.1%	490.06	488.80	1.133	1.096	18.87	17.27	1.30	1.36	0.73	0.66	2.02	2.02
	Pr 0.2%	541.22	539.96	1.233	1.196	19.96	17.97	1.29	1.33	0.72	0.68	2.01	2.02
L.S.D. (0.05)		102.03	102.03	0.42	0.42	1.36	1.56	0.07	0.09	0.17	0.18	0.16	0.17

photosynthesis and Net assimilation rate as well as growth decreased by drought stress, while increasing total phenolic glycoside concentrations (Hale *et al.,* 2005). Hoque *et al.,* (2007) concluded that proline alleviate the adverse effects of salinity stress because of its superior ability to increase the antioxidant enzymes activities. To scavenge ROS, plant tissues contain peroxidase, SOD, and catalase. (Khedr *et al.,* 2003) reported that under salt stress, activities of antioxidant enzyme decrease in plant cells and increase in the presence of proline. In various physiological processes, potassium plays a vital role such as enzyme activation, photosynthesis, and protein synthesis (Epstein and Bloom, 2005).

Yield and its components:

Data in Table (5) show that drought stress reduced yield and its components as indicated with number of spikes/plant, number of grains/spike, number of grains/plant, dry weight of grains/plant and weight of 1000 grains comparable to the control. The severe drought stress treatment was more effective on decreasing yield and its components than the control in both growing seasons.

The remarkable reduction of wheat grain yield under water stress may be attributed to the reductions in number of spikes/plant, number of grains/spike, 1000-grains weight observed in the present work. The decrease in grain yield may be due to disturbed nutrient uptake efficiency and photosynthetic translocation within the plant (Iqbal *et. al.,*1999) Similarly, Akram, (2011) indicated that high relative water contents were associated with increased yield and yield components. In addition, water stress decreased 1000 grain weight and grain yield (El-Banna *et. al.,* 2002). Mirbahar *et al.,* (2009) found that increasing level of water stress decreased significantly spike length, number of grains per spike, and 1000 grain weight. The deficiency of water leads to severe decline in yield traits of crop plants probably by disrupting leaf gas exchange properties which not only limited the size of the source and sink tissues but the phloem loading, assimilate translocation and dry matter portioning are also impaired (Farooq *et al.,* 2009).

Regarding the effects of proline or potassium on yield and its components, result in the same table results show significant increases due to spraying wheat plants with proline or potassium (at rate of 0.1 and 0.2 %). This result was true for two growing seasons.

It could be noticed that spraying wheat plants with proline at rate of 0.2 % had the best results in this respect comparing to the other treatments. The excess in grain yield/plant in response to proline treatment could be discussed on the basis of the review described by Sakr, *et al.,* (2012) who concluded that the exogenously applied osmoregulators glycine betaine and proline can fully or partially counteract the harmful effect of salinity stress on growth and yield of canola. Potassium application could play an important role in alleviation of injury of wheat irrigated with salinized water depend on the level of salinity. especially at lower levels on yield (El-Lethy *et al.,* 2013)

In conclusion, that wheat yield and its components was highly reduced under drought stress. Spraying plants with proline or potassium at rate of 0.1 and 0.2 % improved plant yield but less lower than the control. Moreover, the adverse effects of drought stress could be partially or fully offset by integrated application of proline or potassium. Proline was generally more effective than potassium. Proline led to an enhanced grain yield in the absence of drought stress and this effect was maintained as drought stress increased.

Table 5. Effect of water irrigation intervals and potassium or proline as well as their interactions on yield and yield components of wheat plant during the two growing seasons 2014 /2015 and 2015/2016.

Characters Treatments		No. of spike/ plant		No. of grain/ spike		NO. of grain/ plant		1000 grain weight (g)		Grain yield/ plant (g)	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Effect of water irrigation intervals											
10 days(cont.)		4.60	4.33	59.93	62.67	276.00	272.27	55.45	44.75	15.30	12.19
20 days		3.47	2.40	48.73	55.87	170.13	134.53	50.37	39.65	8.68	5.47
30 days		1.80	1.60	35.40	33.87	65.60	55.60	38.21	33.11	2.56	1.86
L.S.D. (0.05)		0.76	0.54	5.04	5.93	43.80	29.71	5.52	3.81	1.88	0.58
Effect of foliar spray with Potassium or Proline											
Distilled water		2.78	2.11	42.00	45.67	132.78	108.00	45.29	36.31	6.63	4.24
Potassium 0.1%		3.11	2.33	44.89	50.67	149.33	129.33	46.51	37.31	7.55	5.28
Potassium 0.2%		3.33	2.89	48.56	51.33	171.89	160.00	48.39	39.97	8.94	6.77
Proline 0.1%		3.44	3.11	51.44	52.11	188.56	175.89	49.41	40.62	9.90	7.54
Proline 0.2%		3.78	3.44	53.22	54.22	210.33	197.44	50.46	41.63	11.20	8.71
L.S.D. (0.05)		0.50	0.46	4.52	4.18	30.67	22.39	3.13	3.43	1.79	1.01
Water irrigation intervals	Foliar spray					Interaction Effect					
10 days (cont.)	Distilled water	4.33	3.67	56.67	59.00	245.67	216.67	54.33	42.50	13.20	9.05
	K 0.1%	4.33	4.00	58.00	62.33	250.67	249.33	54.37	44.00	13.70	10.97
	K 0.2%	4.67	4.33	59.33	63.00	274.67	272.33	54.50	44.67	14.96	12.07
	Pr 0.1%	4.67	4.67	61.33	63.67	288.00	296.33	56.10	44.83	16.17	13.27
	Pr 0.2%	5.00	5.00	64.33	65.33	321.00	326.67	57.97	47.73	18.46	15.59
20 days	Distilled water	3.00	1.67	41.67	50.33	125.00	79.67	45.67	35.77	5.70	2.84
	K 0.1%	3.33	1.67	43.67	56.33	143.00	94.67	47.97	35.87	6.89	3.45
	K 0.2%	3.67	2.67	48.67	56.67	178.33	150.33	52.23	41.93	9.42	6.33
	Pr 0.1%	3.67	3.00	54.33	58.00	200.33	174.00	52.20	42.27	10.46	7.36
	Pr 0.2%	3.67	3.00	55.33	58.00	204.00	174.00	53.80	42.40	10.91	7.39
30 days	Distilled water	1.00	1.00	27.67	27.67	27.67	27.67	35.87	30.67	0.99	0.85
	K 0.1%	1.67	1.33	33.00	33.33	54.33	44.00	37.20	32.07	2.06	1.42
	K 0.2%	1.67	1.67	37.67	34.33	62.67	57.33	38.43	33.30	2.43	1.91
	Pr 0.1%	2.00	1.67	38.67	34.67	77.33	57.33	39.93	34.77	3.08	1.98
	Pr 0.2%	2.67	2.33	40.00	39.33	106.00	91.67	39.60	34.77	4.24	3.14
L.S.D. (0.05)		1.07	0.89	8.55	8.69	63.94	45.22	7.27	6.48	3.32	1.67

CONCLUSION

It could be concluded that either of potassium or proline at the rate of o.1 and 0.2 % can be applied exogenously to alleviate the harmful effects of prolonging irrigation intervals up to 30 days under Egyptian conditions. Both physio-chemical aspects, growth parameters and yield components of wheat plants c.v. Misr2 were promoted.

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التطبيق المتكامل للبرولين أو البوتاسيوم في التخفيف من الآثار الضارة لفترات الري على نباتات القمح

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إجهاد الجفاف أحد العوامل الأكثر ضررا لنمو وإنتاجية النبات. هنا، أجريت تجربتى أصص فى صوبة قسم النبات الزراعي بكلية الزراعة جامعة الزقازيق- بمحافظة الشرقية -مصر، خلال شتاء موسمين متعاقبين (٢٠١٥/٢٠١٤ و٢٠١٦/٢٠١٥) لدراسة دور كلا من البرولين أو البوتاسيوم في التخفيف والتغلب على الأثار الضارة الناجمة عن فترات الري في نباتات القمح صنف مصر٢. قمنا بتقييم خصائص النمو والمحصول والمكونات البيوكيميائية.أوضحت النتائج اولا، لصفات النمو و للمحصول ومكوناته, أن معامات الرى على فترات (الري كل ١٠ ، ٢٠، ٣٠ يوم) أدى الى النقص في طول النبات (سم) ومساحة الورقة (سم^{٢}) والوزن الجاف للمجموع الخضري و عدد السنابل/نبات وعدد الحبوب/سنبلة وعدد الحبوب/نبات والوزن الجاف للحبوب/نبات بالجرام ووزن الالف حبة بالجرام لنباتات القمح خلال موسمى الزراعة , علاوة علي ذلك كانت معاملة الرى كل ٣٠يوم هى الأكثر فاعلية فى احداث النقص في المحصول ومكوناته. علي النقيض من ذلك, أوضحت النتائج أن التطبيق المتاكامل لكلا من البرولين أو البوتاسيوم (بمعدل ٠.١% و ٠.٢% له دور فى تخفيف تلك الاثار السلبية بتحسين صفات النمو والمحصول ومكوناته تحت ظروف اجهاد الجفاف ولكن تلك الزيادة ظلت أقل من الكنترول. ثانيا، أدى اجهاد الجفاف الى نقص محتوى الماء النسبي ، احتفاظ ورقة النبات بالماء ، فقد الماء النسبي ومحتوي صبغات البناء الضوئى والنشاط الكيموضوئي و في حين ازدادة المحتوى من الفينولات والبرولين و نشاط انزيمات الكتاليز والبيروكسيديز في أوراق نباتات القمح خلال موسمى الزراعة . ثالثا، كان لتأثير كلا من البرولين أو البوتاسيوم دور ايجابى فى زيادة محتوى الماء النسبي ، واحتفاظ ورقة النبات بالماء ، وفقد الماء النسبي ومحتوى صبغات البناء الضوئى والنشاط الكيموضوئي والبرولين و نشاط انزيمات الكتاليز والبيروكسيديز بينما يقل محتوي الفينولات. وعلاوة علي ذلك ،كانت معاملة البرولين ٠.٢% الافضل فاعلية بهذا الخصوص . ويتضح ذلك مقارنة بمعاملات اجهاد الجفاف فقط ولكن تلك القيم ظلت أقل أو قريب من الكنترول. وخلصت النتائج إلى أن التطبيق المتكامل للبرولين أو البوتاسيوم يقلل كليا أو جزئيا من التأثير الضار لإجهاد الجفاف على النمو و والمكونات البيوكيميائية ومحصول نباتات القمح.