J. Plant Production, Mansoura Univ., Vol. 9 (4): 359 - 367, 2018

Response of Barley Plants to Potassium Spraying under Water Deficit Conditions

Rania F. El Mantawy[1] and R. M. Khalifa[2]
[1] Crop Physiology Res. Dep. - Field Crops Research Institute- Agric. Res. Center.
[2] Soil Dep.- Faculty of Agriculture - Damietta University.

ABSTRACT

A field experiment was carried out at the Experimental Farm of Sakha Agricultural Research Station during the winter season of 2014/2015 and 2015/2016 to study the impact of foliar application with potassium on growth, yield, its components and the economic yield as well as on irrigation water productivity of barley Giza 126 cultivar under water deficit conditions. The experiment was laid out in spilt plot design with four replications. The main plots were designated to irrigation treatments i.e. I_0 = full irrigation (control), I_1 = two irrigations at 35 and 70 days after sowing (DAS), and I_2 = one irrigation at 35 days after sowing (DAS), while the sub plots were devoted to four treatments of foliar application with potassium (K_0 = without spray, K_1 = 1% K_2O, K_2= 2 % K_2O and K_3= 3% K_2O) in the form of potassium sulfate (48%). Results showed that, increasing water stress significantly retard photosynthetic pigments, flag leaf area, relative water content (RWC %), yield and its components and carbohydrate content. On the other hand, plants under water stress showed marked increase in grain protein content. Foliar spraying with potassium markedly increased most growth and yield parameters and quality of barley grains. The results showed that high irrigation water productivity (IWP) is attainable without significant yield penalty (utilizing a two irrigations at 35 and 70 days after sowing (DAS), or one irrigation after 35 DAS and foliar spraying with potassium (1% K_2O, or 2 % K_2O, or 3 % K_2O) offering chance for improving land level water use and enhancing the crop economic return.

INTRODUCTION

Barley (*Hordeum vulgare*, L.) is a major cereal grain grown in temperate climates globally. It is the fourth most important cereals of the world after wheat, rice and maize. Barley is one of the most tolerant crops under the adverse environmental conditions Lakshmi *et al.,* (2016).

Agriculture in Egypt depends mainly on irrigated agriculture. We are suffering from a big problem, which is the widening gap between the water needs and the increase of the population, especially as we are under the water poverty limit, so the researchers resorted to new techniques in agriculture to provide irrigation water in this regard (Kheir *et al*., 2013) found that, one of the most important means to provide water is to know when water should be used to obtain the highest water efficiency. Also, El-Seidy *et al*., (2013) mentioned that the cultivation of barley crop in coastal areas and reclaimed land is beneficial for its ability to withstand adverse environmental conditions.

Abiotic stress factors such as drought, extreme temperatures, chemical toxicity, salinity, and oxidative stress leads towards biochemical, morphological, physiological, and molecular changes which negatively affect the plant growth and productivity Lalić *et al*., (2017). Drought stress is one of the most important environmental stresses affecting agricultural productivity worldwide. Soliman *et al*., (2011) reported that tolerance of barley plants to water stress conditions is of advantageous under deficit of irrigation water.

Potassium is a major plant nutrient and plays an important role in several physiological processes, *i.e.* photosynthesis, protein synthesis and maintenance of water status in plant tissues (Marschner, 2012). Also, Shekhawat *et al*., (2013) reported that significant increase was observed in plant height, plant dry weight, yield and yield components of barley due to application of potassium. Cakmak (2005) reported that, potassium has an effective role to survive drought stress in plants by increase translocation to maintain the water balance within the plant.

Even though many studies have previously carried out to investigate the relation of barley to water deficit, nonetheless, a little information is available concerning role of potassium spraying on economic yield of barley under water deficit. So, the problem is the lack of research on the effect of potassium on yield under deficit irrigation. Accordingly, the objective is to investigate and assess whether potassium may ameliorate the passive impacts of water deficit stress on barley through monitoring yield components and physiological activities through the following parameters:

- Irrigation water productivity of barley crop under the studied conditions.
- Evaluation the production of barley crop economically

MATERIALS AND METHODS

An experiment was conducted at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during the two successive seasons 2014/2015 and 2015/2016 to studied the effect of different irrigation treatments and foliar spray with potassium on growth, yield and its components of Giza 126 barley cultivar. Meteorological data pertaining to the two winter growing seasons at Sakha Meteorological Station, Egypt are given in Table (1).

Table 1. Means of some meteorological data for Kafr El-Sheikh area during the two growing seasons (2014/2015 and 2015/2016).

Months.	Temperature(°C)				R.H.(%)				Rain (mm/day)	
	1st		2nd		1st		2nd		1st	2nd
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Aver.	Aver.
November	24.3	13.79	24.4	14.42	87.8	60.5	87.0	64.2	5.9	7.3
December	22.27	9.72	19.7	8.36	88.6	63.5	88.6	67.2	5.7	4.3
January	18.79	6.46	18.4	6.35	88.1	61.1	85.6	62.5	7.03	5.11
February	19.01	7.69	22.58	9.35	86.8	62.7	85.0	53.1	5.42	--
March	22.69	11.69	24.5	11.6	82.36	58.82	81.5	58.3	1.7	4.4
April	25.64	13.7	30.03	18.62	78.3	48.5	81.6	41.8	1.1	--
May	30.19	18.79	30.4	22.8	77.3	46.1	71.0	45.8	---	---

Source: Meteorological station at Sakha Agricultural Research Station (31° 07' N Latitude and 30° 57' E longitude) with an elevation of about 6 meters above sea level.

Soil Physico-Chemical characteristics of the selected experimental site at depth of 0 to 30 cm from soil surface according to Klute (1986) and Page *et al.* (1982) are presented in Table (2).

Table 2. Physico-chemical characteristics of the selected experimental site.

Soil characteristics	Obtained values
Chemical analysis	
Soil reaction pH (1:2.5 soil-water suspension)	
Electrical conductivity, EC dSm^{-1} (Soil past extract) at 25 C°	2.24
Saturation percentage (S.P) %	8.81
Total soluble ions (1:5 Soil-water extractions)	
Soluble cations (meq L^{-1})	
Ca^{+2}	5.2
Mg^{+2}	2.23
Na^{+}	9.37
K^{+}	0.63
Soluble anions	
CO_3^{-2}	0
HCO_3^{-}	7.65
CL^{-}	4.65
SO_4^{-2}	5
Sodium adsorption ratio (SAR)	4.86
Particle size distribution %	
Sand fraction	25.85
Silt fraction	24.65
Clay fraction	49.5
Soil textural class	clayey
Soil moisture constants	
Soil field capacity (F.C %)	37.57
Soil permanent wilting point (P.W.P %)	20.42
Soil available water capacity (A.W. %)	17.15
Soil bulk density (gm cm^{-3})	1.21
macro-nutrients	
N (mg/l)	18.78
P (mg/l)	6.82
K (mg/l)	280.80
Organic matter (O.M) %	1.82

The grains were sown on 26th of November in the two seasons. The experiment was laid out in split plot design with four replication. The main plots were designated to (I_0 = full irrigation (control), I_1 = two irrigations at 35 and 70 days after sowing (DAS), and I_2 = one irrigation at 35 days after sowing (DAS), while the sub plots were devoted to four treatments of potassium spraying (K_0 = without spray, K_1 = 1% K_2O, K_2= 2% K_2O and K_3= 3% K_2O) in the form of potassium sulfate (48%), which were sprayed twice after 35 and 50 days after sowing.

The plants were sprayed at early morning using hand-sprayer, while the control plants were sprayed with fresh water. The plot area was 50 m^2 (5 m width and 10 m length), with 15 cm apart rows. Each experiment was surrounded by a wide border (4m) to minimize the underground water permeability.

Nitrogen fertilizer was added at the rate of 70 kg fad^{-1} in the form of ammonium nitrate (33.5%N) in two equal doses, i.e. before the first and second irrigations in the case of full irrigations, while plots irrigated twice 1/3rd of nitrogen was applied at sowing time and subsequent nitrogen was applied at 1st irrigation and at 2nd irrigation in two splits and in the case of plots irrigated once half N were applied as basal dose, and remaining half of N was applied at 1st irrigation, respectively. The phosphorus fertilizer was incorporated in the soil during land preparation in the form of calcium super phosphate at the rate of 15.5 P_2O_5 fad^{-1}.

Calculation of growing degree days (GDD):

Growing degree days (GDD), is used as an indicator to the growth and development of plants during the growing seasons as presented in Fig.(1 & 2). GDD was calculated according to the following formulae of Bauer *et al.*,(1992)

$$GDD = \sum \left(\frac{T_{max}+T_{min}}{2-T_b}\right) \text{..........Eq. (1)}$$

Where, **GDD is Growing degree days, Tb is the base temperature (5°c)**

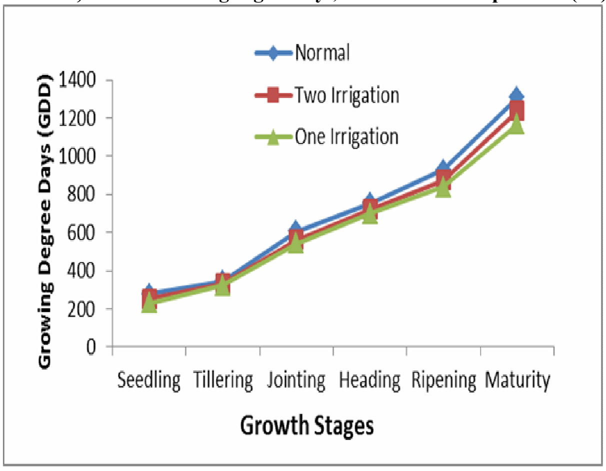

Fig. 1. Growing degree days during the first season (2014/2015).

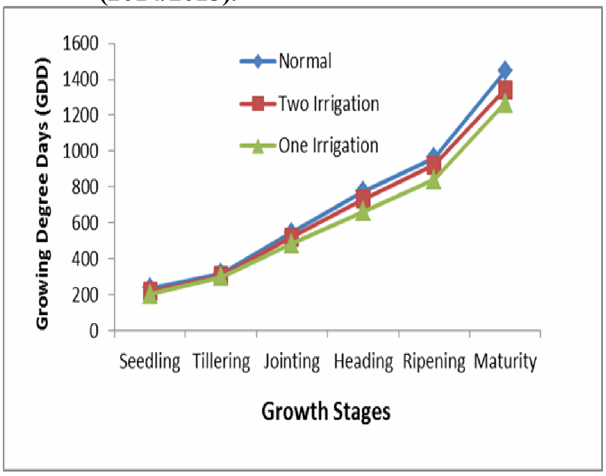

Fig. 2. Growing degree days during the second season (2015/2016).

Data collection and measurement

A. Plant Growth Characters:

Representative plant samples were taken randomly from the second and third row of each plot at heading stage to estimate the following traits:

1. Photosynthetic pigment content in leaves:

The total chlorophyll pigments were determined according to the equation mentioned by Moran (1982).

$$\text{Chl. a} = (12.7x(O.D)664) - (2.79x(O.D)647) \text{....Eq. (2)}$$

$$\text{Chl. b} = (20.7x(O.D)647) - (4.62x(O.D)664) \text{....Eq. (3)}$$

$$\text{Total chlorophyll} = (7.04x(O.D)664) + (20.27x(O.D)647) \text{....Eq. (4)}$$

2. Relative water content (RWC %):

In measuring relative water content, the method of Weatherly (1950) and its modification by Barrs and

Weatherly (1962) was adopted, following the considerations given by El-Sharkawy and Salama (1973). Relative water content was calculated according to the following equation:

$$RWC\ \% = \left(\frac{Fw-DW}{TW-DW}\right) x100 \text{...............Eq.(5)}$$

Where, FW **is fresh weight,** DW **is dry weight,** TW **is turgid weight.**

3. Flag leaf area (cm^2):

Determined by the methods described by Quarrie and Jones (1979).

$$Leaf\ Area = Maximum\ length x Maximum\ width x 0.75 \text{....Eq.(6)}$$

B. Yield and its components:

At harvest, one square meter of barley plants was harvested randomly from each plot to determine the following characteristics: Plant height, number of spikes m^{-2}, number of tillers m^{-2}, number of grains spike^{-1} and 1000-kernel weight, grain yield (tons fad^{-1}), straw yield (tons fad^{-1}) and biological yield (tons fad^{-1}).

C. Determination of technological trait:

1. Grain protein content:

The total nitrogen in grains of barley was determined using Micro-Kjeldahl method and multiplied by 5.75 to obtain the percentage of grain protein according to A.O.A.C.(1990).

2. Grain carbohydrates (%)content: was determined according to Dubois *et al*., (1956).

D. Water relations :

1. Determination of seasonal water applied:

Seasonal water applied was calculated according to Giriappa (1983)

$$W_a = IW + ER + S \text{.....................Eq.(7)}$$

Where:

- IW **is the irrigation water applied.**
- ER **is the effective rainfall water.**
- S **is the contribution of the ground water table to crop water use (neglected) because it wasn't high (about 120 cm).**

2. Assessment of irrigation water productivity:

The irrigation water productivity (IWP, kg m^{-3}) was determined according to the following equation:

$$IWP = \frac{Y_a}{I} \text{.................. Eq.(8)}$$

Where,

- Ya **is *the* actual yield obtained by the different treatments (Kg fed^{-1}).**
- I **is the amount of applied irrigation water (m^3 fed.$^{-1}$).**

E. Economic evaluation

F. Economic evaluation

Economic assessment requires some items through which the evaluation process can be conducted. The suggested items of the economic evaluation for each treatment (separately) in order to Trade – offs between them, economically are:

1-Total seasonal cost.

2-Total seasonal return,

3-Net return (NR) $(NR = Total\ return - Total\ cost)$

4-Return per unit of water: This can be taken as index to the relationship between water applied and the value of crop production (Division of Agricultural sciences irrigation cost, 1978).

Statistical Analysis

The obtained data of the different treated groups were statistically analyzed and comparison among means was performed by computer programming methods (statgraphic- vers-4-2- Display ANOVA),as described by Snedecor and Cochran (1982). Treatment means were compared by Duncan's multiple range test (Duncan's, 1955).

RESULTS AND DISCUSSION

Change in flag leaf chlorophyll:

Chlorophyll content is one of the major factors affecting photosynthetic process. It is clear from Table (3) that, water stress led to decrease in chlorophyll content in barley plants. This decrease in chlorophylls pigments could be due to the closure of stomatal pores to limit water loss through evapotranspiration and at the same time increase proline production in the leaves (Bousba *et al*., 2012). Also, (Smirnoff 1993; Foyer *et al*., 1994) found that, reduction in chlorophyll content under water stress is the production of reactive oxygen species (ROS) such as O^{-2} and H_2O_2, which caused lipid peroxidation and consequently, chlorophyll degradation. Also, stress reduced the chlorophylls content and important photosynthetic pigments (Chéour *et al*., 2014).

Table 3. Photosynthetic pigments as affected by foliar spraying of potassium under various irrigation levels during 2014/2015 and 2015/2016 seasons.

Treatment	Chl.a (mg dm^{-2})		Chl.b (mg dm^{-2})		Total Chl. (mg dm^{-2})	
	2014/015	2015/016	2014/015	2015/016	2014/015	2015/016
	Irrigation treatment (I)					
I_1	2.415 a	2.380 a	1.769 a	1.740 a	4.185 a	4.120 a
I_2	2.301 b	2.270 b	1.612 b	1.568 b	3.913 b	3.838 b
I_3	2.213 c	2.190 c	1.474 c	1.468 c	3.687 c	3.658 c
F-test	**	*	**	**	**	**
	K treatment (K)					
K_0	2.177 d	2.150 d	1.425 c	1.409 c	3.603 d	3.560 d
K_1	2.256 c	2.236 c	1.576 b	1.537 b	3.832 c	3.774 c
K_2	2.354 b	2.334 b	1.734 a	1.710 a	4.094 b	4.044 b
K_3	2.451 a	2.423 a	1.739 a	1.713 a	4.186 a	4.137 a
F-test	*	*	*	*	*	*

***, ** significant at 0.05 and 0.01 level of probability, respectively. Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test.**

Chlorophyll content increased gradually with increase in potassium level application. The highest values were recorded with plants sprayed by 3 % K_2O in compassion to the control values. These results may be due to potassium, which has the important role in photosynthesis, transpiration, stomatal opening and closing, and synthesis of proteins (Milford *et al*., 2007). In the same line, Osman *et al*., (2017) found that application of potassium humate had a major role in regulating the biochemical and physiological processes of wheat plant.

Change in Relative Water Content (RWC %)

In our results, RWC % was significantly decreased by water stress and more reduced RWC% were recorded when plants irrigated one time (Table 4). Decrease in RWC% in plants under drought stress may depend on plant vigor reduction (Liu *et al*., 2002). Under water stress conditions, cell membrane subjects to many changes such as penetrability and decrease in sustainability (Blokhina *et al*., 2003).

Concerning the effect of spraying with potassium on RWC%, its clearly that potassium spray showed marked increase in RWC%. This may be due to potassium is one of the most important element in plants as it have the ability to survive under adverse conditions . In addition, (Serraj and Sinclair 2002) found that, accumulation of K irrigation. Our findings are supported by the results of Thalooth *et al*., (2012) who found that water stress at different growth stages significantly reduced number of tillers and spike plant^{-1} of barley. Also, Alderfasi and Refay (2010) reported that drought stress badly affected wheat grains spike^{-1}. Also, the heaviest 1000-grain weight were recorded with full irrigation (51.76 & 50.27 g), while the lowest values were recorded under one irrigation(45.18 & 44.01 g) during the first and second season, respectively. These results coincide with the findings of Bayoumi *et al*., (2008), Farshadfar *et al*., (2013) and Aowan *et al*., (2012) .

The effect of potassium application on number of tillers and spikes m^{-2} , grains spike^{-1} and 1000-grain weight were presented in Table (5). Potassium at the rate of 3 % K_2O produced maximum number of tillers, spikes m^{-2} , grains spikes $^{-1}$ and 1000-grain weight. These results are in agreement with those obtained by Shekhawat *et al*., (2013) who reported that application of potassium at 40 kg ha- caused significant increase in total tillers, spikes and number of grains spikes $^{-1}$of barley. The results are also in line with Anjum *et al*., (2011) who reported that drought reduced grain weight of maize.

Change in grain and straw yields

The grain and straw yields decreased when crop was irrigated once at 35 DAS. The highest values of grain and straw yields were recorded with full irrigation. These results are in agreement with Mirzaei *et al*., (2011) who reported that drought stress at all growth stages caused reducing in grain yield and yield components. Previous studies also emphasize that a significant decrease in grain yield occurs by inducing drought stress. These results are in the same trend with Kandhro *et al*., (2016) who reported that potassium can compensate drought stress and its application at 50 kg ha^{-1} coupled with one irrigation (35 DAS) and/or two irrigations (35 and 70 DAS) can be suitable for obtaining optimum yield of barley.

As seen from the table in comparison to full irrigation, the reduction in the yield irrigated two irrigation was (-10.00 and -10.67%) and when plants irrigated twice the reduction was (-21.57 and -21.34%) in the first and second seasons respectively. On the other hand, marked increase in yield were observed with increasing the level of potassium percentage (5.80 & 8.39%) with K_1 and (12.90 & 14.68 %) with K_2 and (20.64 &21.67%) with K_3.

Regarding the effect of potassium spray on grain and straw yields were presented in Tables (6). The data showed that K application cause marked increase in both grain and straw yields. These results may be due to potassium has important role in increasing the plant tolerance to water deficit conditions (Mesbah, 2009; and Aowan *et al*., 2012). Similarly, Shekhawat *et al*., (2013) revealed that application of 40 kg K_2O ha^{-1} markedly imporved the grain yield of barley. The results are coincide with the findings of Zareian *et al*., (2014) who found that, Drought affected negatively grain yield and physiological traits .

Table 6. Yield and yield reduction as affected by foliar spraying of potassium under various irrigation levels during 2014/2015 and 2015/2016 seasons.

Treatment	Straw yield(t fad.$^{-1}$)		Grain yield (tons fad.$^{-1}$)		Biological yield(t fad.$^{-1}$)		YR (%)	
	2014/015	2015/016	2014/015	2015/016	2015/016	2015/016	2015/016	2015/016
Irrigation treatment (I)								
I_1	4.10 a	3.91 a	1.90 a	1.78 a	6.00 a	5.70 a	----	----
I_2	3.68 b	3.47 b	1.71 b	1.59 b	5.40 b	5.07 b	-10.00	-10.67
I_3	3.36 c	3.12 c	1.49 c	1.40 c	4.86 c	4.52 c	-21.57	-21.34
F-test	**	**	**	**	**	**	----	----
K treatment (K)								
K_0	3.19 c	3.07 d	1.55 d	1.43 d	4.72 d	4.50 d	----	-----
K_1	3.48 b	3.33 c	1.64 c	1.55 c	5.13 c	4.88 c	5.80	8.39
K_2	3.90 a	3.62 b	1.75 b	1.64 b	5.65 b	5.26 b	12.90	14.68
K_3	4.29 a	3.99 a	1.87 a	1.74 a	6.16 a	5.74 a	20.64	21.67
F-test	**	**	**	*	**	**	----	----

*, ** significant at 0.05 and 0.01 level of probability, respectively. Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test.

Determination of technological trait:

The effect of water deficit and potassium application was presented in Table (7). Its obvious from the data that protein % increased significantly under water stress conditions. Similar results were also given by Thalooth *et al*., (2012) who showed that drought cause increase in protein content of barley grains.

In the case of potassium spray , it was clearly that, our results indicated that the application of K as a foliar spray caused increases in the contents of total carbohydrates of stressed and non -stressed plants. The highest values were obtained by foliar spraying of potassium at the rate of 3% K_2O. These results are also in agreement with those obtained by John and Lester (2011) reported that potassium foliar spray increased protein content in barley grains but at the same time, grain protein contents decreased under the water stress but potassium fertilizers survive the water stress and improving the grain quality as well as yield parameters (Minjian *et al*., 2007).

Water characteristics:

Seasonal irrigation water applied and irrigation water productivity

Data in Table (8) and Figures (3 & 4) showed that, for both growing seasons IWP increased with decreasing irrigation amount and with increasing potassium concentration. In 2014/2015 season, the IWP was within range of 0.81 and 2.21 kg m^{-3}, while in the 2015/2016 season the range was between 0.80 and 2.04 kg m^{-3}.

Table 7. Grain protein and grain carbohydrates content as affected by foliar spraying of potassium under various irrigation levels during 2014/2015 and 2015/2016 seasons.

Treatment	Protein (%)		Carbohydrates (%)	
	2014/2015	2015/2016	2014/2015	2015/2016
	Irrigation treatment (I)			
Full irrigation	9.34 c	9.37 c	63.32 a	62.25 a
Two irrigation	9.61 b	9.68 b	60.20 b	58.96 b
One irrigation	9.82 a	9.88 a	56.08 c	55.54 c
F-test	**	**	**	**
	K treatment (K)			
Control	9.24 d	9.27 d	54.74 d	54.02 d
1 % K_2O	9.53 c	9.63 c	58.86 c	58.30 c
2 % K_2O	9.70 b	9.76 b	61.44 b	60.10 b
3 % K_2O	9.89 a	9.92 a	64.43 a	63.24 a
F-test	**	**	**	**

*,** significant at 0.05 and 0.01 level of probability, respectively . Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test.

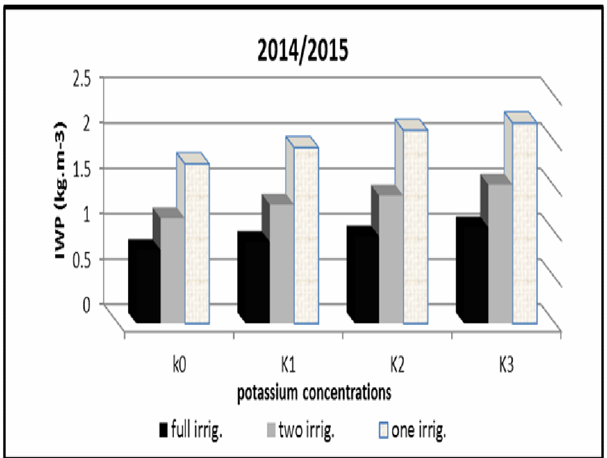

Fig. 3. Effect of foliar spraying with potassium on barley irrigation water productivity under different irrigation events during 2014/2015 season

The values estimated for IWP have very important implications. Under a limited water supply situation where the goal may be to achieve the highest possible IWP, utilizing a two irrigations at 35 and 70 days after sowing (DAS), or one irrigation after 35 DAS and spraying with potassium (1% K_2O, or 2 % K_2O, or 3 % K_2O) offers opportunities for water savings. In other words, utilizing this water application offers water savings of 38.1 % and 61.83 % in case of utilizing two irrigations and one irrigation, respectively (Table 8) compared to the fully irrigated treatment without any significant yield penalty (*-1.26 & 9.81 %)* with two irrigations and one irrigation respectively.

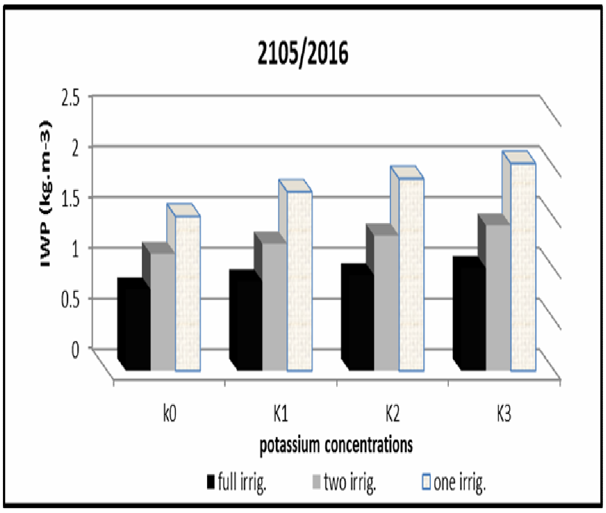

Fig. 4. Effect of foliar spraying with potassium on barley irrigation water productivity under different irrigation events during 2015/2016 season.

Economic evaluation:

Results in Table (9) showed that there was a positive relationship between total seasonal return and irrigation events or amounts of irrigation water applied and with increasing the rate of potassium application. From the data in Table 10 , it was clear that the mean values of the total seasonal return for irrigation treatments were ranged in descending order from full irrigation (10337.1 L.E fed^{-1}) to the treatment of one irrigation (8158.79 L.E fed^{-1}) passing by the treatment of two irrigations (9205.59 L.E fed^{-1}) for the two seasons, Concerning potassium spraying, data showed that within each irrigation treatment, increasing the rate of application resulting in increasing the total seasonal returns. Addition of 3% potassium achieved the highest values of total seasonal return while, the lowest values were obtained with the control .This trend may be due to increasing grain and straw yields by using potassium spraying.

Table 8. Total irrigation water applied (Wa), Irrigation Water Productivity (IWP), Water Savings (WS%) for the different treatments during 2014/2015 and 2015/2016 seasons.

Treatment		Wa (m^3 $fed.^{-1}$) 1st	2nd	Mean	IWP (kg m^{-3}) 1st	2nd	Mean	WS (%) 1st	2nd	Mean
	K_0	2020.79	2054.5	2037.64	0.81	0.80	0.81			
	K_1	2015.00	2022.00	2018.50	0.90	0.88	0.89	0.29	1.58	0.93
I_1	K_2	2008.12	2018.08	2013.10	0.96	0.94	0.95	0.63	1.77	1.20
	K_3	2005.82	2008.64	2007.23	1.06	1.01	1.04	0.74	2.23	1.49
Mean		2012.43	2025.81	2019.11	0.93	0.91	0.92	0.55	1.86	1.21
	K_0	1270.5	1242.23	1256.11	1.16	1.15	1.16	37.15	39.54	38.34
	K_1	1262.52	1285.0	1273.76	1.31	1.25	1.28	37.52	37.45	37.49
I_2	K_2	1258.83	1261.24	1260.03	1.41	1.33	1.37	37.71	38.61	38.16
	K_3	1256.62	1253.92	1255.27	1.53	1.43	1.48	37.82	38.97	38.39
Mean		1261.99	1260.60	1261.29	1.35	1.29	1.32	37.55	38.64	38.10
	K_0	773.56	800.02	786.79	1.76	1.52	1.64	61.72	61.06	61.39
	K_1	770.00	778.65	774.32	1.94	1.76	1.85	61.9	62.1	62.00
I_3	K_2	761.17	791.23	776.20	2.13	1.89	2.01	62.33	61.49	61.91
	K_3	758.32	789.83	774.07	2.21	2.04	2.13	62.47	61.56	62.02
Mean		765.76	789.93	777.84	2.01	1.80	1.91	62.11	61.55	61.83

Data in Table 9 and Fig. 5 revealed that the net seasonal return showed the same trend as in the above mentioned indicator, (*i.e.* the seasonal total return). This trend may be due to that the production cost for each system separately, seem to be semi – fixed , or that the differences between them are relatively very small compared to the corresponding value of the differences between the return for each system which are relatively larger. The highest value (5411.05 L.E fed^{-1}) was obtained by adding 3 % K_2O under full irrigation in the two growing seasons, while, the lowest value of net return (1471.285 L.E fed^{-1}) was recorded by without adding any potassium under one irrigation (after 35 DAS) in the two growing seasons. This may be attributed to increasing initial cost of full irrigation and K_3 treatment (6074 L.E fed^{-1}) as compared to other treatments. It is clear from the data exhibited in Table 10 and Fig. 6 that water return for different treatments showed a reversal tendency to those of previous indicators, in which, Water return decreased as the irrigation water amount increased. While, adding potassium oxide increased such values.

Table 9. Economic criteria for the first and second barley experiment seasons.

Treatments		Productivity (kg $fed.^{-1}$) grain	Productivity (kg $fed.^{-1}$) straw	water applied (m^3 $Fed.^{-1}$)	Total seasonal return (LE $Fed.^{-1}$)	Variable Costs (LE $Fed.^{-1}$)	Total costs (LE $Fed.^{-1}$)	Net return (NR) (LE $Fed.^{-1}$)	Water return (LE m^{-3})
I_1	K_0	1643.00	3618.33	2037.64	9212.03	2162	5762	3450.03	1.69
	K_1	1800.00	3781.67	2018.50	10003.07	2266	5866	4137.07	2.05
	K_2	1911.50	4131.67	2013.10	10648.25	2370	5970	4678.24	2.32
	K_3	2071.50	4500.00	2007.23	11485.05	2474	6074	5411.05	2.70
Mean		1856.50	4007.92	2019.12	10337.10	2318	5918	4419.10	2.19
I_2	K_0	1448.00	3015.00	1256.11	8015.86	2062	5662	2353.86	1.87
	K_1	1626.50	3501.67	1273.76	9030.14	2166	5766	3264.14	2.56
	K_2	1723.00	3758.33	1260.03	9526.70	2270	5870	3656.70	2.90
	K_3	1857.00	4055.00	1255.27	10249.64	2374	5974	4275.63	3.41
Mean		1663.63	3582.50	1261.30	9205.59	2218	5818	3387.59	2.69
I_3	K_0	1288.50	2760.00	786.79	7033.28	1962	5562	1471.28	1.87
	K_1	1435.00	2948.33	774.32	7842.50	2066	5666	2176.50	2.81
	K_2	1558.50	3398.33	776.20	8559.71	2270	5870	2689.71	3.47
	K_3	1645.00	3873.33	774.07	9199.66	2374	5974	3225.66	4.17
Mean		1481.75	3245.00	777.85	8158.79	2168	5768	2390.79	3.08

Price of barley grains (5 L.E per 1 Kg), straw (280 L.E price of 1 ton straw); Fixed Cost = 3600 L.E

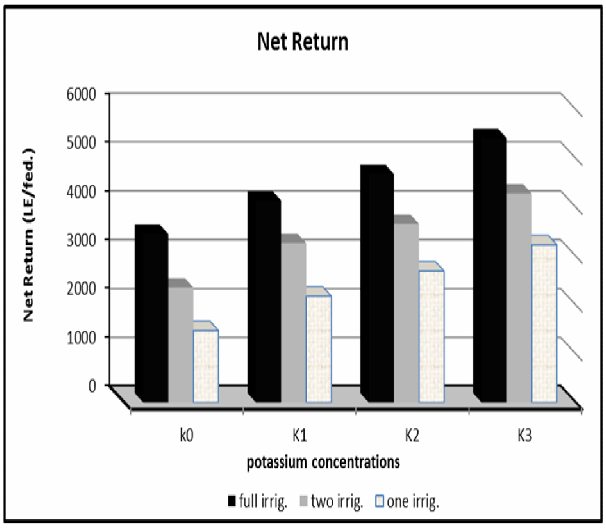

Fig. 5. Mean values of net return of barley yield as affected by different potassium levels under various irrigation levels .

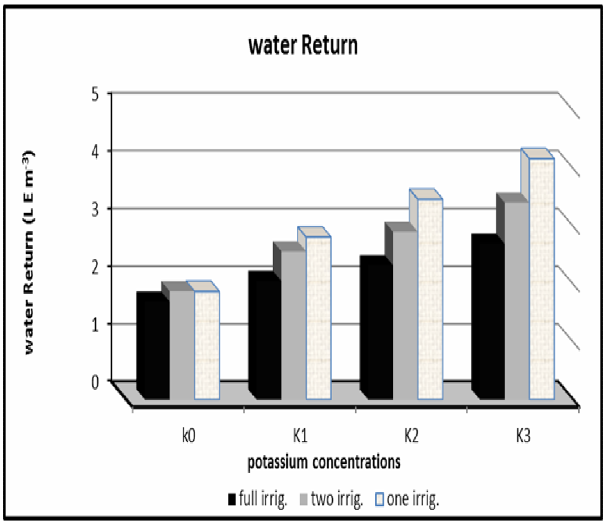

Fig. 6. Mean values of water return of barley yield as affected by different potassium levels under various irrigation levels .

CONCLUSION

In conclusion, the results of this study showed the role of K^+ in regulating the water stress of barley and suggest that K acts as growth enhancer to improve plant growth and photosynthetic pigment content. High IWP is attainable without significant yield penalty (utilizing a two irrigations at 35 and 70 days after sowing (DAS), or one irrigation after 35 DAS and spraying with potassium oxide (3 % K_2O) offering opportunities for improving farm level of water use and sustainable water development and enhancing the crop economic return.

REFERENCES

A.O. A .C. (1990): Official methods of the analysis. Association of Official Agriculture Methods. 15th edition, published by Association of Official Analytical Chemists, Arlington, Virginia, USA.

Alderfasi, A. A. and Y. A. Refay (2010): Integrated use of potassium fertilizer and water schedules on growth and yield of two wheat genotypes under arid environment in Saudi Arabia 1- Effect on growth characters. American-Eurasian J. Agric. Environ. Sci., 9 (3): 239-247.

Anjum, S. A.; L. C. Wang; M. Farooq; M. Hussain; L. L. Xue and C. M. Zou (2011): Brassinolide application improves the drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange. J. Agron. Crop Sci., 197 (3): 177-185.

Aowan, M.; S. Raza; M. F. Saleem; S. A. Anjum; T. Khaliq and M. A. Wahid (2012): Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticum aestivum L.*). J. Anim. Plant Sci., 22 (2): 431-437.

Bauer, A; A. L. Black; A. B. Frank; and E. H. Vasey. (1992): Agronomic Characteristics of Spring Barley in the Northern Great Plains. North Dakota State University Agricultural Experiment Station Bulletin No. 523, 47 pp.

Barrs, H. D. and Weatherly, P. E. C. (1962): Are-examination of relative turgidity technique for estimating water deficits in leaves. Aust. J. Bio. Sci., 15:413-428.

Bayoumi, T. Y.; Eid, M. H. and Metwali, E. M. (2008): Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes. African Journal of Biotechnology. 7(14), 2341- 2352.

Blokhina, O.; E. Virolainen and K. V. Fagerstedt (2003): Antioxidants, oxidative damage and oxygen deprivation stress: A review. Annals of Botany, 91: 179–194.

Bousba, R.; A. Djekoun and N. Ykhlef (2012): Protective enzyme system and osmoprotection in durum wheat (*Triticum durum*. Desf.) leaves under water deficit. International Journal of Management Sciences and Business Res., Vol. 1,: 2226-8235.

Cakmak I., (2005): The role of potassium in alleviating detrimental effects of abiotic stresses in plants, *J. Plant Nutr. Soil. Sci.,* 168, 521-530.

Chéour, F.; I. Kaddachi; D. Achouri; S. Bannour and L. Zorgui (2014): Effects of water stress on relative water, chlorophylls and proline contents in barley (*Hordeum vulgare* L.) leaves. J. Agric. And Veter. Sci., Vol.7 (6): 13-16.

Dahmardeh, K.; M. R. P. Rad; M. R. N. Rad and M. Hadizadeh (2015): Effects of potassium rates and irrigation regimes on the yield of forage sorghum in arid regions. Int. J. Agron. Agril. Res., 6 (4): 207-212.

Division of Agricultural Science Irrigation Costs (1978). University of California.

Dubois, M.; K. A. Gilles; J. K. Hamipton; P. A. Rebets and H. mith (1956): Colorimetric methods for determination of sugars and related substances. Analytical Chemistry, 28(3):350-356.

Duncan, D. B. (1955): Multiple range and multiple F.test Biometrics,11:1-24.

El-Seidy, E. H. E.; Kh. A. Amer; A. A. El-Gammaal and E. E. El-Shawy (2013): Growth analysis and yield response of barley as affected by irrigation regimes. Egypt. J. Agron. 35 (1), 1-19.

El-Sharkawy, H. M. and, F. M. Salama (1973): Response of olive and almond orchards to partial irrigation under dry farming practices in semi arid regions. Π- Plant soil water relations in olive during the growing season. Plant and Soil, 41:13-32.

Farshadfar, E; M. M. Poursiahbidi and S. M. Safavi. (2013): Assessment of drought tolerance in land races of bread wheat based on resistance / tolerance indices. International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 2, 143-158.

Foyer, C. H.; M. Lelandais and K. J. Kunert (1994): Photoxidative stress in plants. Physiol. Plant. 92:696–717. doi:10.1111/j.1399-3054.1994.tb 03042

Giriappa, S (1983): Water use efficiency in agriculture. Oxford-IBH Publishing Co, New Delhi.

Hussain AI Anwar, F; STH. Sherazi; R. Przybylski (2008): Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. Food Chem. 108,986-995.

Jarecki, W.; J. Buczek and D. Bobrecka-Jamro (2017): Response of spring wheat to different soil and foliar fertilization. J. of Central European Agriculture, 18(2), p.460-476.

John, L. J. and G. E. Lester. (2011): Effect of foliar potassium fertilization and source on cantaloupe yield and quality. Better Crops, 95(1): 13-15.

Kandhro, M. N.; B. A. Silachi; S. M. Bhatti ; N. N. Memon and A. W. Baloch (2016): Impact of potassium on growth and yield of barley *(Hordeum Vulgare L.*) under water deficit conditions. J. Agric. And Vet. Sci., 32(1) : 37-45. Pak.

Kheir, A. M. S (2013): Modeling for crop water productivity at north delta soils, Egypt. PhD. Thesis, Fac. of Agric. Mansoura Univ. Egypt.

Klute, A. (1986): Methods of Soil Analysis, (second ed.), American Society of Agronomy, Inc. Soil Science Society of America. Madison, Wisconsin. USA.

Lakshmi, K.; Shephalika, A. and Banisetti K.(2016). Genetic and Genomic Resources for Grain Cereals Improvement. Pages 125-157.

Lalić, A; S. Goreta Ban; S. Perica; D. Novoselović; I. Abičić; J. Kovačević; G. Šimić and V. Guberac (2017): The effect of water stress on some winter barley cultivars during early stages of plant growth. J. Poljoprivreda (1) 22-27.

Liu, W. Z.; D. J. Hunsaker; Y. S. Li; X. Q. Xie and G. W. Wall (2002): Interrelations of yield, evapotranspiration, and water use efficiency from marginal analysis of water production functions. Agricultural Water Management, 56, 143–151.

Mariey, S. and R. Khedr (2017): Evaluation of Some Egyptian Barley Cultivars under Water Stress Conditions Using Drought Tolerance Indices and Multivariate Analysis. J. Sus. Agric. Sci. Vol. 43, No. 2, pp. 105- 114

Marschner, P., (2012): Marschner's Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press:London, UK. pp: 178-189.

Mesbah, E. A. E. (2009): Effect of irrigation regimes and foliar spraying of potassium on yield, yield components and water use efficiency of wheat (*Triticum aestivum L.*) in sandy soils. World J. Agril. Sci., 5 (6): 662-669.

Minjian, C.; Y. Haiqui; Y. Hongkui and J. Chungi. (2007): Difference in tolerance to potassium deficiency between maize inbred lines. *Plant Prod. Sci.,* 10(1): 42-45.

Mirzaei, A.; R. Naseri and R. Soleimani (2011): Response of different growth stages of wheat to moisture tension in a semiarid land. World Appl. Sci. J. 12(1):83-89.

Moran, R. (1982): Formulae for determination of chlorophyllous pigments extracted with N,N-dimethylformamide. Plant Physiol.(69): 1376-1381.

Osman, H.S.M., (2009). Rationing water requirements of rice plant using some regulating compounds. Ph.D. Thesis, Faculty of Agriculture, Ain Shams University, Cairo, Egypt, p: 126.

Osman, M. E. H.; A. A. Mohsen; S. S. El-Feky and W. A. Mohamed (2017): Response of Salt-Stressed Wheat (*Triticum aestivum L.*) to Potassium Humate Treatment and Potassium Silicate Foliar Application. The 7th Inter. Conf."Plant & Microbial Biotech. & their Role in the Development of the Society"pp. 85 -102.

Page, A. L.; R. H. Miller and, D. R. Keeney (1982): Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. Second edition. Agronomy J. 9, 2, Am. Soc. Agron. Inc., Soil Sci. Soc. Am. Inc. Pub. Madison, Wisconsin, USA.

Quarrie, S. A. and H. G. Jones (1979): Genotypic variation in leaf water potential, stomatal conductance and abscisic acid concentration in spring wheat subjected to artificial drought stress. Ann. Bot.,44:323-327.

Serraj, R. and T. R. Sinclair (2002): Osmolyte accumulation: can it really help increase crop yield under drought conditions? Plant Cell Environ. 25, 333-341.

Shekhawat, P. S.; R. P. S. Shaktawat and D. S. Rathore (2013): Effect of nitrogen and potassium levels on growth and yield of barley (*Hordeum vulgare* L.) in loamy sand soil of Rajasthan, *Environ. Ecol.,* 31(3), 1303-1306.

Smirnoff, N. (1993): The role of active oxygen in the response of plants to water deficit and desiccation. New Phytol. 125:27–58.

Snedecor, G. W. and W. G. Cochran (1982): Statistical Methods 6th addition , Iowa state college press .Ams .Iowa, U.S.A.

Soliman, M. A. M.; A. M. O. El-Bawab and El-M. A. El-Kholy (2011): Productivity of some barley cultivars under different methods and amounts of irrigation water*, Int. J. Acad. Res*., 3(1), 43-51.

Thalooth, T.; A. A. Bahr and M. M. Tawfik (2012): Productivity of some barley cultivars as affected by inoculation under water stress conditions. Elixir Appl. Botany 51 (2012) 10743-10749.

Weatherly, P. E. (1950): Studies on the water relations of the cotton plants. I. The field measurement of water deficits in leaves. New Phytol., 49:81-97.

Zareian, A.; H. H. S. Abad and A. Hamidi (2014): Yield, yield components and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars under drought stress and potassium foliar application treatments. International Journal of Biosciences. Vol. 4, No. 5, p. 168-175.

Zhang, L.; M. Gao; Sh. Li; A. K. Ava and M. Ashrsf (2014): Potassium fertilization mitigates the adverse effects of drought on selected *Zea mays* cultivars. Turk J Bot. (2014) 38: 713-723.

استجابة نباتات الشعير للرش بالبوتاسيوم تحت ظروف نقص المياه

رانيا فاروق المنطاوى[1] و رامى محمد خليفة[2]
[1] قسم بحوث فسيولوجيا المحاصيل – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية
[2] قسم الاراضى– كلية الزراعة – جامعة دمياط

تم إجراء تجربة حقلية بمزرعة محطة البحوث الزراعية بسخا – محافظة كفر الشيخ خلال موسمى الشتاء 2015/2014 و 2016/2015 لدراسة تأثير مستويات الرش الورقى بالبوتاسيوم على النمو والمحصول ومكوناته وكفاءة إستخدام المياه علي مستوي الحقل وكذالك التقييم الإقتصادي لمحصول الشعير صنف جيزة 126 تحت ظروف نقص المياه. وقد صممت التجربة في قطع منشقة مرة واحدة فى أربعة مكررات حيث خصصت القطع الرئيسية لمعاملات الري وهى (عدد الريات الموصي به ، اعطاء ريتين كل 35 و 70 يوما من الزراعة، و اعطاء رية واحدة بعد 35 يوما من الزراعة) في حين خصصت القطع الفرعية لمعاملات الرش الورقى بالبوتاسيوم (بدون رش، 1% ، 2٪ ، 3٪). وقد أظهرت النتائج أن زيادة الإجهاد المائي تؤثر بشكل كبير على صفات النمو وأصباغ التمثيل الضوئي وتراكم المادة الجافة ومساحة ورقة العلم ومحتوى الماء النسبي والمحصول ومكوناته ومحتوى الكربوهيدرات. من ناحية أخرى، أظهرت النباتات تحت ظروف الإجهاد المائي زيادة ملحوظة في نسبة بروتين الحبوب. علي الجانب الأخر أدى الرش بأكسيد البوتاسيوم الى زيادة ملحوظه فى معظم صفات النمو وكذلك جودة الحبوب في الشعير. وأوضحت النتائج انه يمكن تحقيق كفاءة عالية لإستخدام المياه علي مستوي الحقل باستخدام معاملة (الري مرتين عند 35 و70 يوم او بالري مرة واحدة بعد 35 يوم من الزراعة مع تطبق الرش الورقي باكسيد البوتاسيوم باي من التركيزات التالية (1% او 2% او 3%) بدون نقص واضح في انتاجية المحصول. وأيضاً لتعظيم الجدوي الاقتصادية من المحصول.