J. Plant Production, Mansoura Univ., Vol. 9 (12): 1157- 1165, 2018

Response of some Field Crops to Foliar Spray by Potassium on Growth, Productivity and Economic Feasibility under Saline Soils Conditions

El-Hawary, M. M.[1*]; M. H. El-Kholy[2] and G. A. M. Ibrahim[3]
[1] Crop Physiology Research Department, Field Crops Research Institute, ARC, 12619, Egypt.
[2] Plant Nutrition and Soil Fertility Research Department, Soils, Water and Environment Research Institute, ARC, Egypt.
[3] Economic Studies Department, Desert Research Center, 11753, Egypt.
***Corresponding author: mhawaryy@yahoo.com**

ABSTRACT

A field trail was conducted at three sites in East Delta Region, Egypt, during the two successive summer seasons 2015 and 2016 as well as winter seasons 2015/2016 and 2016/2017 to study the physiological response of some field crops grown under saline soil conditions to foliar spraying with potassium at 1 and 2% K_2O in the form of K-leaf fertilizer besides control treatment. Results indicated that plant height, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), photosynthetic pigments, soluble sugars, potassium content in leaves, potassium and protein percentages in grains or seeds, as well as yield and yield components for all crops under study were significantly increased when plants received 1% or 2% K_2O. Also, significant increase was achieved in proline, Na^+, and Na^+/K^+ ratio in leaves when plants sprayed with water (control) as compared with other potassium treatments for all crops wheat, barley, faba bean, rice, maize and clover. Foliar spraying with 2% K_2O as K-leaf fertilizer was more efficient for increasing growth, biochemical, potassium percentage, protein percentage and yield of wheat, barley, faba bean, rice, maize and clover crops as compared to untreated potassium fertilizer (control) under saline soils conditions.

Keywords: Foliar potassium, salt stress, physiological parameters, field crops.

INTRODUCTION

Nutrients are requiring for plants physiological and biochemical processes maintenance. These elements availability is often insufficient in soils and must be supplied as fertilizers and essential inputs for the successful crop growth and production. One of the three major macronutrients, potassium (K) has a special position as evident by its role in increasing the yield (Yadav *et al*., 2003 and Read *et al*., 2006) by increasing tolerance to all plants biotic and abiotic stresses. K plays a vital role in plants growth and yield as it is affected in assimilation, transport and storage tissue development (Cakmak 2005), it plays a role in various enzymes metabolic processes and stomata conductance (Hawkesford *et al*., 2012), also has an effect on nitrogen fixation and translocation of plant photosynthetic compounds from leaves to other parts (Savani *et al*., 1995).

Under salt stress, K helps to maintain ion homeostasis and to regulate the osmotic balance. Many reports supported that K enhances antioxidant defense in plants and therefore protects them from oxidative stress under various environmental adversities (Cakmak 2005 and Cha-um *et al*., 2010). In addition, this element provides some cellular signaling alone or in association with other signaling molecules and phytohormones (Hasanuzzaman *et al*., 2018).

Nowadays, potassium fertilization became an important factor for crops production under Egyptian soils. Moreover, potassium fertilizers price is getting higher and becoming unaffordable by farmers, subsequently, foliar spraying of potassium is more suitable, target oriented and economical technique for increasing the fertilizer use efficiency and grain yield over soil application (El Kholy *et al*., 2003; Farooqi *et al*., 2012). However, foliar fertilization with potassium is more economical than soil fertilizations due to the efficiency and lower cost.

Potassium sulfate fertilizer is authorized use in Egypt, according to the research, which has in previous years in partnership with the International Potassium Institute (IPI). Its unique properties allow growers to apply foliar sprays with maximum efficiency, providing fast potassium nutrition and quick correction in the event of a deficiency.

K-Leaf™ is a brand new, fast dissolving, highly soluble sulphate of potash (SOP) fertilizer, especially developed by Tessenderlo Group for foliar application. Moreover, K-Leaf™ may improve root uptake of potassium if the soil has a high fixation capacity for the nutrient. As a supplement to broadcast soil application of fertilizer, foliar application of K-Leaf™ offers a cost-effective means of achieving the highest quality crops. At the same time as assisting growers to produce crops with maximum export value, K-Leaf™ helps to optimize crop yield and protect sensitive environments. K-Leaf™ combines the essential nutrients potassium and sulphur in an optimal form that is highly soluble and readily available to plants. K-Leaf™ foliar sprays have proved to be effective in curing or preventing potassium deficiency in many crops when plant potassium demand is very high (e.g. during tuber, grain or fruit formation and growth) and when the soil has a high potassium fixation capacity and potassium uptake by the roots is limited.

The main objective of the present study was to evaluate using K- Leaf fertilizer at various concentrations on growth, yield and quality of some field crops and its impact on economic feasibility under salt affected soils.

MATERIALS AND METHODS

The present work was carried out at East Delta region, Egypt in three sites during the two successive summer seasons of 2015 and 2016 as well as winter seasons of 2015/2016 and 2016/2017 to study the physiological response of some field crops grown in saline soil to foliar spraying with potassium at various concentrations (1 and 2 % K2O) besides control treatment (without potassium application) in the form of K-leaf (ultra-fine powder; 52% K2O; 56% SO4; 18% S and 0.3% Cl) and their effect on growth, yield, yield components, photosynthetic pigments, soluble sugars and proline contents, Na+/K+ ratio, potassium and protein percentage in grains or seeds.

The field crops and their cultivated cultivars, seasons, sites of the experiment as well as times of potassium application are presented in Table 1.

Table 1. Sites, location, field crops, cultivars, season and time of potassium application.

Site No.	Location	Crop	Cultivars	Seasons	Time of potassium application
(1)	31° 08′ 20″ N 32° 17′ 29″ E	wheat	Masr 1	2015/2016 &	40 & 55 DAS*
		clover	Serw 1	2016/2017	15 day after each cut
		maize	Three way cross 352	2015 and 2016	30 & 45 DAS
(2)	31° 00′ 32″ N 32° 08′ 15″ E	faba bean	Giza 3	2015/2016 & 2016/2017	40 & 55 DAS
		rice	Shaka 101	2015 and 2016	40 & 55 DAS
(3)	31° 00′ 07″ N 32° 09′ 41″ E	barley	Giza 123	2015/2016 & 2016/2017	35 & 50 DAS

***DAS: Days after sowing.**

The experiment was laid out in randomized complete block design (RCBD) with four replicates and each plot was 10.5 m^2.

Some physical and chemical properties of the experimental sites in the two seasons are presented in Table 2.

Table 2. Physical and chemical properties of the experimental sites.

Site	Season	EC dSm^{-1}	pH (1:2.5)	Texture	Cations (ml equevlant/L)				Anions (ml equevlant/L)		
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-}
Site 1	1st	5.1	7.93	clay	5.26	7.78	36.11	1.98	1.40	30.26	19.48
	2nd	4.9	8.04	clay	8.10	6.96	32.81	1.13	5.08	27.41	16.51
Site 2	1st	6.5	8.20	clay	10.00	17.91	54.93	1.54	1.68	60.75	21.95
	2nd	6.2	8.20	clay	10.00	17.71	51.93	1.55	1.68	57.75	21.76
Site 3	1st	9.5	7.93	clay	12.08	19.28	67.28	1.11	2.33	60.90	36.52
	2nd	9.2	8.16	clay	8.68	15.7	71.11	1.12	2.36	63.48	30.77

Field crops were sown on the recommended sowing time. P_2O_5 was added in the form of calcium super phosphate (15.5% P_2O_5) during soil preparation as recommended dose for each crop. Nitrogen fertilizer was added in the form of urea (46% N) at the recommended dose for every crop under study.

Other, cultural practices were applied according to the methods being adopted for every growing crop under study in the locality.

To determined growth traits, five plants were randomly taken from each plot at three different stages after sowing at suitable time for each crop under study. Plants were dried at 70 °C in the oven to a constant weight. According to Hunt (1990) formulas, the following traits were determined:

- Plant height (cm).
- Leaf area index (LAI) = leaf area per plant/ground area.
- Net assimilation rate, in g/m^2/day (NAR)= $(W_2-W_1)(\log_e A_2-\log_e A_1)/(A_2-A_1)(t_2-t_1)$.
- Crop growth rate, in g/day/m^2 (CGR) = $(W_2-W_1)/(t_2-t_1)$.

Where:

- **A_2-A_1= differences in leaf area between two samples.**
- **W_2-W_1= differences in dry matter accumulation of whole plants between two samples in (g).**
- **t_2-t_1= Number of days between two successive samples (day).**
- **Log_e = Natural logarithm.**

At suitable time (mentioned in results) for each crop the following traits were determined:

- Chlorophyll a, chl b and carotenoids) in mg/g fresh weight, according to Metzener *et al.* (1965).
- Soluble sugars using modifications of the procedures by Yemm and Willis (1954).
- Leaf proline content, in µg/g fresh weight, according to Bates *et al*. (1973).
- Potassium, sodium contents and Na^+/K^+ ratio in plants leaves as mmole/kg dry weight, according to Allen *et al.* (1974).

At harvest time, yield and yield components were determined for each crop under study as well as potassium and protein percentage in grains and/or seeds, according to Horneck and Miller (1998).

Economic analysis; total cost of production of studied crops included the expenses on seed/grain, soil preparation, sowing and all other agronomic operations. Net benefit, gross revenue and benefit cost ratio were derived from the data collected.

Data of the two seasons were subjected to statistical analysis of variance according to Steel and Torrie (1980). The treatments average was compared using LSD test at 0.05 level of significant.

RESULTS AND DISCUSSION

- Growth and growth analysis:

Data in Table 3 shows the plant height, crop growth rate (CGR) and net assimilation rate (NAR) in six field crops after treated with foliar spraying with potassium. The plant height values of studied crops were increased when plants treated with both rates of foliar spray by potassium as compared with untreated plants (control) in the two seasons. The increase in plant height increased with increasing potassium rate from 1 to 2 % K_2O. In the same trend CGR and NAR were increased significantly when plants treated with 1% K_2O and 2% K_2O as compared with control treatment in the two seasons for wheat, barley, faba bean, rice, maize as well as clover cuts. Damon and Rengel (2008) reported that higher crop growth rate might be exhibited due to higher photosynthetic efficiency in leaves with increasing K uptake and supplied emerging corps with existing photosynthates for proper filling, producing higher yield. However, the activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is probably more important in regulating the rate of photosynthesis than is the role of K in stomatal activity. Akram *et al.* (2010) reported that potassium accelerated the net assimilation rate (NAR). These results stand in harmony with those obtained by Aown *et al.* (2012); Ali *et al.* (2016).

Leaf area index of studied field crops at three stages was presented in Table 4. The data shows that LAI values were increased significantly in plants treated with 1% & 2% K_2O as compared with untreated plants (control) in the two seasons. This increase was also pronounced in all studied stages of wheat, barley, faba bean, rice, maize as well as at different cuts of clover. This increase is mainly due to the production of new leaves and leaves expansion

through the growth of plants. Munns and Tester (2008) reviewed that plants have a Na^+ exclusion mechanism that maintains a low level of Na^+ in the leaves during salt stress; thus, the major osmoticum in leaves was K^+, where K^+ plays an important role in maintaining cell turgor and osmotic adjustment. Also, potassium activate at least 60 different enzymes involved in plant growth (Robert, 2005). In this connection, Abdel-Aziz and El-Bialy (2004) and Amanullah *et al.* (2016) found that spraying 3% K_2O on maize plants significantly increased LAI.

Table 3. Plant height, crop growth rate (CGR) and net assimilation rate (NAR) of some field crops as affected by foliar spraying with potassium in saline soil for two seasons.

Treatments		Plant height (cm)		CGR (g/day/m²)				NAR (g/m²/day)			
Crop	Potassium	Season		Season		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
				(65-80 day)		(80- 95 day)		(65-80 day)		(80- 95 day)	
	Control	90.50	91.00	13.52	13.59	16.31	16.37	10.08	10.15	11.21	11.25
Wheat	1 % K_2O	91.50	92.00	14.80	14.88	17.47	17.55	10.99	11.04	11.97	12.02
	2 % K_2O	92.25	92.50	14.99	15.08	18.00	18.08	11.27	11.31	12.19	12.24
	LSD 0.05	1.65	0.92	0.18	0.22	0.18	0.19	0.20	0.19	0.20	0.20
				(60-75 day)		(75-90 day)		(60-75 day)		(75-90 day)	
	Control	75.63	75.75	10.28	10.33	11.41	11.46	7.89	7.89	7.20	11.25
Barley	1 % K_2O	76.13	76.25	11.03	11.08	12.00	12.07	8.59	8.59	7.91	12.02
	2 % K_2O	76.38	76.50	11.39	11.44	12.20	12.28	8.69	8.69	8.00	12.24
	LSD 0.05	0.69	0.75	0.20	0.21	0.19	0.19	0.20	0.20	0.22	0.20
				(65-80 day)		(80- 95 day)		(65-80 day)		(80- 95 day)	
	Control	104.8	106.0	11.28	11.33	12.09	12.14	11.07	11.13	13.30	13.35
Faba bean	1 % K_2O	108.0	110.0	11.98	12.04	12.77	12.83	11.87	11.96	14.00	14.10
	2 % K_2O	109.8	112.0	12.48	12.54	13.26	13.33	12.18	12.27	14.68	14.78
	LSD 0.05	4.45	5.40	0.20	0.22	0.20	0.20	0.21	0.20	0.20	0.21
				(65-80 day)		(80- 95 day)		(65-80 day)		(80- 95 day)	
	Control	86.75	87.25	21.29	21.41	27.85	28.09	8.18	8.25	9.38	9.44
Rice	1 % K_2O	87.50	88.00	21.55	21.69	28.09	28.33	8.80	8.89	10.00	10.10
	2 % K_2O	88.00	88.50	21.80	21.93	28.29	28.50	9.09	9.17	10.39	10.48
	LSD 0.05	1.13	1.18	0.45	0.42	0.49	0.32	0.19	0.18	0.19	0.20
				(55-70 day)		(70-85 day)		(55-70 day)		(70-85 day)	
	Control	270.5	272.0	30.43	31.02	26.96	27.30	14.86	15.06	11.81	12.03
Maize	1 % K_2O	280.0	282.5	32.71	33.39	29.34	29.69	15.88	15.88	12.73	13.02
	2 % K_2O	285.8	288.3	33.34	33.94	30.97	31.21	16.62	16.62	13.13	13.44
	LSD 0.05	7.3	6.7	0.63	0.50	0.45	0.52	0.47	0.41	0.31	0.27
				Plant height (cm)				CGR (g/d/m2)			
		2nd cut		3rd cut		4th cut		2nd cut (30-45)		3rd cut (25-40)	
	Control	64.50	65.50	70.50	71.00	61.50	62.75	19.38	19.47	23.39	23.47
	1 % K_2O	69.50	70.63	76.50	77.38	67.50	68.75	20.47	20.58	25.18	25.28
	2 % K_2O	70.50	71.63	77.50	78.63	69.50	70.88	21.38	21.48	26.07	26.19
	LSD 0.05	2.07	2.29	2.06	1.84	2.07	2.34	0.21	0.22	0.19	0.20
Clover		CGR (g/d/m2)		NAR (g/m2/day)							
		4th cut (25-40)		2nd cut (30-45)		3rd cut (25-40)		4th cut (25-40)			
	Control	22.07	22.18	7.37	7.52	9.28	9.39	8.88	9.00		
	1 % K_2O	24.00	24.13	8.07	8.23	10.17	10.33	9.67	9.83		
	2 % K_2O	24.68	24.81	8.37	8.53	10.57	10.72	10.07	10.23		
	LSD 0.05	0.19	0.21	0.21	0.21	0.20	0.19	0.21	0.18		

- **Photosynthetic pigments**

Photosynthetic pigments (chlorophyll a, b and carotenoids) contents of studied crops were shown in Table 5. Photosynthetic pigments were increased significantly when plants treated with 1% & 2% K_2O as compared with untreated plants (control) in the two seasons for wheat, barley, faba bean, rice, maize as well as clover at selected times. This result may be due to that potassium activates the enzymes involved in leaf pigments formation.

In this concern, Yagmur *et al.* (2007) reported that potassium application had positive effects on salinity and alleviated negative effects of salinity on chlorophyll a &b and carotenoids contents of wheat plants. El-Tohamy *et al.* (2006) reported that foliar application of potassium reduced electrolyte leakage, thus increased total chlorophyll content as compared to untreated plants (control). However, foliar application of potassium appeared to be the most effective treatment, improving stomatal conductance and protecting the photosynthetic apparatus, which resulted in maintenance of net photosynthesis compounds rate under salt stress conditions and alleviation of negative effects of salinity. This might be attributed to the efficacy of sulfur present in K-leaf, which is involved in chlorophyll synthesis, resulting in increased photosynthetic rate (Kumar *et al.,* 2008). These results are agreeing with the findings of Vigay *et al.*, (2009); Hussein *et al*., (2012) and El-Hawary and El-Shafey (2016).

Soluble sugars, proline, Na^+, K^+ and Na^+/K^+ ratio content

The contents of soluble sugars, proline, Na^+, K^+ and Na^+/K^+ ratio in leaves of different crops plants under study treated with foliar spray of potassium were shown in Table 6. Soluble sugars and potassium contents were increased in plants treated with foliar spray of potassium and this increase were increased with increasing potassium concentration from 1 to 2 % K_2O in the two seasons, while proline, sodium and Na^+/K^+ ratio were decreased by foliar application of potassium and the highest decrease obtained with plants treated by 2% K_2O in the two seasons for wheat, barley, faba bean, rice, maize and clover. However, absorption of potassium can be significantly increased due to the presence of sulfur (Farrag *et al.*, 1990). These results are in harmony with those obtained by El-Hawary and El-Shafey (2016) and Rajitha *et al.,* (2018).

Table 4. Leaf area index (LAI) of some field crops as affected by foliar spraying with potassium in saline soil for two seasons.

Treatments		Leaf area index (LAI)					
Crop	Potassium	Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd
		(65 day)		(80 day)		(95 day)	
	Control	2.69	2.74	3.08	3.13	3.31	3.37
Wheat	1 % K_2O	2.92	2.97	3.28	3.34	3.59	3.65
	2 % K_2O	3.00	3.05	3.33	3.39	3.68	3.75
	LSD 0.05	0.23	0.20	0.19	0.21	0.19	0.15
		(60 day)		(75 day)		(90 day)	
	Control	1.35	1.39	1.90	1.95	1.72	1.77
Barley	1 % K_2O	1.48	1.53	2.10	2.16	1.89	1.94
	2 % K_2O	1.52	1.58	2.19	2.25	1.97	2.02
	LSD 0.05	0.17	0.18	0.20	0.21	0.19	0.21
		(65 day)		(80 day)		(95 day)	
	Control	2.68	2.73	3.15	3.20	3.88	3.92
Faba bean	1 % K_2O	2.89	2.95	3.38	3.44	4.12	4.18
	2 % K_2O	2.97	3.05	3.47	3.54	4.47	4.54
	LSD 0.05	0.20	0.21	0.18	0.21	0.23	0.24
		(65 day)		(80 day)		(95 day)	
	Control	2.35	2.39	2.69	2.73	2.97	3.02
Rice	1 % K_2O	2.44	2.50	2.81	2.85	3.10	3.18
	2 % K_2O	2.59	2.64	2.91	2.96	3.21	3.30
	LSD 0.05	0.15	0.17	0.16	0.19	0.21	0.17
		(55 day)		(70 day)		(85 day)	
	Control	3.78	3.81	5.10	5.14	5.37	5.43
Maize	1 % K_2O	3.99	4.03	5.49	5.53	5.68	5.74
	2 % K_2O	4.11	4.15	5.58	5.63	5.80	5.87
	LSD 0.05	0.19	0.20	0.20	0.21	0.20	0.19
		(2nd cut 45 day)		(3rd cut 40 day)		(4th cut 40 day)	
	Control	2.17	2.23	2.37	2.44	2.07	2.13
Clover	1 % K_2O	2.37	2.43	2.57	2.63	2.26	2.34
	2 % K_2O	2.48	2.54	2.77	2.84	2.37	2.44
	LSD 0.05	0.21	0.21	0.21	0.20	0.21	0.22

Table 5. Photosynthetic pigments (Chl a, Chl b and carotenoids) contents in leaves of some field crops as affected by foliar application of potassium in saline soil for two seasons.

Treatments		Chl a (mg /g FW)		Chl b (mg /g FW)		Carotenoids (mg /g FW)	
Crop	Potassium	Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd
	Control	0.327	0.333	0.132	0.139	0.071	0.074
Wheat	1 % K_2O	0.348	0.354	0.140	0.147	0.076	0.079
(80 day)	2 % K_2O	0.353	0.359	0.146	0.153	0.079	0.082
	LSD 0.05	0.020	0.020	0.020	0.021	0.018	0.018
	Control	0.291	0.300	0.119	0.123	0.065	0.066
Barley	1 % K_2O	0.311	0.320	0.128	0.132	0.075	0.079
(75 day)	2 % K_2O	0.319	0.328	0.130	0.134	0.078	0.081
	LSD 0.05	0.021	0.020	0.018	0.018	0.010	0.011
	Control	1.240	1.310	0.639	0.648	0.109	0.122
Faba bean	1 % K_2O	1.328	1.400	0.687	0.696	0.129	0.138
(80 day)	2 % K_2O	1.395	1.450	0.700	0.709	0.140	0.151
	LSD 0.05	0.19	0.17	0.020	0.021	0.023	0.021
	Control	0.328	0.336	0.120	0.123	0.061	0.064
Rice	1 % K_2O	0.359	0.366	0.131	0.135	0.067	0.070
(80 day)	2 % K_2O	0.370	0.378	0.135	0.139	0.071	0.074
	LSD 0.05	0.021	0.018	0.017	0.017	0.015	0.015
	Control	1.264	1.278	0.668	0.675	0.111	0.115
Maize	1 % K_2O	1.359	1.465	0.717	0.728	0.127	0.135
(70 day)	2 % K_2O	1.400	1.510	0.748	0.760	0.137	0.143
	LSD 0.05	0.07	0.13	0.022	0.021	0.019	0.019
	Control	0.658	0.671	0.417	0.432	0.115	0.120
Clover	1 % K_2O	0.699	0.713	0.458	0.473	0.129	0.133
(3rd cut 40 day)	2 % K_2O	0.708	0.722	0.467	0.483	0.135	0.140
	LSD 0.05	0.020	0.018	0.021	0.020	0.016	0.019

Table 6. Soluble sugars, proline, Na^+, K^+ and Na^+/K^+ ratio content in leaves of some field crops as affected by foliar spraying with potassium in saline soil for two seasons.

Treatments		Soluble sugars (mg glucose equivelant /g dry tissue)		Proline (µg/g FW)		Na^+ Leaf content (mmole/kg)		K^+ Leaf content (mmole/kg)		Na^+/K^+ ratio	
Crop	Potassium	Season		Season		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Control	21.32	21.47	90.5	88.8	450	447	483	487	0.93	0.92
Wheat	1 % K_2O	22.53	22.63	76.3	74.0	419	409	658	663	0.64	0.62
(80 day)	2 % K_2O	23.29	23.43	75.0	72.5	391	386	679	684	0.58	0.56
	LSD 0.05	0.22	0.21	11.2	12.7	20	19	21	21	0.04	0.04
	Control	15.61	15.68	134.8	133.3	502	501	499	505	1.01	0.99
Barley	1 % K_2O	16.70	16.79	121.0	119.5	488	479	678	683	0.72	0.70
(75 day)	2 % K_2O	17.20	17.29	116.8	115.8	450	440	681	687	0.66	0.64
	LSD 0.05	0.19	0.19	11.3	13.8	19.8	20.1	23.3	23.1	0.08	0.07
	Control	22.49	22.56	84.5	81.8	391	390	447	450	0.88	0.87
Faba bean	1 % K_2O	23.79	23.89	77.8	72.8	340	337	499	507	0.68	0.66
(80 day)	2 % K_2O	24.48	24.58	72.3	66.0	323	316	558	566	0.58	0.56
	LSD 0.05	0.21	0.19	6.04	5.10	18.7	19.3	19.7	20.2	0.05	0.05
	Control	20.16	20.23	93.8	93.3	434	427	501	507	0.87	0.84
Rice	1 % K_2O	22.24	22.30	81.0	78.5	399	391	602	609	0.66	0.64
(80 day)	2 % K_2O	22.70	22.76	78.3	75.3	371	359	649	656	0.57	0.55
	LSD 0.05	0.33	0.32	11.4	11.5	17.9	17.7	16.8	19.1	0.04	0.04
	Control	33.41	33.53	80.8	79.0	305	299	469	473	0.65	0.63
Maize	1 % K_2O	35.80	35.92	75.5	73.0	287	280	607	613	0.47	0.46
(70 day)	2 % K_2O	36.38	36.51	72.5	69.5	247	240	661	667	0.37	0.36
	LSD 0.05	0.18	0.19	2.30	2.90	18.5	17.6	20.3	20.1	0.04	0.05
	Control	8.27	8.33	74.0	71.8	338	331	428	433	0.79	0.76
Clover	1 % K_2O	9.07	9.14	65.8	63.0	317	310	536	544	0.59	0.57
(3rd cut 40 day)	2 % K_2O	9.37	9.44	63.0	60.3	307	297	617	625	0.50	0.48
	LSD 0.05	0.20	0.22	6.14	6.02	21.5	21.1	20.8	20.9	0.05	0.04

- Yield and yield components

The yield and its components of studied field crops treated with foliar spray of potassium were shown in Table 7. The yield and its attributes in wheat, barley, faba bean, rice and maize at harvest time as well as the fresh weight of clover at each cut were increased to somewhat significantly when plants treated by 1% & 2% K_2O as compared to control in the two seasons for all crops under study. The better yield of all crops in the present study under saline conditions could be due to the presence of sulfur in K-leaf which results in enhanced starch accumulation and higher dry matter production in wheat plants (Kumar *et al.,* 2008). Grain yield increased by potassium fertilizer due to improving of enzymes activity in the plant, which leads to increasing translocation of photosynthates compounds from plant leaves to grains (Hussein, 2005; Mesbah, 2009 and Hasina *et al*., 2011). Abdi *et al.* (2002) concluded that foliar spraying with potassium increased 1000 grain weight as a result of nutrients availability which increased the enzyme activation, subsequently easily nutrients translocation from plant leaves to grains compared to soil applied potassium fertilizers exhibited the loss of nutrients via leaching and volatilization. Our findings are in harmonious with those reported by Aboelgoud *et al*. (2015) and Abbas and Awad (2018) on clover; Thalooth *et al.* (2006) on mungbean; Aown *et al.* (2012); Ashraf *et al.* (2013); Kumar *et al.* (2016) on wheat; Ali *et al*. (2016); Gowthami *et al*. (2018) on soybean; Khedr *et al.* (2016) on barley; Zayed *et al.* (2011); El-Hawary and El-Shafey (2016) on rice. Such enhancement effect could be attributed to the favorable effect of nutrient on metabolism and biological activity and its stimulating affection photosynynthetic pigments and enzyme activity that increase plants growth (Tausz *et al.,* 2004).

Table 7. Yield and yield components of some field crops as affected by foliar spraying with potassium in saline soil for two seasons.

Treatments		Yield and yield components											
Crop	Potassium	Season		Season		Season		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
		Spike length (cm)		Spike weight (g)		1000- grain weight (g)		Grain yield (t/fed)		Straw yield (t/fed)		Harvest index	
Wheat	Control	11.9	12.0	4.01	4.04	47.8	48.5	2.83	2.89	4.80	4.89	37.1	37.2
	1 % K_2O	12.3	12.4	4.37	4.42	51.3	52.0	3.14	321	4.93	4.96	38.9	39.2
	2 % K_2O	12.4	12.5	4.49	4.54	53.1	53.8	3.24	3.35	4.95	5.00	39.5	40.1
	LSD 0.05	0.57	0.58	0.16	0.17	0.71	1.23	0.12	0.11	0.10	0.13	0.70	0.50
Barley	Control	7.75	7.88	2.39	2.48	32.5	32.6	1.34	1.36	317	3.20	29.8	29.9
	1 % K_2O	8.13	8.25	2.61	2.70	33.7	33.7	1.47	1.50	3.21	3.26	31.4	31.5
	2 % K_2O	8.25	8.38	2.79	2.88	34.1	34.1	1.50	1.52	3.24	3.27	31.6	31.8
	LSD 0.05	0.44	0.42	0.19	0.18	0.21	0.19	0.03	0.07	0.07	0.07	0.59	0.94
		No. of pods / plant		No. of seeds / plant		100- seed weight (g)		Seed yield (t/fed)		Straw yield (t/fed)		Harvest index	
Faba bean	Control	17.5	18.0	46.5	47.5	86.4	86.6	1.19	1.22	1.55	1.58	36.4	48.5
	1 % K_2O	19.5	20.3	52.5	54.3	93.7	93.9	1.38	1.41	1.59	1.66	38.2	52.0
	2 % K_2O	20.5	21.3	54.5	56.3	94.1	94.5	1.53	1.56	1.63	1.68	38.6	53.8
	LSD 0.05	2.07	2.35	2.07	2.03	1.54	1.41	0.04	0.05	0.09	0.08	1.84	1.39
		Panicle length (cm)		Panicle weight (g)		1000- grain weight (g)		Grain yield (t/fed)		Straw yield (t/fed)		Harvest index	
Rice	Control	21.8	21.9	3.99	4.06	27.5	27.5	2.55	2.61	6.40	6.43	28.5	28.9
	1 % K_2O	22.5	22.6	4.25	4.33	29.1	29.2	2.81	2.87	6.61	6.64	29.8	30.2
	2 % K_2O	22.6	22.9	4.31	4.39	29.5	29.6	2.92	3.00	6.63	6.68	30.6	31.0
	LSD 0.05	0.64	0.67	0.16	0.18	0.20	0.20	0.18	0.19	0.18	0.18	1.81	1.78
		Ear length (cm)		Grain weight /ear (g)		100- grain weight (g)		Grain yield (t/fed)		Straw yield (t/fed)		Harvest index	
Maize	Control	21.5	21.6	231	236	38.2	38.3	2.80	2.84	3.87	3.90	42.0	42.2
	1 % K_2O	23.0	23.5	256	263	40.7	40.8	3.00	3.05	3.89	3.91	43.5	43.8
	2 % K_2O	24.0	24.5	261	269	42.0	42.1	3.06	3.12	3.90	3.91	44.0	44.4
	LSD 0.05	0.65	0.69	18.6	17.0	0.21	0.22	0.17	0.16	0.26	0.12	1.60	1.50
		Fresh weight (t/fed)											
		2nd cut 45 day		3rd cut 40 day		4th cut 40 day							
Clover	Control	13.10	13.21	13.36	13.39	12.24	12.27						
	1 % K_2O	14.06	14.10	14.23	14.32	13.11	13.19						
	2 % K_2O	14.91	14.99	15.11	15.15	14.02	14.07						
	LSD 0.05	0.18	0.18	0.15	0.14	0.20	0.17						

Potassium and protein percentages in grains/seeds.

Potassium and protein percentages in grains/seeds of studied crops were presented in Figure 1. K and protein percentages were significantly increased when plants treated with foliar potassium and this increase increased with increasing the concentration of applied foliar spray of potassium. The highest values of K and protein percentages were achieved from foliar application of 2 % K_2O for all crops under study in the two seasons. Recently, Bellaloui *et al.* (2013) stated that potassium content in plant leaves and seeds increased as a result of raising potassium application rate. The increase in protein was also accompanied by increasing K in leaf tissues and seeds. These results were in agreement with previous studies Magen (1997), Bellaloui *et al*. (2010 and 2013) and Pande *et al*. (2014), they observed an increase in protein percentage with higher K levels. Potassium is directly or indirectly involved in plant protein metabolism (Blevins 1985), with K crucial in most steps of protein synthesis (Evans and Wildes, 1971 and Blevins 1985). John and Lester (2011) concluded that foliar spraying with potassium increased protein content in grains/seeds due to the higher availability of nutrients to cereals crops.

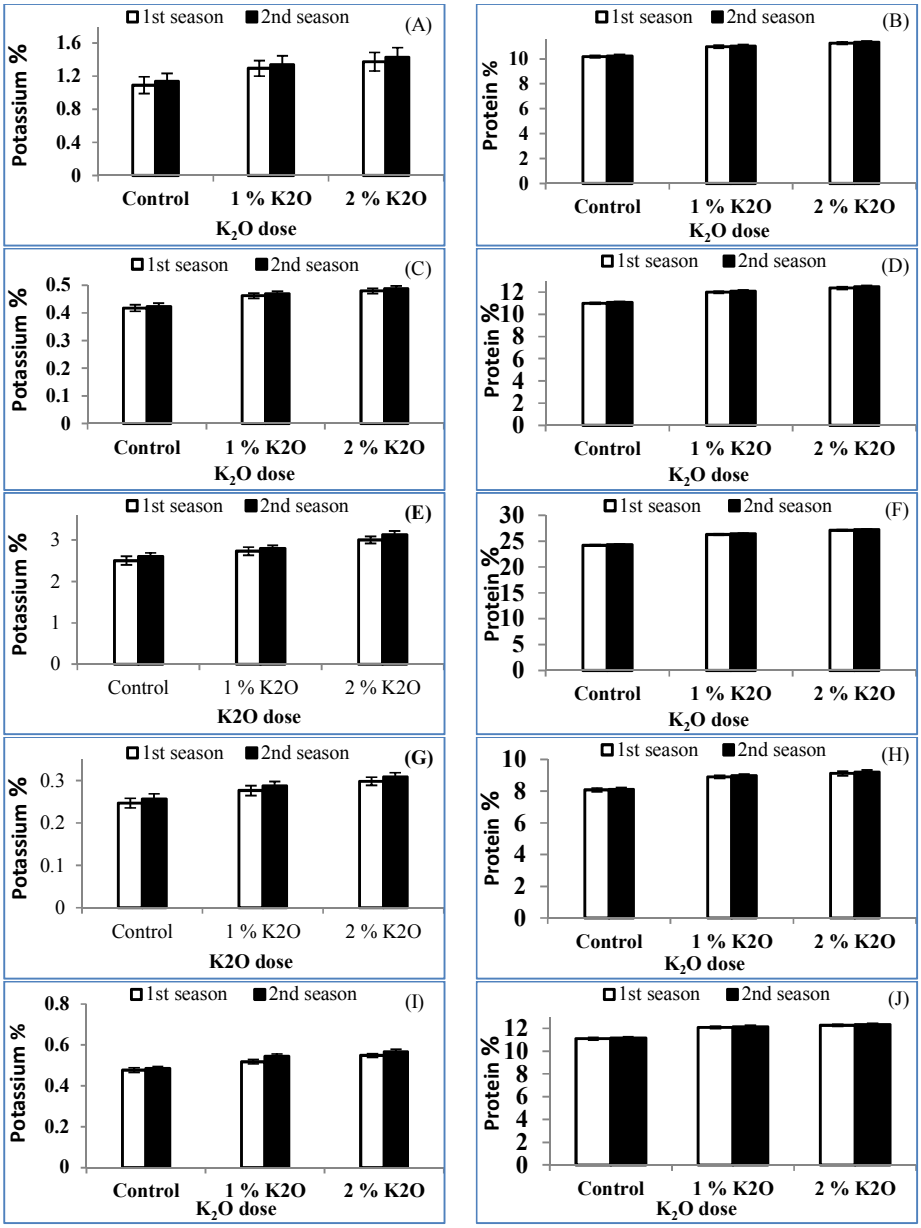

Fig. 1. Effect of foliar spray by potassium on potassium and protein percentages in grains/seeds of some field crops. i.e., wheat A and B; barley C and D; faba bean E and F; rice G and H; maize I and J.

Economic efficiency indicators

Data in Table (8) shows that the average total revenue values of wheat crop are 12752.1, 13823.5 and 14231.1 pounds per feddan for control, 1% and 2% K_2O, respectively, representing 93.7, 101.6 and 104.6% of the average gross revenue. For barley crop the average total revenue values are 8068.7, 8678.2, 8823.1 pounds per feddan, respectively, accounting 94.7, 101.8 and 103.5% of the average gross revenue. Faba beans shows 8372.4, 9591.8, 10533.4 pounds for 0, 1 and 2 % K_2O respectively, representing 87.9%, 100.8%, 110.6% of the of the average gross revenue. For rice yield reached 8699.9, 9493.8 and 9847.5 pounds per feddan respectively, representing 93.1%, 101.6%, 105.4% of the total value of the total revenue. However, for maize yield reached 6625.3, 7056.9 and 7208.4 pounds per feddan respectively, representing 95.1, 101.3, 103.5% of the total value of the total revenue. Also, clover crop shows the average total revenue values 7499.4, 8021.4 and 8531.8 pounds per feddan for 0, 1 and 2 % K_2O respectively, representing 93.5, 100.1, 106.4% of the average gross revenue. The decreasing percentage coefficient of variation between the average total revenue of the three treatments of the study crops means the low dispersion and non-fluctuation of the revenue values. This indicates the increase in economic feasibility when using foliar potassium.

- **Economic efficiency indicators:** Data in Table 9 show the economic efficiency indicators of the studied field crops, net revenues per feddan for wheat were 8332.1, 9331.5 and 9667.8 LE when plants treated with 0, 1 and 2 % K_2O respectively. For the return on investment pound of wheat crop, the values were 1.89, 2.08 and 2.12 LE when plants treated with 0, 1 and 2 % K_2O respectively. The producer profit margin percentage of wheat crop were 65.3, 67.5, 67.9% when plants treated with 0, 1 and 2 % K_2O respectively. For barley crop, the net revenues were 4819.7, 5357.2 and 5430.1 LE fed^{-1};

the return on investment pound were 1.48, 1.61 and 1.60 LE; the producer profit margin were 59.7, 61.7 and 61.5% when plants treated with 0, 1 and 2 % K_2O respectively. Also, for faba bean crop, the net revenues were 4263, 5393 and 6244 LE fed^{-1}; the return on investment pound were 1.04, 1.28 and 1.46 LE; the producer profit margin were 36.9, 41 and 42.3 % when plants treated with 0, 1 and 2 % K_2O respectively. At the same time for the rice crop, the net revenues were 2394.9, 3116.8 and 3398.5 LE fed^{-1}; the return on investment pound were 0.38, 0.49 and 0.53 LE; the producer profit margin were 27.5, 32.8 and 34.5 % when plants treated with 0, 1 and 2 % K_2O respectively. For maize the net revenues were 1655.3, 1996.9 and 2058.4 LE fed^{-1}; the return on investment pound were 0.33, 0.39 and 0.40 LE; the producer profit margin were 25, 28.3 and 28.6 % when plants treated with 0, 1 and 2 % K_2O respectively. Clover crop values; the net revenues were 4420.4, 4870.4 and 5308.8 LE fed^{-1}; the return on investment pound were 1.44, 1.55 and 1.65 LE; the producer profit margin were 58.9, 60.7 and 62.2 % when plants treated with 0, 1 and 2 % K_2O respectively. Abdul *et al*. (2012), Farooqi *et al*. (2012) and Ali *et al*. (2016) concluded that foliar spraying with potassium had greater effects on field crops over soil application resulted from increasing the efficiency of K^+ uptake.

Table 8. The relative importance of the total revenue items of the field crops as affected by foliar spraying with potassium in saline soil for two seasons.

		Average Yield		Average	K-Leaf	Total	Farm Price		Revenues		Total		Co.
	Indicators	Grain (t /fed.)	Straw (t/fed.)	Cost (LE/fed.)	Cost (LE/fed.)	Cost (LE/fed.)	Grain (LE/ton)	Straw (LE/ton)	Grain (LE/fed.)	Straw (LE/fed.)	Revenues (LE /fed.)	%	variation %
wheat	Control	2.86	4.84	4420	0	4420	3220	732	9209.2	3542.9	12752.1	93.7	4.6
	1% K_2O	3.17	4.94	4420	72	4492	3220	732	10207.4	3616.1	13823.5	101.6	
	2% K_20	3.29	4.97	4420	144	4564	3220	732	10593.8	3638.0	14231.8	104.6	
	Average	3.11	4.92	4420	0	4492	3220	732	10003.5	3599.0	13602.5	100	
Barely	Control	1.35	3.18	3249	0	3249	4375	680	5906.3	2162.4	8068.7	94.7	3.8
	1% K_2O	1.48	3.24	3249	72	3321	4375	680	6475.0	2203.2	8678.2	101.8	
	2% K_20	1.51	3.26	3249	144	3393	4375	680	6606.3	2216.8	8823.1	103.5	
	Average	1.45	3.23	3249	0	3321	4375	680	6329.2	2194.1	8523.3	100	
Faba bean	Control	1.20	1.56	4109	0	4109	6197	600	7436.4	936.0	8372.4	87.9	5.8
	1% K_2O	1.39	1.63	4109	90	4199	6197	600	8613.8	978.0	9591.8	100.8	
	2% K_20	1.54	1.65	4109	180	4289	6197	600	9543.4	990.0	10533.4	110.6	
	Average	1.38	1.61	4109	0	4199	6197	600	8551.9	968.0	9519.9	100	
Rice	Control	2.58	6.41	6305	0	6305	2900	190	7482.0	1217.9	8699.9	93.1	5.1
	1% K_2O	2.84	6.62	6305	72	6377	2900	190	8236.0	1257.8	9493.8	101.6	
	2% K_20	2.96	6.65	6305	144	6449	2900	190	8584.0	1263.5	9847.5	105.4	
	Average	2.79	6.56	6305	0	6377	2900	190	8100.7	1246.4	9347.1	100	
Maize	Control	2.82	3.88	4970	0	4970	2143	150	6043.3	582.0	6625.3	95.1	3.5
	1% K_2O	3.02	3.9	4970	90	5060	2143	150	6471.9	585.0	7056.9	101.3	
	2% K_20	3.09	3.91	4970	180	5150	2143	150	6621.9	586.5	7208.4	103.5	
	Average	2.98	3.90	4970	90	5060	2143	150	6379.0	584.5	6963.5	100	
Clover	Control	12.93	-	3079	0	3079	580	-	7499.4	-	7499.4	93.5	5.3
	1% K_2O	13.83	-	3079	72	3151	580	-	8021.4	-	8021.4	100.1	
	2% K_20	14.71	-	3079	144	3223	580	-	8531.8	-	8531.8	106.4	
	Average	13.82	-	3079	0	3151	580	-	8017.5	-	8017.5	100	

Source: (1) Calculated and estimated from Field. (2) The center Department of Agricultural Economics, Ministry of Agriculture.

Table 9. Indicators of economic efficiency of the field crops as affected by foliar spraying with potassium in saline soil for two seasons.

Indicators		Total Cost (LE/fed)	Total Revenues (LE/fed)	Net Revenues (LE/fed)	Total /Revenues Total Cost	Return on Investment Pound(LE)	Boons Producer Profit per ton%	Producer Profit Margin%	Economic Efficiency %
Wheat	Control	4420	12752	8332.1	2.89	1.89	53.2	65.3	288.51
	1% K_2O	4492	13824	9331.5	3.08	2.08	55.0	67.5	307.74
	2% K_20	4564	14232	9667.8	3.12	2.12	55.4	67.9	311.83
Barely	Control	3249	8068	4819.7	2.48	1.48	51.7	59.7	248.34
	1% K_2O	3321	8678	5357.2	2.61	1.61	53.4	61.7	261.31
	2% K_20	3393	8823	5430.1	2.60	1.60	53.2	61.5	260.04
Faba bean	Control	4109	8372	4263	2.04	1.04	33.6	36.9	158.51
	1% K_2O	4199	9592	5393	2.28	1.28	37.3	41.0	169.40
	2% K_20	4289	10533	6244	2.46	1.46	38.6	42.3	173.35
Rice	Control	6305	8699.9	2394.9	1.38	0.38	25.8	27.5	137.98
	1% K_2O	6377	9493.8	3116.8	1.49	0.49	30.8	32.8	148.88
	2% K_20	6449	9847.5	3398.5	1.53	0.53	32.4	34.5	152.70
Maize	Control	4970	36625.	1655.3	1.33	0.33	23.3	25.0	133.31
	1% K_2O	5060	97056.	1996.9	1.39	0.39	26.4	28.3	139.46
	2% K_20	5150	47208.	2058.4	1.40	0.40	26.7	28.6	139.97
Clover	Control	3079	7499.4	4420.4	2.44	1.44	58.9	58.9	243.57
	1% K_2O	3151	8021.4	4870.4	2.55	1.55	60.7	60.7	254.57
	2% K_20	3223	8531.8	5308.8	2.65	1.65	62.2	62.2	264.72

CONCLUSION

This study indicates that foliar spraying with K_2O at 2% concentration in the form K-leaf fertilizer performs better and fulfills potassium requirement of wheat, barley, faba bean, rice, maize and clover as compared to untreated plants (control) under saline soils conditions. Therefore, it is recommended that potassium should be applied preferably through foliar spraying in salt affected soils at

East Delta region. Potassium fertilizer in the form of foliar spraying also renders greater economic returns as compared to untreated plants.

ACKNOWLEDGMENT

The authors are grateful to Mr. Michel Marchand and Mr. Lahcen Kaboury for their supervision, guidance in the planning of this work. Deepest thanks to Tessenderlo Kerley International, part of Tessenderlo Group, Troonstraat 130 Rue du Trône – 1050 Brussels, Belgium for their cooperation and funding this work.

REFERENCES

Abbas, Z.M. and A.M. Awad (2018). Effect of potassium foliar applications on productivity and quality of mono-cut Egyptian clover under saline soil. Egypt. J. Agron., 40(2): 155-163.

Abdel-Aziz, E. A. and O.S. El-Bialy (2004). Response of maize plants to soil moisture stress and foliar spray with potassium. J. Agric. Sci. Mansoura Univ., 29(6): 3599-3619.

Abdi, M.; G. Nour-Mohamedi and A. Golchin (2002). The influence of foliar nutrition of urea and potassium chloride on grain yield, grain protein contents, yield components and leaf relative water content of Sardari wheat under rainfed conditions. J. Agric. Sci., 8(1): 29-38.

Abdul, W.K.; R.A. Mann; M. Saleem and A. Majeed (2012). Comparative rice yield and economic advantage of foliar KNO3 over soil applied K2SO4. Pakistan J. Agri. Sci., 49(4): 481-484.

Aboelgoud, Sh.A.; I.F. Mersal and M.El.M. Haggag (2015). Effect of potassium fertilizer rates and some plant extracts on forage, seed yield and seed quality of Egyptian berseem under saline soil conditions. J.Plant Production Mansoura Univ. 6(7): 1183-1198.

Akram, M.; M.Y. Ashraf; R. Ahmad; M. Rafiq; I. Ahmad and J. Iqbal (2010). Allometry and yield components of maize (Zea mays L.) hybrids to various potassium levels under saline conditions. Archives of Biol. Sci., 62(4): 1053-1061.

Ali, A.; M. Hussain; H.S. Habib; T.T. Kiani; M.A. Anees and M. Abdul Rahman (2016). Foliar spray suppresses soil application of potassium for maize production under rainfed conditions. Turkish J. Field Crops, 21(1): 36-43.

Allen, S.E.; H.M. Grimshaw; J.A. Parkinson; C. Quarmby and J.D. Roberis (1974). Chemical analysis of ecological materials. Black Well Science Puplication Oseney. Oxford, London, pp: 565.

Amanullah; A. Iqbal; Irfanullah and Z. Hidayat (2016). Potassium management for improving growth and grain yield of maize (Zea mays L.) under moisture stress condition. Sci. Rep., 6: 34627; doi: 10.1038/srep34627

Aown, 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. of Animal & Plant Sci., 22(2): 431-437.

Ashraf, M.Y.; N. Rafique; M. Ashraf; N. Azhar and M. Marchand (2013). Effect of supplemental potassium (K+) on growth, physiological and biochemical attributes of wheat grown under saline conditions. Plant Nutr., 36(3): 443-458.

Bates, L.S.; R.P. Waldren and L.D. Teare (1973). Rapid determination of free proline for water-stress studies. Plant and soil, 39: 205-207.

Bellaloui, N.; H.A. Bruns; A.M. Gillen; H.K. Abbas; R.M. Zablotowicz; A. Mengistu and R.L. Paris (2010). Soybean seed protein, oil, fatty acids, and mineral composition as influenced by soybean-corn rotation. Agric. Sci., 1: 102-109.

Bellaloui, N.; X. Yin; A. Mengistu; A.M. McClure; D.D. Tyler and K.N. Reddy (2013). Soybean seed protein, oil, fatty acids, and isoflavones altered by potassium fertilizer rates in the Midsouth. Amercan J. Plant Sci., 4: 976-988.

Blevins, D.G. (1985). Role of potassium in protein metabolism in plants. In: Munson, R.D., Ed., Potassium in Agri- culture, ASA, CSSA and SSSA, Madison, pp: 413-424.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effect of a biotic stresses in plant. J. Plant Nutr. and Plant Sci., 168: 521 – 530.

Cha-um, S.; K. Siringam; N. Juntawong and C. Kirdmanee (2010). Water relations, pigment stabilization, photosyntheticabilities and growth improvement in salt stressed rice plants trated with exogenous potassium nitrate application. Int. J. Plant Prod., 4: 187-198.

Damon, P.M. and Z. Rengel (2008). Crops and genotypes differ in efficiency of potassium uptake and use. Physiologia Plantarum, 133(4): 624-36.

El-Hawary, M.M. and A.I. El-Shafey (2016). Improving rice productivity by potassium fertilization under saline soils conditions. J. Plant Production Mansoura Univ., 7 (7): 677 – 682.

El-Kholy, M. H.; M. M. El-Zeki; A. A. Rahmou and S. G. Metwaly (2003). Rice production at North of Delta Region in Egypt as affected by irrigation intervals and potassium fertilizer forms. Scientific Symposium on "Problems of Soils and Water in Dakahlia and Damietta Governorates" Faculty of Agric. Mansoura Univ., Egypt March 18, pp: 174-180.

El-Tohamy, W.A.; A.A. Ghoname and S.D. Abou-Hussein (2006). Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. J. of Appli. Sci. Res., 2: 8-12.

Evans, H.J. and R.A. Wildes (1971). Potassium and its role in enzyme activation. In: Evans, H.J. and Wildes, R.A., Eds., Potassium in Biochemistry and Physiology, Inter. Potash Institute, Berne, pp: 13-19.

Farooqi, M.Q.U.; R. Ahmad; E.A. Wariach and M. Arfan (2012). Effect of supplemental foliar applied potassium on yield and grain quality of autumn planted maize (Zea mays L.) under water stress. J. Food, Agric. Vet. Sci., 2(3): 8-12.

Farrag, A.; A.A. Shehata and M. M. Kandil (1990). The effect of phosphorus and sulfur fertilizers on seed protein of broad bean plants. In: Proc. Middle East Sulfur Sympo., pp: 361–371. February, 1990, Cairo, Egypt.

Gowthami, P.; G.R. Rao; K. Rao and L.M. Ahamed (2018). Effect of foliar application of potassium, boron and zinc on quality and seed yield in soybean. Int. J. Chem. Stud., 6(1): 142-144.

Hasanuzzaman, M.; M.H.M. Bhuyan; K. Nahar; M.S. Hossain; J. Al Mahmud; M.S. Hossen; A.A. Masud; Moumita and M. Fujita (2018). Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. Agron., 8(31): 1-29.

Hasina, G.; A. Said; B. Saeed and K. Ahmad (2011). Response of yield and yield components of wheat towards foliar spray of nitrogen, potassium and zinc. Asian Res. Pub. Net., 6(2): 23-32.

Hawkesford, M.; W. Horst; T. Kichey; H. Lambers; J. Schjoerring; I.S. Moller and P. White (2012). Function of macronutrients potassium. In: Marschner, Petra(Eds.), Marschner,s Mineral Nutritionof Higher Plants. Elsevier, Adelaide, PP: 178 – 189.

Horneck, D. and Miller R. (1998). Determination of total nitrogen in plant tissue. In: Handbook of Reference Methods for Plant Analysis. Kolra, YP (ed). 73.

Hunt, R. (1990). Basic growth analysis. Published by the Academic Division of Unwin Hyman Ltd., London. pp:55-72.

Hussein, M.M.; S.Y. El-Faham and A.K. Alva (2012). Pepper plants growth, yield, photosynthetic pigments, and total phenols as affected by foliar application of potassium under different salinity irrigation water. Agric. Sci., 3: 241-248.

Hussein, S.M.A. (2005). Effect of supplemental irrigation, seeding rate and foliar of potassium, macro and microelements on wheat activity under the rainfed conditions. Bull. Fac. Agri., Cairo Univ., Egypt, 56(3): 431-453.

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.

Khedr, R.A.; R.F. El-Mantawy and I.M. Soltan (2016). Response of hull-less barley to potassium on saline soil conditions. Proce., The Sixth Field Crops Conf., FCRI, ARC, Giza, Egypt, 22-23 Nov. 2016.

Kumar, A.R.; N. Kumar and P. Jeyakumar (2008). Effect of post-shooting spray of sulfate of potash (SOP) on yield and quality of banana cv. Robusta (AAA-Cavendish). Res. J. Agri. Biol. Sci., 4: 655–659.

Kumar, M.; A. Sarangi; D.K. Singh; A.R. Rao and S. Sudhishri (2016). Response of wheat cultivars to foliar potassium fertilization under irrigated saline environment. J. Appl. and Natu. Sci., 8 (1): 429 – 436.

Magen, H. (1997). IPI Activity in India-Summary Report for 1993-1997: Results from Field Experimentation and Description of Promotional Activity. International Potash Institute, Horgen, 33.

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. Agric. Sci., 5(6): 662-669.

Metzener, H.; H. Rav and H. Senger (1965). Untersuchungen Zur Synchronisier-barkeit einzelner pigment. Mangol-mutanten von Chlorella. Planta, 65: 186-194.

Munns, R. and M. Tester (2008). Mechanisms of salinity tolerance. Annu. Rev. Plant Biol., 59: 651-681.

Pande, M.; M.B. Goli and N. Bellaloui (2014). Effect of foliar and soil application of potassium fertilizer on soybean seed protein, oil, fatty acids and minerals. American J. Plant Sci., 5: 541-548.

Rajitha, B.; P. Latha; P. Sudhakar and V. Umamahesh (2018). A comparative study on the effect of foliar application of nitrogen, phosphorus, potassium, iron and zinc on proline content, yield and cost-benefit ratio of groundnut plants grown under water stress conditions. Int. J. Pure. App. Biosci., 6(1): 784-789.

Read, J.J.; R.K. Reddy and J.H. Jenkins (2006). Yield and fiber quality of upland cotton as influenced by nitrogen and potassium nutrition. European J. Agron., 24: 282 – 290.

Robert, P.H. (2005). The role of potassium. Aqua Botanic, pp: 1-6.

Savani, V.N.; M.R. Vaioshnav; P.R. Vaishnav and V.B. Darji (1995). Statistical estimiation of relative changes in P content with different levels of applied phosphorus in groundnut. J. Gujarat Agric. Univ., 21: 119 – 123.

Steel, R.G.D. and J.H. Torrie (1980). Principles and procedures of statistics, 2nd Ed., McGraw-Hill Co., New York, USA.

Tausz, M.; W. Trummer; A. Wonisch; W. Goessler; D. Grill; Jiménez; S. Maria and D. Morales (2004). A survey of foliar mineral nutrient concentrations of Pinus canariensis at field plots in Tenerife. Forest Ecology and Man., 189: 49-55.

Thalooth, A.T.; M.M. Tawfik and M.H. Mohamed (2006). A comparative study on the effect of foliar application of zinc, potassium and magnesium on plants grown under water stress conditions. World J. of Agric. Sci., 2(1): 37-46.

Vigay, N.; A. Kumar and A. Bhoite (2009). Influence of nitrogen, phosphorus and potassium fertilizer on biochemical contents of Asparagus racemonus. Res. J. Environ. Sci., 3: 285-291.

Yadav, R.L.; N.L. Sen and B.L. Yadav (2003). Response of onion to nitrogen and potassium fertilization under semi-arid condition of Rajasthan. Indian J. Horti., 60: 176 – 178.

Yagmur, M.; D. Kaydan and N. Okut (2007). Alleviation of salinity stress during seed germination in wheat (Triticum aestivum) by potassium applications. Indian J. Agric. Sci., 7; 77(6): 379-382.

Yemm, E.W. and A.J. Willis (1954). The respiration of barley plants. IX. The metabolism of roots during the assimilation of nitrogen. New Phytol., 55: 229-252.

Zayed, B.A.; W.H.M. El-Kallawy and R.N. Gorgy (2011). Effect of different schedules of potassium foliar application on yield, yield components and some physiochemical properties of hybrid rice under saline soil conditions. J. Plant Production, Mansoura Univ., 2(10): 1299-1310.

إستجابة بعض المحاصيل الحقلية للرش الورقى بالبوتاسيوم على النمو والإنتاجية والجدوى الإقتصاديه تحت ظروف الأراضى الملحية

محمد محمد الهوارى[1]، محمود حسن الخولى[2] و جمال الدين أحمد محمود إبراهيم[3]

[1] قسم بحوث فسيولوجيا المحاصيل – معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- الجيزة- مصر

[2] قسم بحوث تغذية النبات وخصوبة التربة– معهد بحوث الأراضى والمياه والبيئة- مركز البحوث الزراعية- الجيزة- مصر

[3] قسم الدراسات الإقتصادية- مركز بحوث الصحراء- المطرية- مصر

أجريت تجربة حقلية خلال الموسم الصيفى 2015 و 2016 والموسم الشتوى 2016/2015 و2017/2016 فى ثلاث مواقع لدراسة استجابة بعض المحاصيل الحقلية للرش الورقى بالبوتاسيوم فى صورة K-leaf بتركيزات صفر و 1 و 2% K_2O على محاصيل القمح والشعير والفول البلدى والأرز والذرة الشامية والبرسيم المصرى تحت ظروف الأراضى الملحية. أوضحت النتائج أن الرش الورقى بالبوتاسيوم بتركيزات 1 أو 2% K_2O أدت الى زيادة معنوية فى إرتفاع النبات ودليل مساحة الأوراق (LAI) ومعدل نمو المحصول (CGR) وصافى معدل التمثيل الضوئى (NAR) ومحتوى الأوراق من كلوروفيل A ، B والكاروتينويد ، محتوى الأوراق من أيون البوتاسيوم وكذلك طول السنبلة أو الكوز، وزن السنبلة أو وزن الحبوب بالكوز، وزن الألف حبة أو بذرة و محصولى الحبوب أو البذور والقش للفدان ودليل الحصاد ونسبة البوتاسيوم والبروتين فى الحبوب أو لبذور فى القمح والشعير والفول البلدى والأرز والذرة وكذلك فى الثلاث حشات للبرسيم المصرى. كما إرتفع الإيراد الكلى وصافى العائد للفدان، عائد الجنية المستثمر، نسبة هامش ربح المنتج، وقل معنويا محتوى الأوراق من البرولين والصوديوم وكذلك نسبة عنصر الصوديوم الى البوتاسيوم عند رش النباتات بتركيزات 1 و 2% K_2O لجميع المحاصيل الحقلية تحت الدراسة.