J. Plant Production, Mansoura Univ., Vol. 7 (7): 677 - 681, 2016

Improving Rice Productivity By Potassium Fertilization Under Saline Soils Conditions

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ABSTRACT

A field trail was conducted at a field near Port Said Agricultural Research Station farm, ARC, during the two successive summer seasons 2013 and 2014 to study the physiological response of rice Giza 178 cultivar grown under saline soil to potassium fertilization as soil dressing at rates of 0, 24, 36 and 48 kg K_2O/fad and spraying 2% K_2O in combination with adding 24 and 36 kg K_2O/fad. Results of combined analysis could be summarized as follows: Significant increase was recorded in plant height, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), photosynthetic pigments, potassium content, panicle length, panicle weight, 1000- grain weight, grain and straw yields when plants received 36 kg K_2O /fad plus spraying 2% K_2O. Also, significant increase was recorded in proline and sodium contents, and sodium/potassium ratio in leaves when plants sprayed with water (control) as compared with other potassium treatments.
Keywords: Rice, salt stress, potassium fertilization.

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereal crop in the world, yielding one–third of the total carbohydrate source. Three billion people consider rice as their stable food, accounting for 50–80% of their daily calorie intake. Rice is a salt–sensitive monocot (Maas and Hoffman, 1997; Shereen *et al.*, 2005 and Darwish *et al.*, 2009).

Salinity is a limiting environmental factor for plant production, and is becoming more prevalent as the intensity of agriculture increases. Around the world, 100 million ha, or 5% of arable land, is adversely affected by high salt concentrations, which reduce crop growth and yield (Ghassemi *et al.*, 1995; Gunes *et al.*, 2007; Kumar *et al.*, 2010 and Tavakkoli *et al*., 2011). The various environmental programs carried throughout the world estimates that approximately 20% of agricultural land and 50% of cropland in the world is salt-stressed (Munns and Tester, 2008). Also, the water available in the salt–contaminated soil is restricted, inducing osmotic stress (Castillo *et al.*, 2007; Pagter *et al.*, 2009 and Siringam *et al.*, 2011). Salinity and sodicity can reduce plant growth and alter ionic relations by ionic and osmotic effects and oxidative stress (Borsani *et al.*, 2001 and Eraslan *et al.*, 2007). Salinity inhibits plant growth by ion toxicity(mainly of Na^+ and Cl^-), osmotic stress, and nutritional disruption (Caines and Shennan, 1999). Plant adaptations to salinity include sequestration of salt ions in vacuoles and accumulation of compatible compounds, such as sugars, proline and glycine betaine in the cytoplasm to balance the osmotic pressure (Jampeetong and Brix, 2009). Dhanapackiam and Muhammad (2010) showed that NaCl had a greater effect on osmotic pressure.

Plants require potassium for physiological processes such as the maintenance of membrane potential and turgor, activation of enzymes, regulation of clever pH, cation- anion balance, regulation of transpiration by stomata and the transport of assimilates and subsequently raised rice tolerance for salinity (Golldack *et al*., 2003 and Noaman, 2004). Zayed *et al.*, (2007) found that increasing the K uptake ability under stress enable rice plant to grow healthy under salt stress.

Foliar application of potassium has attracted considerable attention in recent years because its importance for the quick and adequate supply to plants at the time of seed formation to improve productivity. Anton and Ahmed (2001) found that raising foliar spraying levels of K_2O from 0.5% up to 2% on barley plants significantly increased plant height, spike length, grain weight/spike, 1000 grain weight, straw and grain yields/fad. Also, Abdo and Anton (2009) found that applying 24 kg K_2O/fad in combination with spraying 1% K_2O on sesame plants significantly increased plant height, fruiting zone length, leaf area index (LAI), relative growth rate (RGR), net assimilation rate (NAR), total chlorophyll, carotenoides contents of leaves, chlorophyll fluorescence, 1000-seed weight, number of capsules, seed weight/plant, straw and seed yields/fad. However, Ebrahimi *et al*. (2012) stated that potassium application alleviated the stress condition and significantly improved dry matter, yield and yield components in rice.

The present investigation was carried out to study the physiological response of rice plants to potassium fertilization as soil dressing and foliar spraying in saline soil of East Delta region.

MATERIALS AND METHODS

The present work was carried out at a farm near Port Said Agric. Res. Station farm, ARC, during the two successive summer seasons of 2013 and 2014 to study the physiological response to potassium fertilization as soil dressing and foliar spraying on growth, yield, yield components, photosynthetic pigments and proline contents as well as Na^+/K^+ ratio of rice plants grown in saline soil.

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

Five samples were collected from different locations of experimental site and analyzed to determine some physical and chemical properties as presented in Table 1.

Table 1: Some physical and chemical properties of the experimental site in the two summer seasons 2013 and 2014.

Season	EC	pH (1:2.5)	Texture	Cations (ml equevlant/L)				Anions (ml equevlant/L)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
2013	7.57	8.05	clay	9.84	11.64	62.24	2.34	-	1.01	65.9	19.15
2014	7.21	7.98	clay	10.05	11.56	60.07	2.45	-	1.03	64.21	18.89

Rice grains cv. Giza 178were sown on 6th June and 11th June in the first and second seasons, respectively. 15 kg P_2O_5/fad was added as calcium super phosphate (15.5% P_2O_5) at land preparation. 60 kg N/fad in the form of urea (46% N) was added in three doses at 20, 35 and 50 days after sowing.

The treatments are as follows:

1- Spraying with water (control).
2- 24 kg K_2O/fad.
3- 36 kg K_2O/fad.
4- 24 kg K_2O/fad + spraying 2% K_2O.
5- 36 kg K_2O/fad + spraying 2% K_2O.
6- 48 kg K_2O/fad.

Potassium fertilizer as soil dressing treatments in the form of potassium sulphate (48% K_2O) were added in two equal doses at 35 and 50 days after sowing as well as foliar spraying with 2% K_2O (in the form of solo-potassium 50% K_2O) were applied at 35 and 50 days after sowing (DAS). Other, cultural practices were applied according to the methods being adopted for growing rice crop in the locality.

To calculate growth analysis, five plants were randomly taken from each plot at 65, 80 and 95 days after sowing (DAS). Plants were dried at 70 °C in oven to a constant weight. According to Hunt (1990) formulas, the following traits were determined:

- Leaf area index (LAI)= leaf area per plant/ground area occupied by plant
- 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(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).
- Loge = Natural logarithm.

At 80 days after sowing (DAS) samples were taken to determined:

- Photosynthetic pigments (chl a, chl b and carotenoides) in mg/g fresh weight, according to Metzener *et al.* (1965).
- Leaf proline concentration, in mg/g fresh weight, according to Bates *et al.* (1973).
- Potassium and sodium content in rice plant as mmole/kg dry weight, according to Allen *et al.* (1974).

Harvesting took place at 3/10/2013 and 9/10/2014 in the first and second seasons, respectively. At harvest time, plant height (cm), panicle length (cm), panicle weight (g), 1000-grain weight (g), grain and straw yields (t/fad) were determined.

Data of the two seasons were combined and statistically analyzed according to Steel and Torrie (1980). The discussion of the results were carried out on the basis of combined analysis for the two seasons.

RESULTS AND DISCUSSION

1- Growth and growth analysis:

- Plant height:

Data in Table 2 indicate that plant height increased with increasing the dose of potassium fertilization up to 36 kg K_2O plus spraying with 2% K_2O. Such treatment significantly increased plant height compared with control or other potassium treatments, except adding 48 kg K_2O/fad. In this respect, Anton and Ahmed (2001) reported that barley plant height was gradually increased with increasing foliar spraying of potassium concentration from 0.5 up to 2 % K_2O.

- Leaf area index (LAI):

Data of Table 2 show that LAI increased by advancing rice age up to 80 days after sowing (DAS) and decreased at 95 DAS. This increased is mainly due to the production of new leaves and leaves expansion through the growth of rice plant. LAI was significantly affected with potassium application at different stages of rice growth *i.e*. 65, 80 and 95 DAS. However, plants treated with 36 kg K_2O/fad plus spraying with 2% K_2O had the highest values of LAI at all growth stages viz. 65, 80 and 95 DAS compared to control and other potassium treatments. These findings due to potassium activates at least 60 different enzymes involved in plant growth (Robert, 2005). In this connection, Abdel-Aziz and El-Bialy (2004) found that spraying with 3% K_2O of maize plants significantly increased LAI. Also, Abdo and Anton (2009) found that applying 24 kg K_2O/fad in combination with spraying 1% K_2O of sesame plants significantly increased LAI.

- Crop growth rate (CGR):

As shown from Table 3, adding 36 kg K_2O/fad plus spraying with 2% K_2O significantly increased CGR at the two periods under study *i.e* (65-80) and (80-95) day. Such finding was attributed to the role of K in dry matter accumulation. In this respect Mahendera-Singh *et al*. (1992) found that spraying 200 ppm potassium on maize plants increased leaves dry matter.

- Net assimilation rate (NAR):

It was noticed from Table 3 that net assimilation rate significantly increased with adding potassium fertilization at the two periods (65-80) and (80-95) DAS when plants received 36 kg K_2O /fad in combination with spraying 2% K_2O. Similar results were obtained by Abdo and Anton (2009) they found that on sesame plants, applying 24 kg K_2O/fad in combination with spraying with 1% K_2O significantly increased NAR in the first period without significant difference with adding 48 kg K_2O/fad.

Table 2: Plant height and leaf area index (LAI) of rice plants as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	Plant height (cm)			LAI 65 DAS			LAI 80 DAS			LAI 95 DAS		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Spraying with water	87.25	88.75	88.00	1.88	1.92	1.90	2.87	2.95	2.91	2.47	2.55	2.51
24 kg K_2O/fad.	87.50	89.50	88.50	2.02	2.09	2.05	3.09	3.17	3.13	2.69	2.71	2.70
36 kg K_2O/fad.	88.75	90.50	89.63	2.27	2.31	2.29	3.26	3.38	3.32	2.87	2.91	2.89
24 kg K_2O/fad. + spraying 2%K_2O	87.75	90.25	89.00	2.34	2.38	2.36	3.20	3.35	3.28	2.93	2.98	2.95
36 kg K_2O/fad. + spraying 2%K_2O	91.00	92.00	91.50	2.59	2.62	2.60	3.51	3.61	3.56	3.15	3.20	3.17
48 kg K_2O/fad.	90.50	92.25	91.38	2.50	2.53	2.51	3.52	3.60	3.56	3.09	3.11	3.10
LSD at 0.05	1.98	2.76	2.24	0.12	0.12	0.09	0.13	0.11	0.11	0.12	0.11	0.07

Table 3: Crop growth rate (CGR) and net assimilation rate (NAR) of rice plants as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	CGR (g/day) (65-80) day			CGR (g/day) (80-95) day			NAR (g/m^2/day) (65-80) day			NAR (g/m^2/day) (80-95) day		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Spraying with water	24.04	24.15	24.10	27.36	27.46	27.41	9.59	9.66	9.62	8.88	8.93	8.90
24 kg K_2O/fad.	24.91	25.10	25.01	28.01	28.10	28.06	10.10	10.20	10.15	9.36	9.44	9.40
36 kg K_2O/fad.	25.59	25.86	25.72	28.79	28.84	28.81	11.19	11.29	11.24	10.23	10.36	10.29
24 kg K_2O/fad. + spraying 2%K_2O	25.42	25.79	25.60	29.39	29.45	29.42	11.13	11.27	11.20	10.56	10.61	10.59
36 kg K_2O/fad. + spraying 2%K_2O	26.75	26.81	26.78	30.44	30.52	30.48	11.34	11.42	11.38	10.90	10.96	10.93
48 kg K_2O/fad.	26.23	26.46	26.34	29.82	29.92	29.87	11.32	11.35	11.33	10.77	10.85	10.81
LSD at 0.05	0.67	0.53	0.59	0.17	0.12	0.09	0.20	0.14	0.16	0.12	0.10	0.08

2- Photosynthetic pigments:

Combined data in Table 4 show that chl a, chl b and carotenoides concentration of leaves at 80 DAS significantly increased by adding 36 kg K_2O /fad plus spraying 2% K_2O. Such finding may be due to that potassium activates the enzymes involved in the formation of leaf pigments. Furthermore, Abdo and Anton (2009) found that on sesame plant, applying 24 kg K_2O/fad in combination with spraying 1 % K_2O significantly increased total chlorophyll and carotenoides contents of leaves.

3- Proline content in leaves:

Data in Table 5 shown proline content of leaves, where the highest value of proline content was obtained from sprayed plants with water (control), while the lowest value was gained from application of 36 kg K_2O/fad plus spray with 2% K_2O. Similar results was obtained by Noroozi and Sepanlou (2013) they found that, the application of potassium to barley led to improving of physiological traits and decreased proline content.

Table 4: Photosynthetic pigments (chl a, chl b and carotenoides contents) of rice leaves at 80 DAS as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	Chl a (mg /g f w)			Chl b (mg /g f w)			Carotenoids (mg /g f w)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Spraying with water	0.279	0.282	0.281	0.112	0.115	0.113	0.067	0.071	0.069
24 kg K_2O/fad.	0.288	0.296	0.292	0.119	0.126	0.122	0.071	0.073	0.072
36 kg K_2O/fad.	0.308	0.314	0.311	0.125	0.135	0.130	0.075	0.077	0.076
24 kg K_2O/fad. + spraying 2%K_2O	0.294	0.314	0.304	0.118	0.131	0.125	0.073	0.076	0.075
36 kg K_2O/fad. + spraying 2%K_2O	0.317	0.327	0.322	0.133	0.138	0.135	0.080	0.082	0.081
48 kg K_2O/fad.	0.315	0.325	0.320	0.130	0.136	0.133	0.079	0.081	0.080
LSD at 0.05	0.012	0.014	0.012	0.011	0.010	0.010	0.008	0.005	0.006

4- Sodium and potassium concentration and Na^+/K^+ ratio:

Data of sodium, potassium concentration and Na^+/K^+ ratio were shown in Table 6. Sodium concentration as well as Na^+/K^+ ratio in rice plants recorded the maximum values when plants sprayed by water (control), while lowest values of Na^+ and Na^+/K^+ ratio was obtained by adding 36 kg K_2O/fad plus spraying 2% K_2O. The reverse trend was obtained with respect K^+ concentration which increased by treated plants with adding 36 kg K_2O/fad plus spraying 2% K_2O, which were intern reflected on obtaine the lowest values of Na^+/K^+ ratio. Muhmmad and Neue (1987), Qadar (1998), Zayed (2002), and Abdel Rahman *et al.*, (2004) stated similar results .

Table 5: Proline content of rice leaves at 80 DAS as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	Proline (mg /g f w)		
	2013	2014	Comb.
Spraying with water	0.152	0.150	0.151
24 kg K_2O/fad.	0.126	0.121	0.124
36 kg K_2O/fad.	0.112	0.106	0.109
24 kg K_2O/fad. + spraying 2%K_2O	0.114	0.108	0.111
36 kg K_2O/fad. + spraying 2%K_2O	0.084	0.083	0.084
48 kg K_2O/fad.	0.091	0.089	0.090
LSD at 0.05	0.012	0.011	0.011

Table 6: Sodium and potassium concentration and Na+/K+ ratio of rice leaves at 80 DAS as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	Na^+ Leaf content (mmole/kg)			K^+ Leaf content (mmole/kg)			Na+/K+ ratio		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Spraying with water	830	824	827	487	496	491	1.71	1.66	1.68
24 kg K_2O/fad.	631	626	628	536	546	541	1.18	1.15	1.16
36 kg K_2O/fad.	600	592	596	560	565	563	1.07	1.05	1.06
24 kg K_2O/fad. + spraying 2%K_2O	609	603	606	554	561	557	1.10	1.08	1.09
36 kg K_2O/fad. + spraying 2%K_2O	550	547	548	590	595	593	0.93	0.92	0.92
48 kg K_2O/fad.	572	565	568	581	592	587	0.98	0.95	0.97
LSD at 0.05	16.5	13.8	14.3	10.6	12.0	10.7	0.04	0.04	0.04

5- Yield and yield components:

Data in Table 7 show that potassium fertilization significantly increased yield and its components of rice plants. Results indicate that applying 36 kg K_2O/fad plus spraying 2% K_2O gave the highest values of panicle length, panicle weight, 1000-grain weight, grain and straw yields of rice plants. These results could be ascribed to the enhanced effect of potassium on rice growth which in turn resulted higher yield components, grain and straw yields/fad. Tandon (1990) explained such results that potassium involves in the activation of large number of enzymes in the production and translocation of photosynthates compounds from source to sink. These results are in harmony with those obtained by Zayed *et al*. (2007) they found that the application of 72 kg K_2O /ha on rice plants significantly increased yield attributes and grain yield compared to 24 and 48 kg K_2O/ha. Also, Ebrahimi *et al.* (2012) concluded that the use of potassium alleviated the adverse effects of high salinity on rice plant and improved growth parameters, yield and yield components.

Table 7: Yield and yield components of rice plants as affected by potassium fertilization in saline soil for two summer seasons of 2013 and 2014.

Treatments	Panicle length (cm)			Panicle weight (g)			1000-grain weight (g)			Grain yield (t/ha)			Straw yield (t/ha)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Sprayingwith water	19.75	19.88	19.81	2.88	2.93	2.91	19.93	20.23	20.08	2.63	2.64	2.63	3.94	3.96	3.95
24 kg K_2O/fad.	20.38	20.75	20.56	3.21	3.28	3.24	21.40	21.70	21.55	2.73	2.73	2.73	4.09	4.12	4.10
36 kg K_2O/fad.	21.00	21.13	21.06	3.40	3.45	3.42	22.65	22.88	22.76	2.83	2.84	2.83	4.24	4.26	4.25
24 kg K_2O/fad. spraying 2%K_2O	20.88	21.13	21.00	3.35	3.41	3.38	22.45	22.60	22.53	2.78	2.80	2.79	4.18	4.21	4.19
36 kg K_2O/fad. spraying 2%K_2O	22.25	22.63	22.44	3.80	3.85	3.82	24.70	24.85	24.78	2.87	2.90	2.88	4.31	4.32	4.32
48 kg K_2O/fad.	22.00	22.13	22.06	3.73	3.77	3.75	24.25	24.50	24.38	2.87	2.87	2.87	4.30	4.32	4.31
LSD at 0.05	0.77	0.72	0.69	0.09	0.09	0.09	0.63	0.58	0.55	0.02	0.02	0.02	0.03	0.04	0.03

CONCLUSION

In the light of the present results, it clearly that the maximum grain yield of rice grown in saline soil was obtained from application of 36 kg K_2O/fad in combination with spraying 2% K_2O. However, from economic point of view its more efficiency to practices adding 36 kg K_2O/fad and foliar spraying with 2% K_2O in salt affected soil in East Delta.

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تحسين إنتاجية محصول الأرز باستخدام التسميد البوتاسى تحت ظروف الأراضى الملحية

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أجريت تجربة حقلية بحقل قريب من المزرعة البحثية لمحطة البحوث الزراعية ببورسعيد، جنوب بورسعيد، خلال موسمى ٢٠١٣ ، ٢٠١٤ لدراسة تحسين إنتاجية محصول الأرز صنف جيزة ١٧٨ تحت ظروف الأراضى الملحية عن طريق معاملات التسميد البوتاسى وهى: بدون (الرش بالماء)، ٢٤، ٣٦ ، ٤٨كجم K_2O /فدان، ٢٤كجم K_2O /فدان مع الرش الورقى بتركيز ٢% K_2O و ٣٦كجم K_2O /فدان مع الرش الورقى بتركيز ٢% K_2O. أوضحت النتائج الأتى: أدى إضافة ٣٦كجم K_2O /فدان مع الرش الورقى بتركيز ٢% K_2O الى زيادة معنوية فى طول النبات، دليل مساحة الأوراق (LAI) عند ٦٥ ، ٨٠ و٩٥ يوم من الزراعة، معدل نمو المحصول (CGR) عند فترتى ٦٥-٨٠ و ٨٠-٩٥ يوم من الزراعة، صافى معدل التمثيل الضوئى (NAR) عند فترتى ٦٥-٨٠ و ٨٠-٩٥ يوم من الزراعة، محتوى الأوراق من كلوروفيل أ ، ب والكاروتنيد وأيون البوتاسيوم وكذلك طول السنبلة، وزن السنبلة، وزن ال ١٠٠٠ حبة و محصولى الحبوب والقش للفدان.زاد معنويا محتوى الأوراق من البرولين والصوديوم وكذلك نسبة عنصر الصوديوم الى البوتاسيوم عند رش النباتات بالماء (معاملة الكنترول) وذلك مقارنة بمعاملات البوتاسيوم الأخرى.