Potassium Use Efficiency Under Drought and Saline Soil Conditions in Egyptian Agriculture

Abd El Hadi, A. H[1]; Khadr, M.S[1] and Marchand, M[2]

1. **Soils, Water & Environment Research Institute, ARC, Egypt.**
2. **Coordinator WANA Region, IPI, Switzerland.**

Summary:

A series of field trials was carried out in new reclaimed sandy and calcareous soils to study the effect of potassium sulfate (SOP) at 4 application levels (0, 120, 240 and 360 kg K_2O/ha) under normal and low water conditions on the production of some key field crops (wheat, faba bean, sesame, ground nut and corn). In a salt affected soil, potassium sulfate (SOP) and potassium chloride (MOP) were tested on rice production under two K_2O rates (70 and 140 kg K_2O/ha). The obtained results were as follows:

1- In sandy soil: wheat, faba bean, sesame and groundnut responded to SOP application up to 240 kg K_2O/ha under both irrigation water levels. Grain yield increases obtained were 18, 11, 24 and 9% under normal water level and reached to 45, 23, 29 and 23% under low irrigation water level compared to control (0 K_2O) respectively.

2- In calcareous soil, wheat, faba bean and corn responded to SOP application up to 360 kg K_2O/ha, for wheat and corn under both water irrigation levels, while faba bean responded to SOP up to 240 kg K_2O/ha. Grain yield increases obtained were 11 and 16% for faba bean; 21 and 29% for wheat and 8-22% for corn under normal and low water level respectively.

3- In the salt affected soil, significant grain and straw yield increases were obtained by addition of SOP and MOP fertilizers. Using SOP resulted in an increase over the control (0 K_2O) in rice grain yield of 25-30% in the first location and 10-11% in the second location, while the grain yield increases obtained with MOP were lower than SOP and reached 23-12% for the first location and ranged between 4 and 1% for the second one, with higher Cl % in the rice grain yield compared to rice grain yield with SOP.

1- Introduction:

In Egypt, irrigated agriculture represents more than 95% of the cropping area, with two crops per year, and uses about of 84% of the water resources (Abu Zeid, 1994). The continuous increase in water demand for agriculture makes the issues of satisfying such demand with limited water very serious. This intensive cropping system depletes the soil in some plant nutrients, which should be compensated by fertilizers application.

In this respect (Hamdi, et al 1971) found that after 5 successive crops, the supplying power of K of unfertilized alluvial soils of Nile-valley decreased. (Abd El Hadi, et al., 1990) found that addition of SOP increased the production of most field crops. Faizy (1997) found that the yield and quality of cotton, maize and rice grains increased with the addition of SOP. Under desert conditions El Kadi, (1997) reported that wheat, corn, and sugar beet responded to K application. In Teheran, Malakouti (1997) found that the introduction of high yielding varieties potato, sugar cane, and sugar beet responded to K application.

Several researches demonstrate the influence of potassium on tolerance to stress, and its decisive role on the efficiency of water use in the plant. It is well established that plants adequately supplied with K can utilize the soil moisture more efficiently than K-deficient plants.

The results obtained by Lindhaer (1985) showed that K-fertilization besides increasing dry matter production and leaf area development greatly improved the retention of water in the plant tissues even under conditions of sever water stress.

Salinity in the Nile-Delta increases progressively from less than 4 ds/m in the Southern part to about 16ds/m in the northern coastal area, which is suffering from intrusion of seawater, water shortage and poor quality of irrigation water. Addition of K to saline soils cultivated with rice plants avoids Na^+ toxicity by maintaining a high level of K^+ in the terms of high level of K^+ uptake against Na^+ (Zayed, 2002), (El Kohly et al., 2003).

The objective of this work is to study the effect of K-addition on the production of some main field crops in calcareous, sandy and clay soils which suffer from salinity and water stress under surface irrigation system.

2. Experimental design:

2-1: At the eastern and western part of the Nile-Delta which represents a great part of sandy and calcareous soils, field trials were carried out to study the effect of K-addition at 4 levels (0, 120, 240 and 360 Kg/ha) on the production of some main field crops (wheat, faba bean as winter crop and sesame & groundnut as summer crops) in the sandy soil, while in the calcareous soil (wheat and faba bean as a winter crops and corn as summer crop) under surface irrigation with normal (recommended water irrigation) and the low (half of the recommended water irrigation level).

2-2: At the northern part of Nile-Delta which is suffering from salinity, water stress and poor water quality, two field trials were conducted to compare the relative effectiveness of potassium sulfate (SOP) and potassium chloride (MOP) on rice production.

The experimental design was complete randomized block with 4 to 6 replications. Recommended crop varieties were cultivated and fertilized by recommended nitrogen and phosphorous amounts in proper time. Soil samples were collected before carrying out the field experiments to determine the physical and chemical properties after Jackson (1973). The chemical characteristics of the soils are presented in table (1).

The data indicated that:

In the sandy soil the total salts fairly high with low concentration of available N, P and K, while in calcareous soil, the available N and P were low and K was moderate but with high $CaCO_3$ (24.3%). The cation exchange capacity (CEC meq/100g soil) was low in both sandy and calcareous soils. However, soil characteristics at El Serw are heavy clay soil (CEC = 40 meq/100g soil) with a tendency to salinize, with moderate level in K, P and N. surface irrigation is done with Nile water for all the field experiments.

Table (1): Soil analysis of the experimental sites.

Location	pH	TSS (%)	$CaCO_3$ (%)	N	P (ppm)	K (ppm)	CEC meq/100 g soil	Soil texture
Ismailia	**8.7**	**0.24**	**3.90**	**60**	**8.5**	**250**	**9.9**	**Sandy soil**
Nubaria	**8.2**	**0.28**	**24.3**	**20**	**8.1**	**530**	**12.3**	**Sandy loamy soil**
El Serw	**8.7**	**0.46**	**2.5**	**35**	**7.8**	**450**	**44.2**	**Clay soil**

3- Results and discussion:

3-1: In sandy soil:

The data presented in table (2) show that wheat grain yield increased by increasing K_2O rates. The maximum grain yield was obtained from K_2 level (240kg K_2O/ha) under normal irrigation with yield increase % of (+8%) while this increase was as high as (+45%) with the same rate of K_2O under low irrigation level comparing with the control treatment. The results showed a highly significant effect of the water irrigation level. For faba bean grain yield, the results showed that a highly significant effect of both K_2O-rates and water irrigation level.
As for K_2O, the rate of K_2O resulted in the maximum yield with an increase of about 11.0 and 23% for the normal and low irrigation respectively, comparing with the control (Table 2).
These results insure the importance of K role in the water economy in crop production. In this respect (Mengel and Forster, 1973) found that high K plants need less water to produce a given yield than K-deficient plants. It is clearly shown that K-fertilization increased sesame yield by (+29%) higher percent at low irrigation than the same rate of K_2O under normal irrigation (+24%). For groundnut yield, the same trend was found by sesame yield. There is a highly significant effect of both K-fertilizing rates and the irrigation level. Also the K_2O rate has resulted in the maximum groundnut yield with increases percent of about 9% and 23% under normal and low irrigation respectively. It is clearly shown the decisively influence of K in enhancing plant tolerance to drought stress conditions. Similar finding were found by Polaria et al (1989) with groundnut yield.

Table (2): Effect of different levels of potassium and irrigation water levels on wheat, faba bean, sesame and groundnut grain yield in a sandy soil.

Kg K_2O/ha		Winter crops t/ha				Summer crops t/ha			
		Wheat grain yield		Faba bean grain yield		Sesame grain		Groundnut grain	
		Normal irrigation	Low irrigation	Normal irrigation	Low irrigation	Normal irrigation	Low irrigation	Normal irrigation	Low irrigation
K_0	0	4.40	2.43	1.49	1.25	0.62	0.57	1.48	1.25
K_1	120	4.60	3.16	1.54	1.32	0.71	0.57	1.54	1.31
K_2	240	5.19	3.52	1.65	1.54	0.77	0.73	1.61	1.54
K_3	360	4.96	3.80	1.58	1.45	0.73	0.74	1.58	1.45

L.S.D. 5%

K-rates	n.s t/ha	0.09 t/ha	0.078t/ha	0.07t/ha
Irrigation	0.55	0.95	0.046	0.05
IX K-rate	n.s	n.s	n.s	n.s
C.V %	18.8	5.20	10.4	5.10

3-2: In calcareous soil:

Wheat grain data recorded in (Table 3) indicated that grain yield increased with increasing K-rates under both normal and drought conditions. The maximum yield increase is reached at K_3 (360 kg K_2O / ha) with a (+29%) under drought and with (+21.0%) under normal condition compared to control treatment.

The effect of K-fertilization and irrigation water level on faba bean grain yield show significant increases with yield increase of 0.31 t/ha (+11%) under normal and low irrigation level compared to control. The same trend was indicated by Shehata et al (1989 and 1990). The obtained results of corn grain yield (table 3) showed that grain increased with increasing rates of K_2O. The maximum yield was obtained by K_2 rate (240 kg K_2O / ha) for normal irrigation level with increase of 0.73 t/ha. (+8%) and at K_3 (360 kg K_2O / ha) for low irrigation with increase of 1.55 t/ha (+22%) for low irrigation level compared to control. Kock and Estes (1975) concluded that K-deficient plants of Zea mays L. had greater stomatal diffuse resistance than those with higher K-rates.

The results indicate that, there is a positive and significant effect of potassium, in spits of soil which is rich in K (saturation rate up to 10%) the explanation might related to the high $CaCO_3$ and the competition of both cations as far as root absorption is concerned.

Table (3) Effect of different rates of potassium and irrigation water levels on wheat, faba bean and corn grain yield in calcareous soils.

Kg K_2O/ha		Winter crops t/ha				Summer crops t/ha	
		Wheat grain yield*		Faba bean grain yield		Corn grain yield**	
		Normal irrigation	Low irrigation	Normal irrigation	Low irrigation	Normal irrigation	Low irrigation
K_0	0	4.43	3.72	2.82	2.07	9.03	7.02
K_1	120	5.10	4.52	2.94	2.28	9.35	7.59
K_2	240	5.17	4.72	3.13	2.41	9.76	7.81
K_3	360	5.37	4.81	3.03	2.27	9.62	8.57

L.S.D. 5%

K-rates	0.64	0.15	0.723
Irrigation	0.5	0.10	0.64
IX K-rate	n.s	n.s	n.s
C.V %	14.62	6.57	10.42

*** Average of two trials ** Average of 4 trials**

3-3: In heavy clay soil:

Growing rice at North Delta as summer crop is compulsory to wash salts out of the soil profile of salt affected soils. In this study rice was comprised as a summer crop.
The obtained results in (Table 4) showed yields as a result of using both SOP and MOP fertilizers with no significant difference between its two rates of K-fertilizers. Using SOP fertilizer resulted in an increase of rice grain yield over control (O K_2O) treatment being 25% and 30% at the first location and 10 and 11% at the second location with the rates of 70 and 170 K_2O/ha respectively. While MOP caused an increase of rice grain yield over control treatment being 23% and 12% at the first location and 4% and 1% at the second location with using the above mentioned two rates.
This trend was found by Abd El Hadi et al (2002) and El Kholy et al (2003). The high rate of MOP (140 kg K_2O / ha) showed inconsistent reduction in both grain and straw yield and this might be possibly to the toxic effect of chloride anion when rice plants are exposed to water stress.
In this connection Lam and Melean (1979) reported that the chloride salts had the most detrimental effect to yield and N and P contents while the sulfate salts were beneficial when the electrolyte concentration and P in the soil were not high.
Results of Cl % and SO_4% in the brown rice showed (Table 4) that application of MOP increased Cl%, while SOP decreased its content. The addition of SOP increased SO_4%, while MOP decreased its content.

Table (4): Effect of different sources of potassium fertilizers and its rates (kg K_2O/ha) on rice production at El Serw area (t/ha) and Cl^- and SO_4^- concentrations in grains:

Treatments	K_2O/ha	First location		SO_4%	Cl%	Second location		SO_4%	Cl%
		Grain	Straw			Grain	Straw		
Control	-	7.02	7.54	0.28	1.58	7.71	8.10	0.24	1.64
SOP	70	8.74	9.38	0.31	1.54	8.50	9.10	0.27	1.60
	140	9.10	9.75	0.36	1.50	8.54	9.17	0.30	1.54
Mean		8.92	9.56	0.34	1.52	8.52	9.14	0.28	1.57
MOP	70	8.61	9.31	0.27	1.68	8.04	8.62	0.23	1.74
	140	7.88	8.77	0.28	1.75	7.75	8.38	0.21	1.82
Mean		8.25	9.04	0.28	1.71	7.90	8.50	0.22	1.78
LSD at 5%		0.71	0.67			0.84	0.91		

Conclusion

In sandy soil and calcareous soil all crops are responding to potash fertilizer application. Wheat, faba bean, sesame, groundnut and corn responded to SOP application up to 240 kg K_2O/ha under normal irrigation. Concerning corn, sesame and wheat, the response under low irrigation water is effective also at higher rate (360 kg K_2O/ha). Grain yield increases are better under low irrigation regime confirming the essential role of potassium in water exchanges in the plant with its consequence on water stress resistance.

In salt affected soils, significant grain and straw yield increases were obtained by addition of SOP. Low rate of MOP can improve production with a lower performance compared to SOP, while high dose of MOP clearly demonstrate the detrimental effect of chlorine.

In both locations with high potassium content, Nubaria and El Serw, the response to potassium is consistent, showing that high production requires a large availability of mineral elements during critical stages.

References

- Abd El Hadi, A.H.; Khadr, M.S. and Hassan, M.A.M. (1990): Effect of fertilization on the productivity of major crops under intensive cropping system in Egypt. 3rd international congress program of soil science society of Pakistan, March 20-22.
- Abd El Hadi, A.H.; Khadr, M.S.; El Kholy, M.H.; Zahran, F.A. and Negm. A. M. (2002): Comparative effect of potassium sulphate and potassium chloride on crop production and soil chemical properties under Egyptian conditions. Egypt. J. Agric. Res. 80 (2).
- El Kadi, M. (1997): Response to potassium of some field crops and trees fruit grown in desert soils. Regional workshop of the International Potash Institute, Food security in the WANA region. The essential need for balanced fertilization. Bornova, Izmir, Turkey 26-30 May.
- El Kholy, M.H.; El Zeki, M.M.; Rahou, A.A. and Metwally, S.G. (2003): Rice production at North of Delta Region in Egypt as affected by irrigation intervals and potassium fertilizer forms. Faculty of Agriculture, Mansoura University, Egypt, March, 18 pp 174-180.
- Faizy, S. (1997): Effect of balanced fertilization on yield and crop quality in Egypt. Regional workshop of the International Potash Institute. Food security in the WANA region. The essential need for balanced fertilization. Bornova, Izmir, Turkey, 26-30 May.
- Hamdi, H.; El Damaty, A.H. and Zanaty, M. (1971): A comparative study for determination of potassium supplying power of the soil of Egypt. U. A. R. J. Soil Science, 11, 205-212.
- Jackson, M.L. (1973): Soil chemical analysis. Prentice-Hall Inc. N. J. Lam, H. and E.O. Melean (1979): Effect of salts on DM yield and N.P contents of rice plants. Common Soil Science Plant Analysis 10, 969-979.
- Lindhauer, M.G (1985): Influence of nutrition and drought on water relation and growth of sunflower. Z. pflanzenernh. Bodenk. 148, 654-669
- Malakouti, M.J. (1997): Potassium status in soils and crops recommendations and present use in Iran. Regional workshop of the International Potash Institute, Food Security in the WANA region. The essential need for balanced fertilization. Bornova, Izmir, : 26-568- May.
- Mengel, K. and Forster, H. (1973): Der Einfuss der Kalium Kon Zentration der Bodenlosung auf den wasserverbrauch und die K-Aufnalssme von Zuckerruben. Z. pflanzenernah. Bodenk. 148-156
- Polaria, K.B. (1989): Pattern of N, P and K accumulation in groundnut varieties as influenced by soil moisture stress at different growth stages. Legume Research. 7(2):95.
- Shehata, H, m.A. and El Kadi, M.A. (1990): Influence of k-fertilization for crops on water use efficiency in calcareous soils. Desert Inst. Bull, ARE, 40. 177.
- Zayed, B.A. (2002): Performance of some rice cultivars as affected by irrigation and potassium fertilizer treatments under saline soil conditions. Ph. D. Thesis fac. Of Agric. Mansoura Univ. Egypt