Effect of Soil Salinity on K Critical Level for Cotton and its Response to Sources and Rates of K-Fertilizers

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ABSTRACT

In addition to reducing water availability and producing toxic ion effects in saline condition, high concentrations of Na^+ and Cl^- ions will normally upset or inhibit the cotton plant nutrition. Therefore, soil test interpretation in measuring nutrient availability and recommending fertilizer levels may be different in saline and non-saline soils. In order to estimate K critical level, 15 different main cotton fields under saline conditions and 10 fields under non-saline conditions were selected in Khorasan province in 2001-2002. Then, a field experiment with a completely randomized block design with two-potassium rates of 0 (K_0) and 200(K_1) kg/ha K_2SO_4 and three replications were carried out to estimate the critical level of K. Secondly, to determine the effects of sources and rates of K on the yield of cotton balls, completely randomized block factorial experiment was conducted with two sources of K [K_2SO_4 (SOP) and KCl (MOP)] and five rates of K [0, 50, 100, 150 and 200 kg/ha K_2O] at two locations, namely with saline (EC = 17 dS/m, Kava= 200 mg/kg) and non-saline conditions (EC = 2.1 dS/m, K_{ava}=180 mg/kg). The results showed that, the use of K increases cotton balls yield significantly (13% and 6% for saline and non-saline soils, respectively). The K critical levels estimated by Mitscherlich-Bray equation were 244 and 213 mg/kg in saline and non-saline soils, respectively, while by Cate-Nelson graphical method the figures were 240 and 210 mg/kg in saline and non-saline soils, respectively. Also, the type of fertilizers used had a significant effect on the cotton yield. The maximum yield of cotton balls in saline condition was obtained using SOP (25% yield increase in comparison with MOP) and in non-saline condition by MOP (10% yield increase in comparison with SOP). The relation between the potassium application and the yield of cotton balls (response curve) showed that maximum yield was obtained with the use of 125 and 100kg/ha K_2O under saline and non-saline conditions, respectively. With respect to the positive effects of K in saline soils, the application of K fertilizer is highly recommended under those conditions.

KEY WORD: Soil salinity; Potassium; Critical level; K-fertilizer; Cotton yield.

1. Introduction

Irrigation with saline waters for agricultural purposes has produced favorable results (Rhoades, 1987). Nevertheless, the final outcome of such a practice on crop nutrition of mineral elements and on soil fertility is not well recognized. Soil salinity affects the yields of agricultural crops in various ways including a reduced level of plant available water, increased amounts of toxicity levels for certain toxic ions, reduced activity levels for the essential nutrients, high ratios of Na^+/ Ca^{++}, Na^+/K^+, Mg^{++}/ Ca^{2+}, Cl^-/NO_3^- in plant tissues, nutritional problems, and reduction in crop yields and qualities as the most pronounced effects (Feigin, 1985, Grattan and Grieve, 1992). Potassium (K) is the main cation of plant, and as such it makes a major contribution to reducing the osmotic potential in root cells to facilitate turgor pressure-driven solute transport processes and to sustain the overall water balance of plant (Marschner, 1995). Therefore, existence of sufficient amount of K for the plant life is necessary, especially in the saline conditions. There is a low concentration of K in the soil solution. The element is readily absorbed on to surface of soil particles and is fixed, and thus unavailable, within layers of expandable 2:1 clay minerals. In some vermiculite soils, application of K as high as 700 kg/ha were ineffective at correcting visual symptoms in K-deficient cotton (Cassman, 1986). As well as, in saline conditions, K bioavailability is decreased in soil solution by high concentration of Cl^- and Na^+ that causes disorders in plant nutrition. Dorudi and Siadat (1999) reported that, despite high K concentration in salt-stressed wheat, it was showed K deficiency specially, in old leaves. They found that, K accumulation in leaf vacuoles might be for neutralizing negative charge, due to Cl^-, therefore, K no effect on vital reactions. So, soil test interpretation for measuring nutrient availability may be different in saline and non-saline soils. The first step to recognize and prevent K deficiency is to separate soils with K potential from the soils without this potential. Also, suitable application and selection of fertilizer is a management method for enhancing yield and resistance of plants to salinity. Based on these facts, the objectives of this study were to estimate of K critical level for cotton and its response to K fertilizers (K_2SO_4 and KCl) in saline and non-saline calcareous soils of Iran.

2. Materials and methods

2.1. Experiment 1: In order to estimate K critical level in saline and non-saline soils, soil samples were collected from 15 different main cotton fields under saline conditions and from 10 fields under non-saline conditions in Khorasan province (Iran). The soils were selected on the basis of the differences in their extractable K (measured by ammonium acetate extractant). A field experiment was conducted as a complete randomized block design with three replications. The treatments in this study were two-K rates 0 (K_0) and 200(K_1) kg ha^{-1} K (as K_2SO_4). Some physicochemical characteristics of the samples are given in Table 1. N and P fertilizer were added as urea [$CO(NH_2)_2$, 350 kg ha^{-1}] and triple superphosphate [$Ca(H_2PO_4)_2$, 100 kg ha^{-1}] respectively, and used before sowing. Seed of cotton (varamin variety) was sown as furrow system. Yield of cotton bolls and relative yield were calculated in each location after harvest. The relative yield is ratio of yield obtained in treatment without K (K0) to maximum yield (K1). K critical level was estimated in each location, by Cate-Nelson graphical method and Mischerlish-Bray equation (Black, 1995). This equation takes the form, log (A-Y)= log A - C_1b, where A is the yield in 200 kg ha^{-1} SOP, Y is yield without K (K0), b is soil available K and C_1 is equation constant, respectively.

Table 1. **Physical and Chemical Properties of Soils**

Soil No.	Location	EC^a ($dS\ m^{-1}$)	SAR	SP	T.N.V	Clay	pH	K_{av} ($mg\ kg^{-1}$)
					(%)			
1	Kashmar	18.35	26.50	40.6	19.5	28.0	8.0	325
2	Kashmar	22.20	24.00	44.5	18.0	32.0	8.1	380
3	Kashmar	17.05	25.10	41.3	19.2	30.0	8.0	290
4	Kashmar	19.50	22.90	47.0	18.5	32.0	8.1	355
5	Kashmar	15.67	18.60	40.9	17.0	30.0	8.0	350
6	Kashmar	17.12	21.50	49.7	18.0	34.0	8.1	405
7	Nishaboor	14.22	9.80	42.8	16.6	22.6	7.9	190
8	Nishaboor	17.75	11.64	40.0	20.7	22.6	8.2	220
9	Nishaboor	22.30	18.00	38.0	15.5	19.1	7.8	250
10	Torbat	16.75	20.20	40.0	19.8	20.2	8.2	300
11	Torbat	8.77	11.50	47.0	18.5	26.5	8.0	191
12	Torbat	14.00	9.30	45.8	17.5	24.0	7.8	218
13	Torbat	17.50	6.10	33.9	16.6	14.5	7.9	180
14	Torbat	10.50	16.10	39.0	8.3	19.0	8.3	280
15	Birjand	9.80	7.50	40.0	18.0	22.0	8.0	294
16	Nishaboor	1.48	3.30	31.0	13.5	8.6	8.2	265
17	Nishaboor	1.36	3.40	27.4	16.0	5.6	8.0	235
18	Birjand	3.90	2.50	32.7	17.9	19.4	8.1	255
19	Birjand	2.80	1.75	25.1	22.1	11.4	8.0	190
20	Kashmar	1.80	3.20	29.4	19.2	10.6	8.1	450
21	Kashmar	2.10	3.40	37.0	20.5	12.6	8.0	570
22	Kashmar	2.43	2.80	28.8	19.2	4.6	8.0	355
23	Kashmar	1.40	2.30	28.9	20.1	3.6	7.9	395
24	Kashmar	3.20	4.40	28.1	19.2	6.6	7.8	235
25	Kashmar	2.90	3.70	28.9	19.5	6.6	8.0	245

2.2 Experiment 2: To determine the effect of sources and rates of K on the cotton yield, field study was conducted as a factorial experiment in a complete randomized block design with three replications. Treatments were two source of K [K_2SO_4 (SOP) and KCl (MOP)] and five rates of K [0(control), 50, 100, 150 and 200 kg/ha K_2O]. Two locations selected, saline conditions (EC = 17 dS/m, K_{ava}= 200 mg kg^{-1}) and non-saline conditions (EC = 2.1 dS/m, K_{ava}=180 mg kg^{-1}). MOP added in two equal portions, before and after 40 days of cultivation. The cultural practices for this trial carried were out like above. K concentration of leaf determined 60 days after planting. So, Yield of cotton bolls measured in each location after harvest.

3. Results and discussion

Applying K in experiment 1 increased significantly yield of cotton bolls ($P<0.05$) in saline and non-saline conditions (Fig 1). Yield increased 13% in saline and 6% in non-saline soils. It seems that, K improved cotton yield with decreasing sodium uptake in saline soils (competitive effect). Botella et *al*. (1997) found that salinity decreases growth of maize shoot, when K concentration in nutrient solution was low. They showed that, NaCl salinity decreases net K uptake and its transfer from roots to shoot. Al-karaki (2000) reported that addition of K ameliorated the effects of NaCl and improved the growth parameters in tomato. He concluded that, salinity reduced net K uptake and, to a lesser extent, K translocation from the roots to the shoot. The inhibitory effect of salinity on K translocation was greater at low K supply. Addition of K decreased Na uptake. Dorudi and Siadat (1999) reported that, K significantly increased wheat yield and maximum yield of wheat was obtained from applying 120 kg ha^{-1} SOP in saline soils.

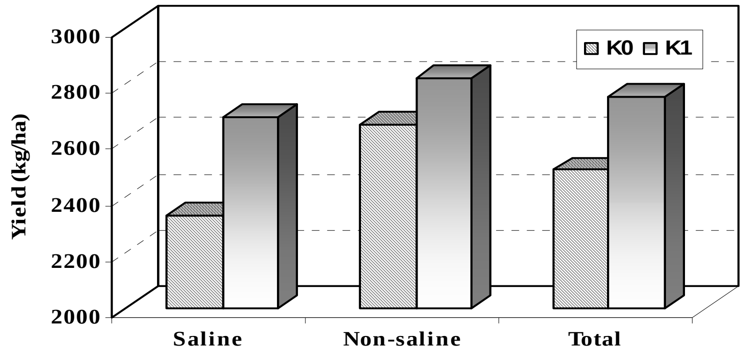

Fig. 1. The effect of K (SOP) on cotton boll yield on saline and non-saline soils.
(Mean value is 15, 10 and 25 locations, respectively)

On the basis of data in Table 2 and by using of Mischerlish-Bray equation, coefficients C_1 calculated for each location and mean values for saline and non-saline soils. Using these coefficients and relative yield, equations derived for saline and non-saline soils. The C_1 coefficients were equivalent to 0.003370 and 0.003863 for saline and non-saline soils respectively. At relative yield of 85%(in the absence of applied K fertilizer), the Mischerlish-Bray equation indicated the critical level of available K in the soil was 244.5 mg kg^{-1} and 213 mg kg^{-1} for saline and non-saline soils, respectively. A general Mischerlish-Bray equation derived for saline and non-saline soils combined. In the condition K critical level was 233 mg kg^{-1} for 85 % relative yield. As a results K critical level in saline soils is more than non-saline soils and this value for total soils is between saline and non-saline conditions.

Table 2. The effect of K on yield, relative yield and increasing yield in saline and non saline soils

Soil No.	Yield (kg ha^{-1})		Relative Yield (%)	Yield Addition (kg ha^{-1})
	K_0	K_1		
1	1644.2	1893.7	86.8	249.5
2	2169.0	2300.5	94.2	131.5
3	1774.2	2196.8	80.7	422.6
4	3015.7	3116.9	96.7	101.2
5	2720.5	3281.6	82.9	561.1
6	2836.7	2766.7	102.5	-70.0
7	2271.6	2935.7	77.3	664.1
8	2139.2	2514.5	85.0	375.3
9	2251.6	2387.2	94.3	135.6
10	2259.2	2716.6	83.1	457.4
11	2026.7	2582.7	78.4	556.0
12	2022.8	2421.6	83.5	398.8
13	1766.5	2466.1	71.6	699.6
14	2966.7	3176.3	93.4	209.6
15	3116.6	3490.5	89.2	373.9
16	3036.0	3243.0	93.61	207.0
17	4076.0	4536.0	89.85	460.0
18	1226.0	1530.0	80.13	304.0
19	1403.0	1873.0	78.68	380.0
20	1460.0	1436.0	101.67	-24.0
21	1416.0	1646.0	98.17	30.0
22	3033.0	3106.0	97.64	73.0
23	3370.0	3326.0	101.32	-44.0
24	3380.0	3630.0	93.1	250.0
25	3960.0	3966.0	99.84	6.0

According to the Cate-Nelson method, the K critical level was 240 and 210 mg kg^{-1} for saline and non-saline soils, respectively. At values of greater than or equal to 240 and 210 mg kg^{-1} in saline and non-saline soils, cotton achieved about 85% of maximum yield in the absence of fertilizer application (Fig. 2 and 3). These results had close agreement with the value obtained by Mischerlish-Bray method. Krauss (1994) reported that K critical level (exchangeable) for sandy soils is more than 125(mg kg^{-1}) and for heavy clay soils is more than 375(mg kg^{-1}) in Central Europe. Olfati et *al*. (1999) on the basis of their studies in Iran, reported that, K critical level in different locations for wheat varied from 140 (mg kg^{-1}) in Boushehr and Iranshahar to 350(mg kg^{-1}) in Lorestan, and in through out the country was 241 (mg kg^{-1}).

It seem that, because K uptake in cotton decreased due to competitive effect of Na in saline soils, as a result plant needs to K greater than non-saline soils, therefore K critical level increased in the conditions. Greenway and Mannus (1980) reported that, with increasing of salts concentration and Na in soil solution, Ca and K concentration decreased in tissues of plant types. Janzen and Chang (1987) found that barley plant exposed to Na_2SO_4 salinity contained only one-third the concentration of K in their shoot than those grown in non salinized. Since cotton is tolerant to salinity, difference between K critical level in saline and non-saline conditions is only 30(mg kg^{-1}). On the other hand, if a plant was semi-tolerant, this difference might be increased.

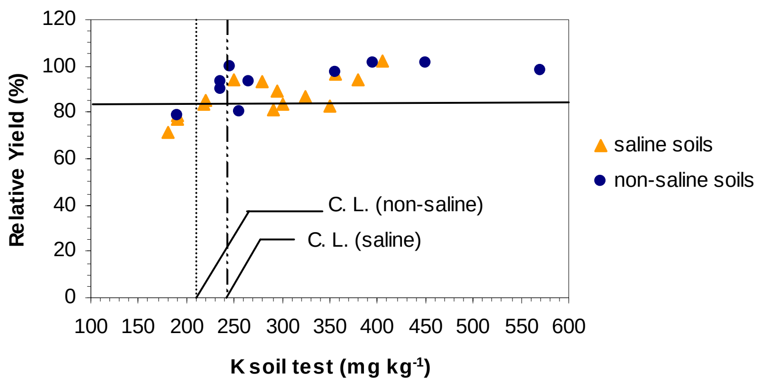

Fig. 2. K critical level for saline and non-saline soils by Cate-Nelson graphical method.

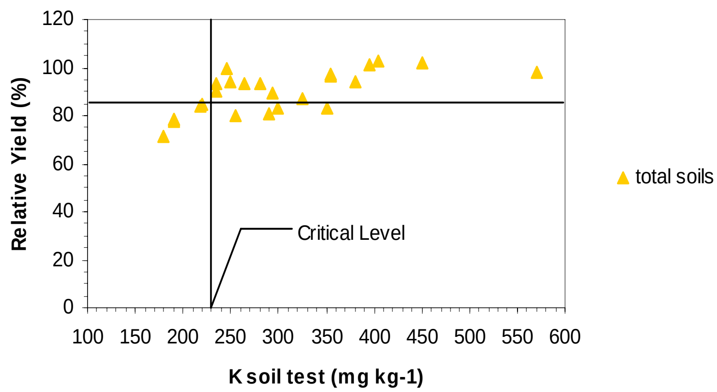

Fig. 3. K critical level for total soils (saline and non-saline soils) by Cate-Nelson graphical method.

About 62.5% and 50% of soils with K available less than 240 mg kg^{-1} and 210 mg kg^{-1} responded to application of K in saline and non-saline soils, respectively. Relationship between soil available K and additional yield of cotton ($Y_{k1} - Y_{k0}$) in saline and non-saline soils is shown in Fig. 4. There is negative response in soil available K more than 440 and 480 mg kg^{-1} in saline and non-saline soils, respectively. On this basis, available K sufficiency range in the soils is shown in Table 5. Sufficiency range of K in saline soils is narrower and smaller than non-saline soils. Grattan and Grieve (1992) reported that sufficiency range may be widened, narrowed, or it may shift in one of direction or the order depending on plant species (or variety), the particular nutrient, salinity level and environmental conditions.

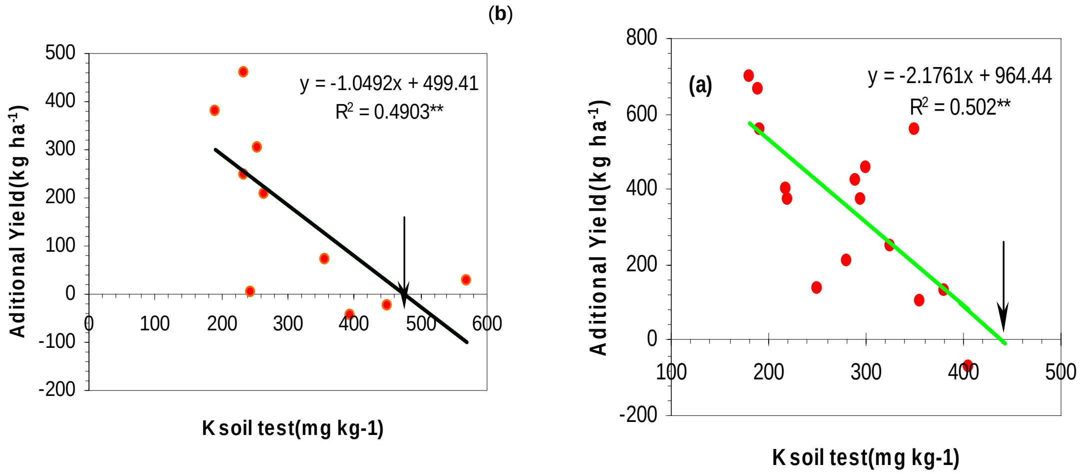

Fig. 4. Relationship between K available and increasing yield of cotton in saline (a) and non-saline (b) soils.

In addition, K critical level increased in saline soils, but toxicity level decreased. It seems that, in saline conditions with increasing available K concentration in soil and imbalance of other nutrients (i.e. Ca, Mg) upper level (toxicity level) is less and sufficiency range is narrower.

Table 3. The optimum level available K (mg/kg) of soil for cotton.

Soil	Low	Sufficient	High
Saline	<240	240 – 440	>440
Non-saline	<210	210 – 480	>480

In other experiments, also, fertilizer sources of K had significant effect on the cotton yield only in saline conditions (Fig. 5). The response of cotton to K differed when applied together with Cl^- or $SO4^{2-}$. In saline condition, maximum yield of cotton bolls was obtained by the use of SOP (25% yield increase in comparison with MOP) while in non-saline condition by MOP (10% yield increase in comparison with SOP). Tan and Shen (1993) reported that, no change in cotton yield were observed when Cl^- concentration were below 1600 mg kg^{-1} but, cotton seed maintained a Cl^- concentration in range 0.48-0.59 mg $g^{-1\ DM}$ and the lint length was constant in the range of 28-29 mm when Cl^- application was increased up to 3200 mg kg^{-1} soil.

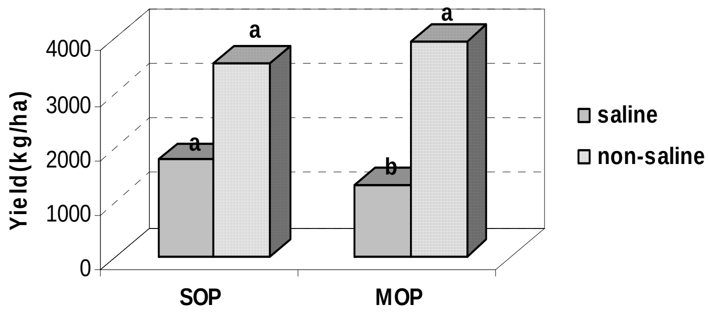

Fig. 5. Effect of SOP and MOP on cotton yield in saline and non-saline soil.

The relation between the K application and the yield of cotton bolls (response curve) showed that maximum yield was obtained from the use of 100 and 125 kg ha^{-1} K_2O, in the saline and non-saline conditions, respectively (Fig. 6). The result showed that, despite cotton yield was lower in saline soil than non-saline soil but almost there was no difference in rates of K application.

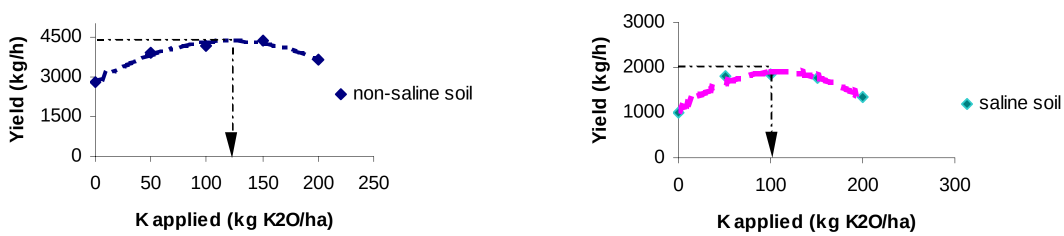

Fig. 6. Effect of K application on cotton yield in saline and non-saline soil.

4. Conclusion

The results indicate that application of K improved growth and yield of cotton especially in saline soils. Modifications in the evaluation of soil K and in the fertilizer recommendation will be necessary. K critical level in saline soils (240 mg kg^{-1}) is more than non- saline soils (210 mg kg^{-1}). Also as, K sufficiency range in saline soils is smaller than non-saline soils. Therefore, increasing K fertilizer in this condition should be done with awareness. On the other hand, application of SOP in saline soil is better than MOP. Rate of K application is almost equal in saline and non-saline soils even though cotton yield is lower in saline condition.

References

1. Al karaki, G. N. 2000. Growth, sodium and potassium uptake and translocation in salt stressed tomato. *J. Plant Nut*. 23: 369-379
2. Black C. A. 1995. Soil Fertility Evaluation and Control. Iowa State University. Lewis Pub. London. P746
3. Botella, M. A., V. Martinez. J. Pardines, and A. Cerda. 1997. Salinity induced potassium deficiency in maize plants. *J. Plant Physiol*. 150:200-205
4. Cassman, K. G. 1986. Soil crop management and plant factors, which influence cotton potassium nutrition on vermiculitic soils of the San Joaquin valley. *J. Fert. Issues.* 3: 38-45.
5. Dorudi, M. S. and H. Siadat. 1999. The effect of irrigation salinity, potassium sulfate and urea on yield and nutrients concentration in wheat. *Agricultural Science Journal of Iran*. (Wheat special issue) 12:187-196 (Persian).
6. Feigin, A. 1985. Fertilization management of crops irrigated with saline water. *Plant Soil*, 89:285-299.
7. Grattan, S. R. and C. M. Grieve. 1992. Mineral nutrient acquisition and response by plant grown in saline environments. *Agric. Ecosys. Environ*. 38:275-300.
8. Greenway, H. and R. Munns. 1980. Mechanism of salt tolerance in nonhalophytes. Annu.Rev. *Plant Physiol*. 31:149-190.
9. Janzen, H. H. and C. Chang. 1987. Cation nutrition of barley as influenced by soil solution composition in a saline soil. *Can.J.Soil Sci*. 67:619-629.
10. Krauss, A. 1994. Potassium in soils: dynamics and availability. Iran Agrofood Export Promotion Center of Iran. Tehran.
11. Marschner, H. 1995. Mineral Nutrition of Higher Plants. London: Academic Press.
12. Olfati, M., M. J. Malakouti, and M. R. Balali. 1999.Estimating K critical level for wheat. *Agricultural Science Journal of Iran*. (Wheat special issue) 12:46-53. (Persian).
13. Roades, J. D. 1987. Use of saline water irrigation. *Water Quality Bull*. 12:14-22.
14. Tan, N. X. and J. X. Shen. 1993. A study on the effect of Cl on the growth and development of cotton. *Soil Fert*. 2:1-3.