VARIOUS RATES OF K AND Na INFLUENCE GROWTH, SEED COTTON YIELD AND IONIC RATIO OF TWO COTTON VARIETIES IN SOIL CULTURE

Liaqat Ali[1]*, Rahmatullah[1], Muhammad Aamer Maqsood[1], Muhammad Ashraf[1], Tariq Aziz[2] and Shamsa Kanwal[1]
[1]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad
[2]Sub-campus University of Agriculture, Faisalabad at Depalpur, Okara
*Corresponding author's e-mail: shafqat_l @ yahoo.com

Cotton is generally grown on alkaline calcareous soils in arid and semi-arid areas of the country. Sodium can interact with other earth cations like K, Ca and Mg. Therefore, a pot study was conducted to investigate the growth, yield and ionic response of two cotton varieties. Four levels of K and Na were developed after considering indigenous K, Na status in soil. The treatments of K+Na in mg/kg were adjusted as: 105+37.5, 135+30 135+37.5 and 105+30 (control). Control treatment represented indigenous K, Na status of soil. The experiment continued until maturity. Application of K and Na increased seed cotton yield and boll weight significantly ($p<0.01$). Both varieties varied non-significantly with respect to K:Na ratio in leaf. The beneficial effects of Na with K application over control on seed cotton yield and boll weight were greater in NIBGE-2 than in MNH-786. Increase in seed cotton yield was attributed to maximum boll weight of both varieties. Significant negative correlation ($r= -0.89$, -0.76, $n= 4$) was found between K:Na ratio and K use efficiency in shoot of NIBGE-2 and MNH-786, respectively.
Keywords: Cotton (*Gossypium hirsutum* L), yield, yield components, K:Na ratio, K use efficiency

INTRODUCTION

The economy of Pakistan is dependent on agriculture, and soil being the basic resource for agriculture has prime importance in this respect. Out of the total area of 80 million hectares of the country, only 20 million hectares are cultivated. Inherent and management problems further limit the use of cultivable lands. The soils are generally alkaline-calcareous in nature. Widespread deficiency of nitrogen (N), phosphorus (P) and potassium (K) has been reported (Rashid and Rafique, 1997). Potassium fertilizer use in the country has been slower than N and P. This primarily has been due to misunderstanding that our soils being alluvial are rich in K and need no application of K fertilizer. Mica and K-feldspar are also major K minerals of sand and silt fractions (Mengel and Rahmatullah, 1994). Although total soil K content is adequate, the release rate of K in most cases has not been enough to meet crop demand, especially under high yield rates. In the present day of intensive and high yield oriented agriculture, there is a negative K balance and consequently the soils are being mined of this essential nutrient (Roy, 2000; Ahmad, 2000). Malik *et al*. (1989) reported annual decline of 8.8 mg kg^{-1} of K due to crop depletion in soil K on the basis of results from 45921 soil samples from various parts of Punjab.

Cotton being a cash crop of Pakistan is affected by potassium (K) deficiency. It is commonly grown in many arid and semi arid regions of the world. Fertilization of cotton with K is rather a complex phenomenon. Soils vary widely in their K supplying capacity and K fertilizer requirement. When K fertilizer is applied to soil, some fertilizer may be bound or trapped with in soil minerals so that part of it is either not available or slowly available to plants (Reddy *et al.,* 2000).

Potassium is the seventh most abundant element in earth crust and third major essential element in plant nutrition. Liebig (1841) was the first to establish its essentiality for plant growth. Potassium is the most abundant cation in cells of non-halophytic higher plants (Maathuis *et al*., 1997). Potassium is absorbed by plants in larger amount than any other mineral element except N (Daliparthy *et al*., 1994). Maser *et al*., (2002) reported that K^+ counteracts Na^+ stress while Na^+ in turn, can to a certain extent alleviate K^+ deficiency. Sodium can replace K^+ particularly in its osmotic functions in the vacuole. Thus under K^+-starvation addition of Na^+ actually promoted plant growth. The extent of replacement of K^+ by Na^+ depends largely on plant species. Several scientists (Marschner, 1971, 1995; El-Sheikh and Ulrich, 1970) have reported a clear positive relationship between the uptake and translocation of Na^+ to the shoot and the extent of replacement of K^+ in the plant species. Moderate salinity with adequate nutrition did not have adverse effects on growth but at higher salt concentration, shedding and premature leaf senescence was observed (Brugnoli and Bjorkman, 1992). The findings of El- Gharib and Kadry (1983) and Salih and Abdul-Halim (1985) indicated that low salinity, with optimal supply of nutrients, increased the yield of seed cotton. Dry matter production of crop is mostly dependent on its assimilatory system. Cotton is one of the salt tolerant crops (Maas, 1990). Increase in growth with low concentration of salts has been observed (Pessarakli, 1995). Under mild salinity, NIAB-78 exhibited increase in root growth but not shoot (Jafri and Ahmad, 1994). Zhang *et al*. (2006) explained that cotton growth, nutrient absorption and yield were improved by adding appropriate amounts of K and Na. K:Na ratio attributed to K/Na exchange across the plasma lemma of root cortex cells and selective uptake of K (Jeschke and Wolf, 1988). Passive accumulation of Na in the roots and shoots caused the low K: Na ratios in both the tissues (Greenway and Munns, 1980).

Under moderate salinity, Na concentration in leaves was modest and K concentration was higher than Na (Thomas, 1980). Khan *et al*. (1998) reported that NIAB-78, the most tolerant cultivar, retained higher Na concentration in the roots than MNH-93. Retention of high Na in the roots could be the mechanism of salt tolerance in cotton. High accumulation of Na in the leaves of salt tolerant cultivars of cotton has also been found (Leidi and Saiz, 1997). The differential ion uptake and distribution indicated several regulation mechanisms acting at different rates (Jeschke, 1984).

The present soil culture investigation was planned to evaluate the growth, yield and ionic response of the two cotton varieties to K and Na rates validating the results of solution culture experiments in which the varieties behaved differently at varying rates of K and Na in the root medium with respect to their ionic distribution pattern /translocation and uptake kinetics.

MATERIALS AND METHODS

The experiment was carried out in a wire house of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad to determine growth and yield response of selected cotton varieties to K and Na application in soil culture. The average day temperature was 45±3°C and the night temperature 31±5°C, and relative humidity ranged from 25 to 58 percent.

The soil used in pots was collected from the University Research Farm. It was air-dried, ground, passed through 2 mm sieve and mixed thoroughly. Texture of the soil was sandy clay loam, pH 8.10, organic matter 0.71 %, $CaCO_3$ 4.5 %, ECe 1.2 dS m^{-1}, Olsen-P 6.7 mg kg^{-1}, NH_4OAc-K 105 mg kg^{-1} and Na 27 mg kg^{-1} based on the methods as described in part-3, Methods of Soil Analysis (Bigham, 1996). The soil was sandy clay loam hyperthermic Ustalfic Haplargid according to FAO (1990) and Soil Survey Staff (1998). A detailed soil survey of the experimental area was carried out with the help of expertise of Soil Survey of Pakistan. The soil belongs to Hafizabad Soil Series as described by Soil Survey Report (1969). Two cotton varieties, NIBGE-2 and MNH-786 were used in this experiment. Twelve kilograms of air-dried, sandy clay loam soil was filled in each of the 32 glazed pots (45.5 x 31.0 cm). The pots were lined with polyethylene sheet to avoid accretion of salts by the pot. They were kept inside wire house under natural light. All the pots received a uniform basal dose of one third of 112.5 mg of N and full dose of 37.5 mg of P_2O_5 per kg of soil at the time of sowing. All the nutrients were applied in solution form. At field capacity, four seeds of the two cotton varieties were sown in the pots on June 28, 2006. Each variety was quard-replicated according to completely randomized design in factorial arrangement. Four treatments were adjusted according to initial K and Na level in soil. Initial K+Na level in soil was 105+30 mg kg^{-1}. The four treatments of K+Na in mg kg^{-1} were as: 135+30, 105+30, 135+37.5 and 105+37.5. Nitrogen, phosphorous in the form of urea, single super phosphate and potassium, sodium as their sulphate were used. Thinning was done 10 days after emergence, to allow one plant to grow in each pot. Weeding and other plant protection measures were done when it was necessary. Distilled water was used for irrigation purpose during the growth period. The youngest fully expanded main stem leaf samples were collected from each pot at 80 days after planting. The leaves were stored on ice, carried to the laboratory and dried for 48 h at 72°C to a constant weight for ionic analysis. Well ground samples were digested in 10 ml of (3:1) nitric: perchloric acid mixture following Miller, 1998. The digested samples were diluted with distilled water and K, Na concentration in samples was determined with flame photometer (Jenway PFP 7). K:Na ratio was calculated by dividing K concentration with Na concentration. At maturity, plants were hand-picked, and data for number of bolls plant^{-1}, average boll weight (g boll^{-1}) and seed cotton yield (g plant^{-1}) were recorded at the time of maturity. Plants were harvested from each treatment. They were partitioned in to shoot and root. They were oven dried at 72°C for 48 h for dry weight (g plant^{-1}) of shoot and root. K use efficiency in shoot was calculated by dividing shoot dry matter by K concentration in shoot**.** The data obtained were subjected to statistical analysis using computer software "MSTAT-C" (Russell and Eisensmith, 1983) following the methods of Gomez and Gomez (1984). Completely randomized factorial design was employed for analysis of variance. Duncan's multiple range test was used for mean separation (Duncan, 1955).

RESULTS AND DISCUSSION

Two selected cotton varieties were grown to ascertain growth, yield and ionic response to various K, Na rates in a pot study, using soil as a culture medium. Main effects of varieties, and K+Na rates significantly ($p<0.01$) influenced seed cotton yield (Table 1).

Table 1. Seed cotton yield (g plant^{-1}), total number of bolls plant^{-1} and average boll weight (g boll^{-1}) of selected cotton varieties grown with different K and Na rates in soil culture

(Values are means of four replicates)

Treatments	Seed cotton yield (g plant^{-1})			Total no. of bolls plant^{-1}			Average boll weight (g boll^{-1})		
	Cotton Varieties			Cotton Varieties			Cotton Varieties		
K+Na (mg kg^{-1})	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean
135 + 30	29.57 NS	21.58	25.57 b	8.75 NS	7.75	8.25	3.33 NS	2.96	3.14 a
105 + 30 (control)	17.95	17.33	17.64 c	8.25	6.25	7.25	2.87	2.58	2.72 b
135 + 37.5	32.79	24.87	28.83 a	10.25	8.75	9.50	3.61	2.97	3.29 a
105 + 37.5	21.33	16.90	19.11 c	10.00	7.00	8.50	2.56	2.54	2.55 b
Mean	25.41 a	20.17 b		9.31 a	7.44 a		3.09 a	2.76 b	

NS= non-significant

Means with different letter(s) differ significantly according to Duncan's Multiple Range Test ($p<0.01$)

Application of K+Na rates @ 135+37.5 mg kg^{-1} increased average seed cotton yield (28.83 g plant^{-1}) followed by (25.57 g plant^{-1}) when grown with 135+30 mg kg^{-1} for both varieties. NIBGE-2 produced significantly ($p<0.01$) more seed cotton yield (25.41g plant^{-1}) than MNH-786. Moderate salinity with adequate nutrition did not have adverse effects on growth but at higher salt concentration, shedding and premature leaf senescence was observed (Brugnoli and Bjorkman, 1992). The findings of El-Gharib and Kadry (1983) and Salih and Abdul Halim (1985**)** indicated that low salinity, with optimal supply of nutrients, increased the yield of seed cotton. The higher seed cotton yield at K+Na treatment (135+37.5 mg kg^{-1}) was due to heavier boll weight. Figure 1 explains significant positive relationship (R^2=0.79, 0.88 for both varieties, respectively, n=4) between boll weight and seed cotton yield. The main effects of K+Na rates and interaction were found non-significant with respect to total number of bolls (Table 1). Main effects of K+Na rates and varieties varied average boll weight significantly ($p<0.01$). Interaction between K+Na rates and varieties had non-significant effect on boll weight. Maximum boll weight (3.29 g boll^{-1}) was produced at 135 +37.5 mg kg^{-1} K+Na, which was non-significant in the plants when grown with 135+30 mg kg^{-1} K+Na treatment. Maximum boll weight was produced by NIBGE-2 (Table 1).

Dry matter production of crop is mostly dependent on its assimilatory system. Cotton is one of the salt tolerant crops (Maas, 1990). Increase in growth with low concentration of salts has been observed (Pessarakli, 1995). It was important to note that K+Na treatments did not significantly ($p<0.01$) influence the shoot dry matter at final harvest, but enhanced the seed cotton yield significantly. The maximum total dry matter was produced at 135+37.5 mg/kg K+Na. Main effects of varieties and interaction influenced the shoot dry matter production significantly ($p<0.01$) (Table 2). Higher average shoot dry matter (48.91g plant^{-1}) was

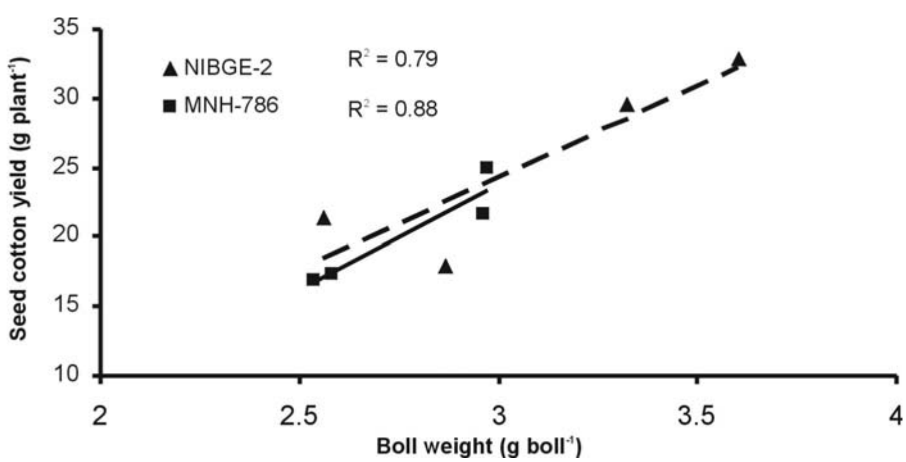

Fig. 1. Relationship between boll weight and seed cotton yield of two cotton varieties grown with various rates of K and Na in soil

produced by NIBGE-2 than that of MNH-786. Main effects of K+Na rates affected the root dry matter markedly, as against the shoot dry matter. Maximum mean root dry matter (4.78 g plant^{-1}) was produced at 135+37.5 mg kg^{-1} K+Na treatment, which was 26 % higher than the control (Table 2). The differences in root dry matter production were significant (p<0.01) due to interaction between rates of K+Na application and varieties. Significant (p<0.01) differences in total dry matter were observed due to K+Na rates. Maximum average total dry matter (57.40 g plant^{-1}) was produced in plants when grown with 135+37.5 mg kg^{-1} K+Na treatment. However, remaining three treatments behaved equally for total dry matter production of the two varieties. Under mild salinity, NIAB-78 exhibited increase in root growth but not shoot (Jafri and Ahmad, 1994). Zhang *et al*., (2006) explained that cotton growth, nutrition absorption and yield were improved by adding appropriate amounts of K and Na. Main effects of rates of K and Na significantly (p<0.01) influenced K:Na ratio in leaf. Varieties and their interaction with rates of K and Na influenced K:Na ratio in leaf non-significantly (Table 3). Maximum mean K:Na ratios in leaf (2.25) i.e. 149 % more than control, was observed at K+Na @ 135 +30 mg kg^{-1} due to addition of more K and minimum K:Na (0.47) i.e. 48 % less than control, was obtained at 105+37.5 mg kg^{-1} in both varieties due to addition of Na in a treatment. Thomas (1980) reported that under moderate salinity, Na concentration in leaves was modest and K concentration was higher than Na. Khan *et al*. (1998) reported that NIAB-78, the most tolerant cultivar, retained higher Na concentration in the roots than MNH-93. A high accumulation of Na in the leaves of salt tolerant cultivars of cotton has also been found (Leidi and Saiz, 1997). Jeschke and Wolf (1988) explained that K:Na ratio was attributed to K/Na exchange across the plasma lemma of root cortex cells and selective uptake of K. The results were not in agreement with those of Greenway and Munns, 1980. Main effects of rates of K+Na application and varieties had significant (p<0.01) effect on K use efficiency in shoot (Table 3). Interaction between rates of K+Na application x varieties influenced K use efficiency non-

Table 2. Total dry matter, shoot dry matter and root dry matter (g plant^{-1}) of selected cotton varieties grown with different K and Na rates in soil culture

(Values are means of four replicates)

Treatments	Total dry matter (g plant^{-1})			Shoot dry matter (g plant^{-1})			Root dry matter (g plant^{-1})		
	Cotton Varieties			Cotton Varieties			Cotton Varieties		
K+Na (mg kg^{-1})	**NIBGE-2**	**MNH-786**	**Mean**	**NIBGE-2**	**MNH-786**	**Mean**	**NIBGE-2**	**MNH-786**	**Mean**
135 + 30	53.06 NS	50.46	51.75 b	48.28 b	46.33 b	47.30 NS	4.78 ab	4.13 b-d	4.45 ab
105 + 30 (control)	49.71	49.30	49.50 b	45.73 b	45.70 b	45.71	3.98 cd	3.60 d	3.79 c
135 + 37.5	60.83	53.98	57.40 a	55.70 a	49.55 b	52.63	5.13 a	4.43 bc	4.78 a
105 + 37.5	50.40	49.18	49.79 b	45.95 b	45.30 b	45.63	4.45 bc	3.88 cd	4.16 bc
Mean	**53.49**	**50.73**		**48.91a**	**46.72 b**		**4.58 a**	**4.01 a**	

NS = non-significant
Means with different letter(s) differ significantly according to Duncan's Multiple Range Test (p<0.01)

Table 3. K : Na ratio and K use efficiency (g^2 SDM/mg K) in shoot of selected cotton varieties grown with different K and Na rates in soil culture

(Values are means of four replicates)

Treatments	K : Na ratio in leaf			K use efficiency (g^2 SDM/mg K)		
	Cotton Varieties			Cotton Varieties		
K+Na (mg kg^{-1})	**NIBGE-2**	**MNH-786**	**Mean**	**NIBGE-2**	**MNH-786**	**Mean**
135 + 30	2.25 NS	2.25	2.25 a	2.05	2.26	2.16 b
105 + 30 (control)	0.89	0.92	0.91 b	2.82	2.89	2.86 b
135 + 37.5	1.01	1.02	1.01 b	2.70	2.55	2.63 b
105 + 37.5	0.46	0.49	0.47 c	3.86	4.49	4.17 a
Mean	**1.15**	**1.17**	**1.16**	**2.86 b**	**3.05 a**	

NS = non-significant
Means with different letter(s) differ significantly according to Duncan's Multiple Range Test (p<0.01)

significantly. Highest mean K use efficiency in shoot of 4.17 g^2 SDM/mg K was observed with 105+ 37.5 mg kg^{-1} followed by K use efficiency of 2.86, 2.63 and 2.16 g^2 SDM/mg K at K+Na @105+30, 135+37.5 and 135+30 mg kg^{-1} respectively. Higher K use efficiency of 3.05 g^2 SDM/mg K was shown by MNH-786 than NIBGE-2 (2.86 g^2 SDM/mg K). Significant negative correlation (r= -0.89, -0.76, n= 4) was found between K:Na ratio and K use efficiency in shoot of NIBGE-2 and MNH-786, respectively (Fig. 2).

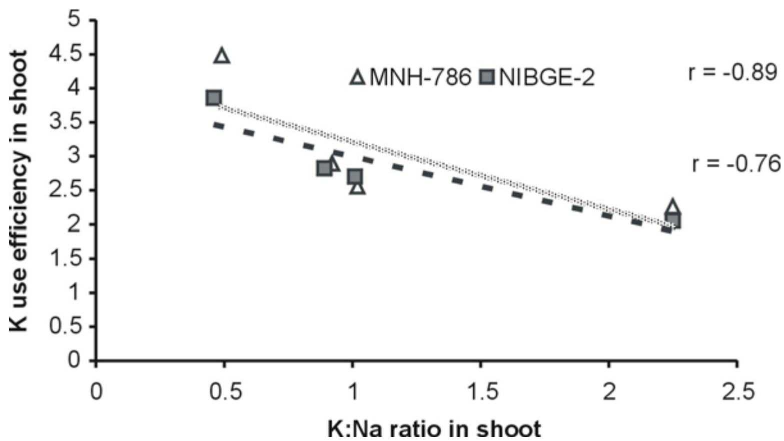

Fig. 2. Correlation between K:Na ratio and K use efficiency in shoot of two cotton varieties

CONCLUSION

Plant growth, yield and ionic ratio differed significantly with the application of K and Na. Maximum beneficial effects of Na with deficient K were observed on seed cotton yield, and boll weight in NIBGE-2 than in MNH-786. Significant negative correlation between K:Na ratio and K use efficiency in shoot of both varieties i.e. NIBGE-2 and MNH-786 was observed. Both varieties behaved equally with respect to K:Na ratio whereas, MNH-786 excelled over NIBGE-2 with respect to potassium use efficiency. The results suggested that both varieties may be tested under field conditions for their response to different K and Na rates.

ACKNOWLEDGEMENT

Authors are grateful to Higher Education Commission of Pakistan for providing financial support under the project "Development of S&T Manpower through Indigenous Ph. D. Scholarship Scheme."

REFERENCES

Ahmad, N. 2000. Integrated nutrition management in Pakistan: Status and Opportunities Proc. Symp. "Integrated Plant Nutrition Management": National Fertilizer Development Center, Islamabad. p.1-337.

Bigham, J.M. 1996. Methods of Soil Analysis. Part 3, Chemical Methods. SSSA and ASA, Madison, WI, USA.

Brugnoli, E. and O. Bjorkman. 1992. Growth of cotton under continuous salinity stress–influence on allocation pattern, stomatal and non stomatal components of photosynthesis and dissipation of excess light energy. Planta. 187: 335-347.

Daliparthy, J., A.V. Barker and S.S. Mondal. 1994. Potassium fractions with other nutrients in crops. A review focusing on the tropics. J. Plant. Nutr. 17: 1859-1886.

Duncan, D.B. 1955. Multiple Range and Multiple F-tests. Biometrics 11: 1-42.

El-Gharib, E.A. and W. Kadry. 1983. Effect of potassium on tolerance of cotton plants to salinity of irrigation water. Ann. Agric. Sci. Moshtohor 20: 27-34.

El-Sheikh, A.M. and A. Ulrich. 1970. Interaction of rubidium, sodium and potassium on the nutrition of sugar beet plants. Plant Physiol. 46: 645-649.

FAO (Food and Agriculture Organization). 1990. Soil Map of the World. FAO Soil Classification. Rome, Italy.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. John Wiley & Sons, NY, USA.

Greenway, H. and R. Munns. 1980. Mechanism of salt tolerance in non-halophytes. Ann. Rev. Plant Physiol. 3: 149-190.

Jafri, A.Z. and R. Ahmad. 1994. Plant growth and ionic distribution in cotton under saline environment. Pak. J. Bot. 26: 105-114.

Jeschke, W.D. 1984. K^+-Na^+ exchange at cellular membranes, intracellular compartmentation of cation and salt tolerance. In: Salinity tolerance in plants. Strategies for Crop Improvement. (Eds.) R.C. Staples and G.H. Toenniessen. John Wiley and Sons, New York. p.37-66.

Jeschke, W.D. and O. Wolf. 1988. External K supply is not required for root growth in saline conditions: Experiments with *Ricinus communis* L. grown in a reciprocal split root system. J. Exp. Bot. 39: 1149-1167.

Khan, A.N., R.H. Qureshi and N. Ahmad. 1998. Performance of cotton cultivars as affected by types of salinity. 1 Growth and Yield. Sarhad J. Agric. Sci. 14: 73-77.

Leidi, E.O. and J.F. Saiz. 1997. Is salinity tolerance related to Na accumulation in upland cotton seedlings? Plant and Soil. 190: 67-75.

Liebig, J. 1841. The Organic Chemistry and its Application on Agriculture and Physiology. Verlag, Viehweg, Braunschweig. Germany.

Maas, E.V. 1990. Crop salt tolerance. In: Agricultural salinity assessment and management. Tanji (Editor). Am. Soc. Civil Eng., New York. p.262-304.

Maathuis, F.J.M., A.M. Ichida, D. Sanders and J.I. Schroeder. 1997. Roles of higher plant K^+ channels. Plant Physiol. 114: 1141-1149.

Malik, D.M., R.A. Chaudhry and G. Hassan. 1989. Crop response to potash application in the Punjab. Proc. workshop on "The Role of Potassium in Improving Fertilizer Use Efficiency". National Fertilizer Development Center, Islamabad. p.71-93.

Marschner, H. 1971. Why can sodium replace K in plants? In: Potassium in Biochemistry and Physiology. Proc. Colloc. Int. Potash Inst., 8th Bern, Switzerland. p.50-63.

Marschner, H. 1995. Mineral Nutrition of Higher Plants. Academic Press, London.

Maser, P., B. Eckelmann and R. Vaidyanathan. 2002. Altered shoot/ root Na distribution and bifurcating salt sensitivity in *Arabidopsis* by genetic disruption of the Na transporter AtHKT1. FEBS Letters. 53: 157-161.

Mengel, K. and Rahmatullah. 1994. Exploitation of potassium by various crop species from primary minerals in soils rich in micas. Biol. Fertil. Soils 17: 75-79.

Miller, R.O. 1998. Nitric-Perchloric wet digestion in an open vessel. In: hand book of reference methods for plant analysis. (Ed.) Y.P. Kalra, CRC Press Washington, D.C., U.S.A. p.57-62.

Pessarakly, M. 1995. Physiological responses of cotton *(Gossypium hirsutum* L.) to salt stress. In: Handbook of Plant and crop physiology. (Ed.) M. Pessarakly, Dekker, New York, p.679-693.

Rashid, A. and E. Rafique. 1997. Nutrient indexing and micronutrient nutrition of cotton and genetic variability in rapeseed-mustard and rice to boron deficiency. Annual Report 1997. Land Resources Research Institute, National Agricultural Research Centre, Islamabad.

Reddy, K.R., H.F. Hodges and J. Varco. 2000. Potassium nutrition of cotton. Bulletin 1094. Agric. Comm. MSU, Div. Agric. Forestry and Vetr. Med. USA.

Roy, R.N. 2000. Integrated plant nutrition systems-conceptual overview. Proc. symp. on "Integrated Plant Nutrition Management." National Fertilizer Development Centre, Islamabad. p.45-48.

Russel, D.F. and S.P. Eisensmith. 1983. MSTAT-C. Crop and Soil Science Department, Michigan State University, East Lansing, M1.

Salih, H.M. and R.K.A. Halim. 1985. Effects of levels of two dominant salt types in Iraq on some components of cotton yield. J. Agric. Water Resources Res. 4: 1-14.

Soil Survey Report. 1969. Directorate of Soil Survey (WP), S.S. Project of Pakistan.

Soil Survey Staff. 1998. Keys to Soil Taxonomy. 8th ed. United States Department of Agriculture, Natural Sources Conservation Service, Washington DC 20402.

Thomas, J.R. 1980. Osmotic and specific salt effects on growth of cotton. Agron. J. 72: 407-412.

Zhang, Y., Q. Li, X. Zhou, C. Zhai and R. Li. 2006. Effects of partial replacement of potassium by sodium on cotton seedling development and yield. Jour. of Plant Nutri. 29(10): 1845-1854.