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Seed cotton yield, ionic and quality attributes of two cotton (*Gossypium hirsutum* L.) varieties as influenced by various rates of K and Na under field conditions

***Liaqat Ali**[*1], **Muhammad Ashraf**[2], **Muhammad Aamer Maqsood**[3], **Muhammad Sohail**[4] **and Abdul Hannan**[5]*
[1]Adaptive Research Farm, Vehari, Pakistan
[2]University College of Agriculture, University of Sargodha, Sargodha, Pakistan
[3]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan
[4]Cotton Research Station, Sahiwal, Pakistan
[5]Reclamation Farm, Sargodha, Pakistan

Abstract

Cotton is more sensitive to low K availability than most other major field crops, and often shows symptoms of K deficiency in soils not considered K deficient. Field investigation was conducted at Sahiwal to study the effect of different rates of K and Na application on seed cotton yield, ionic ratio and quality characteristics of two cotton varieties. Ten soil K: Na ratios were developed after considering indigenous K, Na status in soil. The treatments of K+Na in kg ha^{-1} to give K:Na ratios were as: 210+ 60 (3.5:1) i.e. control, 225 + 60 (3.75:1), 240 + 60 (4:1), 255 + 60 (4.25:1), 270 + 60 (4.5:1), 210 + 75 (2.8:1), 225 + 75 (3:1), 240 + 75 (3.2:1), 255 + 75 (3.4:1) and 270 + 75 (3.6:1). Control treatment represented indigenous K, Na status of soil. The experiment continued until maturity. Maximum seed cotton yield of NIBGE-2 was observed at K: Na ratio of 3.6:1. Variety NIBGE-2 manifested greater seed cotton yield than MNH-786. Leaf K: Na ratio of two cotton varieties differed significantly ($p < 0.01$) due to varieties, rates of K and Na and their interaction. Variety NIBGE-2 maintained higher K: Na ratio than MNH-786 and manifested good fiber quality. There was significant relationship ($R^2 = 0.55$, $n = 10$) between K: Na ratio and fiber length and significant relationship ($R^2 = 0.65$, $n = 10$) between K concentration and fiber length for NIBGE-2. There was also significant relationship ($R^2 = 0.91, 0.78$, $n = 10$) between boll number and seed cotton yield for both varieties. The increase in yield was attributed to increased boll weight.

Key words: Cotton (*Gossypium hirsutum* L.), seed cotton yield, ionic ratio, fiber quality

Introduction

Cotton is grown under a wide range of climate, soil and cultural practices. Soils, used for cotton production, vary in native fertility, and the use of fertilizers has played a major role in increasing cotton productivity. Since cotton produces vegetative and reproductive growth simultaneously over a long time, its nutritional needs are perhaps more complex than that of any other field crop (Grimes and El-Zik, 1990). Cotton is more sensitive to low K than most of the other crops and was the most responsive to K fertilization (Oosterhuis *et al*., 1997). Potassium dissolved in soil solution is in equilibrium with K^+ attached or bound electrostatically to organic matter and the surface of clay particles. Thus, only a portion of total soil K is soluble, in an exchangeable form and readily available to plant roots. However, at other times K held in a non exchangeable form in soil minerals can become exchangeable. When K fertilizer is applied to soil, some fertilizer may be bound or trapped within soil minerals so that part of it is either not available or slowly available to plants (Reddy *et al.,* 2000). In Pakistan, 6.8 m ha of land is salt-affected. Out of this, 2.67 m ha is in Punjab. Slightly saline land in Punjab is 472.4, moderately saline 805, severely saline 788 and very severe saline land is 652 thousand hectares (Anonymous, 2003). So there is dire need to screen cotton genotypes which have stable performance over range of salt affected lands. This will help a lot to improve and increase the cotton area and production.

A moderate increase in soil Na reduced the total K requirement due to a Na-K substitution that is known to maintain cotton yields at lower levels of K supply (Cassman *et al*., 1991). Significant differences in character have also been reported among varieties of different species including cotton (Qadir and Shams, 1997; Ashraf and Ahmad, 2000). Ali *et al*. (2006) reported that screening of thirty cotton genotypes on the basis of their potassium use efficiency and potassium substitution by sodium could be an effective approach for enhancing growth and yield under

*Email: shafqat_l@yahoo.com

potassium deficient conditions. Overall, genotype NIBGE-2 had the highest potential for better growth in potassium deficient soils due to increased total dry matter and high total potassium uptake in shoot. Potassium deficiency affects cotton growth. Sodium can substitute K for some non-specific functions in plants. Four cotton genotypes i.e. NIBGE-2, MNH-786, FH-1000 and NIAB-111 showed significant effect for their growth rates and potassium use efficiency grown at various K: Na ratios under hydroponics.

Maximum total dry matter was accumulated by NIBGE-2 whereas maximum K:Na ratio in shoot was obtained by MNH-786 followed by NIBGE-2 when 1/3rd potassium was replaced with sodium (Ali *et al*., 2009a). To cope with the problem of salinity, exploitation of genetic potential of plants for their adaptability to adverse soil conditions is an easy approach. Ibrahim *et al*. (2007) concluded that K^+:Na^+ ratio of seven cotton genotypes differed significantly with regard to growth and salinity tolerance at 100 and 200 mol m^{-3} NaCl concentration in rooting medium. Maximum yield was observed when 0.10 to 0.13 kg K was taken up for each kg of lint produced (Kerby and Adams, 1985). 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. Reddy and Zhao (2005) reported that critical leaf K concentration for biomass and stem growth was 12 g kg^{-1}, and for leaf area expansion the critical value was 17 g kg^{-1}. 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 ratio in both the tissues (Greenway and Munns, 1980). The synergistic or antagonistic effect between K^+ and Na^+ depends on the amount of each element present in the soil and on the plant type (Marschner, 1995). Leidi and Saiz (1997) observed the association of high shoot Na with salt tolerance of cotton.

The main feature of the tolerant genotype (Z407) was a higher accumulation of Na^+ in leaves and an apparent capacity for K^+ redistribution to younger leaves. They observed that the higher tolerance in Z407 is the result of several traits such as a higher Na^+ uptake and water content. Gareth Wyn Jones *et al*. (1979) suggested a minimum value for K: Na of 1 for normal growth of plants subjected to saline conditions. The impact of K-fertilizer is not always visible and consistent in terms of improvement in fiber quality parameters (Bauer *et al*., 1998). Whereas other researchers (Mullins *et al*., 1999) reported a considerable increase in various fiber quality parameters by K fertilizer addition on an irrigated soil. Pettigrew *et al*. (1996) studied genotypic interactions with K and N in cotton of varied maturity. They found that K-unfertilized treatments reduced fiber elongation by 3%, fiber length by 1%, uniformity ratio by 1%, fiber fineness by 10% and fiber maturity by 5% in all varieties. Bradow and Davidonis (2000) also reported that high rates of potassium correlated with improved fiber whiteness, fiber maturity, micronaire and decreased fiber yellowness. Ye *et al.* (1997) observed increase in fiber length and fiber fineness in upland cotton under soil salinity of 0.42%. These fiber quality responses under K deficient conditions were similar to those found by earlier workers (Cassman *et al.,* 1990; Pettigrew *et al*., 1996). Low micronaire cotton (<3.5 µg $inch^{-1}$) will have a thin cell wall with a smaller amount of cellulose in the fiber cell. Added K would increase metabolic processes related to secondary wall thickening (Bradow and Davidonis, 2000). Pettigrew (2003) found that plants grown at 0 kg K ha^{-1} produced lint with low micronaire, but values were not less than 3.8. Due to 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). The high requirement of K in cotton coupled with an inherent low root length density and immobile nature of the element, means that K uptake is particularly sensitive to poor root growth and deficiencies may appear even in soils with a relatively high K content. Ali *et al*. (2009b) concluded that beneficial effects of Na with K application over the control on seed cotton yield and boll weight were greater in NIBGE-2 than in MNH-786. Significant negative correlation was found between the K:Na ratio and K use efficiency in shoots of NIBGE-2 and MNH-786, respectively.

Ali *et al.* (2009c) elucidated that higher but non significant relative water contents were observed in treatments of 135+30 mg kg^{-1} followed by 135+37.5 mg kg^{-1}. The beneficial effects of Na with K application were observed greater in NIBGE-2 than in MNH-786. Both varieties varied non-significantly with respect to K:Na ratio in leaf water potential and total chlorophyll contents. Maser *et al.* (2002) reported that K^+ counteracts Na^+ stress while Na^+ in turn, can alleviate K^+ deficiency to a certain degree. Sodium can replace K^+ to a certain degree, particularly in its osmotic functions in the vacuole. Thus under K^+ starvation, addition of Na^+ may actually promote plant growth. The extent of replacement of K^+ by Na^+ depends largely on the plant species. Marschner (1995) 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. The accumulation of Na^+ ions inside the vacuoles provides a 2-fold advantage: a) reducing the toxic levels of sodium in cytosol; and b) increasing the vacuolar osmotic potential with the concomitant generation of a more negative water potential that favors water uptake by the cell and better tissue water retention under high salt salinity (He *et al*., 2005). Zhang *et al*. (2006) explained that cotton growth, nutrition absorption and yield were improved by adding appropriate amounts of K^+ and Na^+. Dry matter production of crop is mostly dependent on its assimilatory system. Assimilatory system comprises of all green area of plants. Khan *et al.* (1998) reported that NIAB-78, the most tolerant cultivar, retained higher Na^+ concentration in the roots than MNH-93. While D-9 was the most salt sensitive. Retention of high Na^+ in the roots could be the mechanism of salt tolerance in cotton. A high accumulation of Na^+ in the leaves of salt tolerant cultivars of cotton has also been found (Leidi and Saiz, 1997).

Present field study was undertaken to explore differences in seed cotton yield, ionic ratio and fiber characteristics of both cotton varieties under various K and Na rates.

Materials and Methods

The present investigation was started in May, 2006 under field conditions at Cotton Research Station Sahiwal. Plot size was measured at 5.5x3 m. The experiment was conducted during the summer when mean day temperature was 42 ± 4.5 °C and night temperature was 30 ± 7.6 °C, and day length was 14 h. The relative humidity ranged from 45 to 78%. The soil in experimental field was normal, non-saline, sandy clay loam having electrical conductivity of the saturation extract (ECe), 0.74 dS m^{-1}; pH, 8.21; organic matter, 0.63%; $CaCO_3$, 3.4%; Olsen-P, 7.5 mg kg^{-1}; NH_4OAc-K, 101 mg kg^{-1} and extractable Na, 26 mg kg^{-1}. Taxonomic class of the soil was mixed, hyperthermic Ustalfic Haplargid according to FAO (1990) and Soil Survey Staff (1998). The soil was Hafizabad Series as described by Soil Survey Report (1969). Two cotton varieties, NIBGE-2 and MNH-786 were sown to validate their performance under field conditions. At field capacity, delinted cotton seed of both the varieties was sown @ 25 kg ha^{-1} in field. The experiment design was a split plot with three replicates. Potassium and sodium treatments were kept in main plots while varieties were sown in sub plots. There was 75 cm row to row distance. Ten treatments were applied by developing required K:Na ratios after considering indigenous K and Na level in soil. The treatments of K+Na in kg ha^{-1} with K:Na ratios were as: 210+ 60 (3.5:1) i.e. control, 225 + 60 (3.75:1), 240 + 60 (4:1), 255 + 60 (4.25:1), 270 + 60 (4.5:1), 210 + 75 (2.8:1), 225 + 75 (3:1), 240 + 75 (3.2:1), 255 + 75 (3.4:1) and 270 + 75 (3.6:1). Control treatment represented indigenous K, Na status of soil. One 3rd dose of urea and full dose of single super phosphate (SSP) fertilizers were used to apply as basal recommended doses of N @ 170 kg ha^{-1} and P @ 57 kg ha^{-1} at the time of sowing. Remaining doses of urea were applied twice, 1/3rd at first irrigation and 1/3rd at pre-flowering stage. Potassium and sodium were applied as their sulphates. Thinning was done at 10 days after emergence. After germination the plant to plant distance was maintained at 15 cm to provide 37 plants of uniform size in each row. There were four rows in each plot. Weeding and other plant protection measures were adopted according to conventional practices, when it was necessary. Canal water of ECe = 0.26 dS m^{-1} was applied for irrigation purpose during the growth period.

Leaf samples were collected at 80 days after planting. Youngest fully expanded leaves were collected from main stem (fourth leaf from the top) from 10 randomly selected plants from each plot during the morning hours. These ten leaves per plot were stored in ice box, carried to the laboratory and dried for 48 h at 70 ºC for chemical analysis. Well ground leaf samples were digested in 5 mL of (3:1) nitric: perchloric acid mixture following Miller (1998). The digested samples were diluted with distilled water as per requirement and K and Na in the digest was determined with flame photometer (Jenway PFP 7). K: Na ratio was calculated by dividing K concentration with its Na concentration. The fiber quality characters i.e. Staple length (mm) by Fibrograph model 430, USA, Fiber strength (g tex^{-1}) by Stelometer model 154, Spinlab, USA and Fiber fineness or micronaire value (µg $inch^{-1}$) were determined after picking of seed cotton at maturity in the month of November, 2006.

The data obtained were subjected to statistical analysis using computer software "MSTAT-C" (Russell and Eisensmith, 1983) by following the methods of Gomez and Gomez, (1984). Analysis of the data was carried out according to split plot design. Duncan's multiple range tests was used for mean separation (Duncan, 1955).

Results and Discussion

Seed cotton yield

The data regarding seed cotton yield of two cotton varieties grown with various rates of K and Na are presented in Table 1. Differences in seed cotton yield due to rates of K and Na, varieties and their interaction were significant ($p < 0.05$). Maximum yield (2232 kg ha^{-1}) was obtained with 270 kg K+ 75 kg Na ha^{-1} at ratio 3.6:1. The yield was 28% higher than that at 270 kg K+60 kg Na. Varieties varied significantly ($p < 0.01$) for seed cotton yield. NIBGE-2 yielded better than MNH-786. Rates of K and Na x varieties interaction varied significantly ($p < 0.05$) with respect to seed cotton yield. Zhang *et al*. (2006) examined the effects of replacing K with Na and found that highest final seed cotton yield appeared when K and Na were added at rates of 115 and 65 mg kg^{-1}, respectively, in the top 20 cm of soil. Main effects of K and Na rates and

Table 1: Seed cotton yield (kg ha^{-1}) of two cotton varieties grown with various rates of K and Na under field conditions

(Values are means of 3 replicates)

Treatment (Kg ha^{-1})				Seed cotton yield (kg ha^{-1})		
K^+		Na^+	K^+:Na^+ ratio	NIBGE-2	MNH-786	Mean
225	+	60	3.75:1	1515 hij	1434 ij	1475 e
240	+	60	4:1	1657 f-i	1394 jk	1525 de
255	+	60	4.25:1	1717 e-h	1596 g-j	1657 cd
270	+	60	4.5:1	1778 d-g	1697 fgh	1737 c
210	+	60(control)	3.5:1	1192 kl	1030 lm	1111 f
225	+	75	3:1	1939 cde	1859 c-f	1899 b
240	+	75	3.2:1	2040 bc	1758 d-g	1899 b
255	+	75	3.4:1	2222 ab	1960 cd	2091 a
270	+	75	3.6:1	2384 a	2081 bc	2232 a
210	+	75	2.8:1	1434 ij	828 m	1131 f
Mean				**1788 a**	**1564 b**	

Means with different letter(s) differ significantly according to Duncan's Multiple Range Test ($p < 0.05$)

varieties produced significantly ($p < 0.01$) different number of bolls plant^{-1} (Table 2). Maximum numbers of bolls (24) were obtained with 270 kg K+75 kg Na. Highly significant ($p < 0.01$) differences in boll no. were manifested by varieties and the highest no. of bolls were obtained with NIBGE-2. Interaction between varieties and rates of K and Na was non significant ($p < 0.01$) for total number of bolls plant^{-1}. There were significant ($p < 0.01$) main effects of cotton varieties and rates of K and Na on boll weight (Table 2). Mean total boll weight ranged between 2.50 and 3.66 g boll^{-1} obtained at 210+60 and 270+75 kg K+Na, respectively. Variety, NIBGE-2 exhibited maximum boll weight. Interaction between varieties and rates varied significantly ($p < 0.01$) due to boll weight. Moderate salinity with adequate nutrition, did not have adverse effects on growth (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 present investigation determined changes in seed cotton yield and yield components, due to K, Na rates. The observed data is consistent with reports that K deficiency causes premature termination of reproductive growth (Pettigrew, 2003) and low boll weight (Kerby and Adams, 1985). It is suggested that highest seed cotton yield obtained by both varieties was due to the addition of K with Na @ 270 + 75 kg ha^{-1}. There was significant relationship (R^2 = 0.91, 0.78, n = 10) between boll number and seed cotton yield for both varieties (Figure 1). The increase in yield could mainly be attributed to increase in boll weight as evident in Figure 2.

Quality attributes

The present investigation determined changes in ionic relations and fiber quality, due to K and Na rates. Micronaire (µg inch^{-1}) value varied significantly ($p < 0.01$) due to the main effects of K and Na rates and varieties. The increased micronaire of 5.12 was obtained with 240+75 kg K+Na (Table 3). The variety, NIBGE-2 had the highest micronaire value. Although, the micronaire of the varieties increased (higher values of micronaire represent lower fineness) with the addition of Na in soil medium, therefore, the differences between varieties were consistent. Various rates of K and Na affected fiber strength of both cotton varieties significantly ($p < 0.05$) (Table 3).

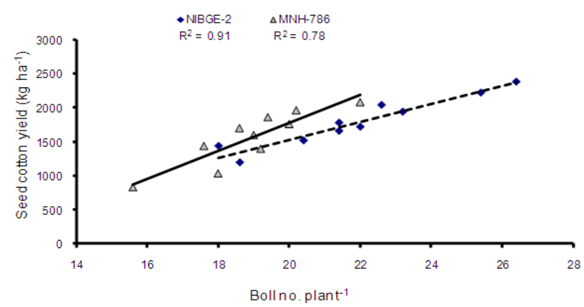

Figure 1: Relationship between seed cotton yield and boll number for both varieties

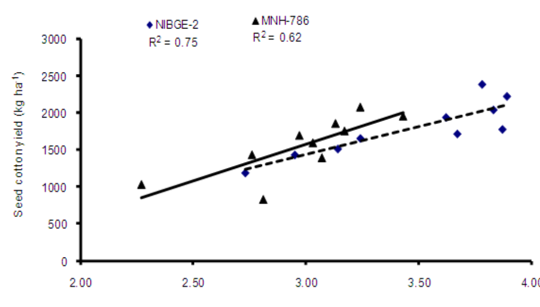

Figure 2: Relationship between seed cotton yield and boll weight for both varieties

Variety NIBGE-2 proved to be better in fiber strength value over MNH-786 under different rates. A maximum fiber strength value of 24.15 was observed with 270+ 60 kg K+Na. Various scientists were reported effects of limited nutrient availability on cotton fiber development (Bradow and Davidonis, 2000). There were significant ($p < 0.01$) main effects of rates of K and Na, varieties and their interaction on fiber length. The increase in fiber length was significant ($p < 0.01$) under all K and Na treatments (Table 3). Overall, NIBGE-2 performed better for fiber length than MNH-786. Increase in fiber length and fiber fineness had been observed in upland cotton under soil salinity of 0.42% (Ye *et al.,* 1997). These fiber quality responses under K deficient conditions were similar to those found by earlier workers (Cassman *et al.,* 1990; Pettigrew *et al*., 1996). Low micronaire cotton (<3.5 µg inch^{-1}) will have a thin cell wall with a smaller amount of cellulose in the fiber cell. Added K would increase metabolic processes related to secondary wall thickening (Bradow and Davidonis, 2000). Pettigrew (2003) found that plants grown at 0 kg K ha^{-1} produced lint with low micronaire, but values were not less than 3.8. Potassium stress directly influenced fiber quality. Because low K concentration in cotton leaf i.e. (8.58 mg g^{-1} leaf) produced low quality fiber, when both varieties were grown at K+Na 210+60 kg ha^{-1} i.e. control. The results are consistent with Bradow and Davidonis (2000).

Ionic relations

Main effects of K and Na rates, varieties and their interaction significantly ($p < 0.01$) varied K concentration (Table 4). Reddy and Zhao (2005) reported that critical leaf K concentration for biomass and stem growth was 12 g kg^{-1}, and for leaf area expansion the critical value was 17 g kg^{-1}. In this study, leaf K concentration of 8.58 mg g^{-1} was observed with 210+60 kg ha^{-1} K+Na i.e. control. A maximum K concentration of 23.61 mg g^{-1} was observed with 270+60 kg ha^{-1} K+Na. Minimum K concentration of 2.38 mg g^{-1} was obtained with 210+75 kg ha^{-1} K+Na. Both varieties varied significantly in K concentration and NIBGE-2 had the maximum concentration. Main effects of K and Na rates, varieties and their interaction varied significantly with respect to Na concentration in leaves (Table 4). Maximum Na concentration of 14.32 mg g^{-1} was noted with 210+75 kg ha^{-1} K+Na. NIBGE-2 exhibited highest Na concentration. Leidi and Saiz (1997) observed the association of high shoot Na with salt tolerance of cotton. Potassium: sodium ratio in leaves differed significantly ($p < 0.01$) due to main effects K and Na rates, varieties and their interaction (Table 4). Maximum K:Na ratio of 3.78 was demonstrated with 255+60 kg ha^{-1} K+Na. Two cotton varieties differed significantly for K:Na ratio in leaf. Maximum ratio was manifested by NIBGE-2 than MNH-786. Maintenance of higher K:Na ratio in NIBGE-2 indicated its relative superiority in fiber characteristics. It was attributed to K/Na exchange across the plasma lemma of root cortex cells and selective uptake of K (Jeschke and Wolf, 1988). Since, Gareth Wyn Jones *et al.*, (1979) suggested a minimum value for K:Na of 1 for normal growth of plants subjected to saline conditions. Some treatments exhibited K:Na ratio less than 1, that accounted for passive accumulation of Na in the roots and shoots thereby causing the K: Na ratios low in both the tissues (Greenway and Munns, 1980). There was significant relationship ($R^2 = 0.55$, $n = 10$) between K: Na ratio and fiber length and significant relationship ($R^2 = 0.65$, $n = 10$) between K concentration and fiber length for NIBGE-2 (Figure 3 and 4).

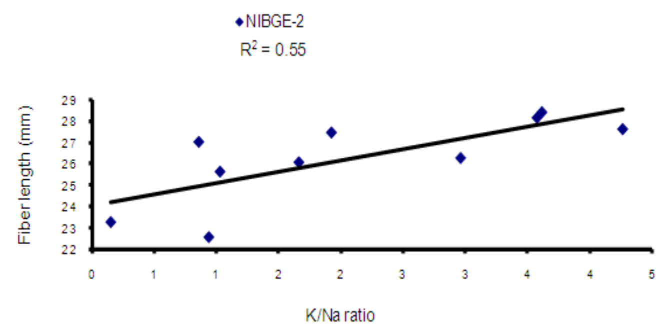

Figure 3: Relationship between fiber length and K/Na ration for NIBGE-2

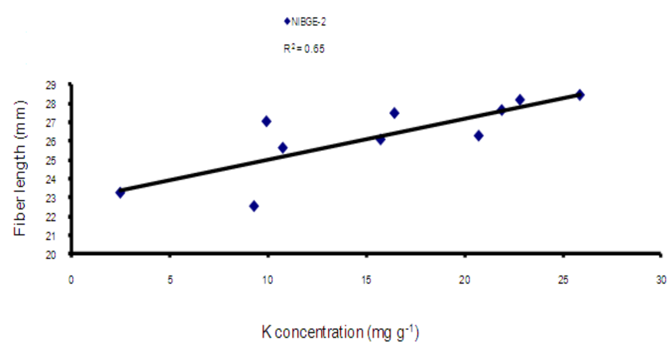

Figure 4: Relationship between K concentration and fiber length (mm) for NIBGE-2

Conclusion

Results of the present study indicated that K application @ 270 kg ha^{-1} along with Na @ 75 kg ha^{-1} increased seed cotton yield, boll number and boll weight significantly in both varieties. The variety NIBGE-2 produced relatively heavier and increased number of bolls and maintained good fiber quality than the MNH-786 under various K, Na rates. It was also associated with maintenance of higher K:Na ratio in the leaves. It is, therefore, suggested that the varieties with such characteristics could be expected to perform better in normal soil. The

Table 2: Number of bolls $plant^{-1}$ and boll weight (g $boll^{-1}$) of two cotton varieties grown with various rates of K and Na under field conditions

(Values are means of 3 replicates)

Treatments (Kg ha^{-1})				Number of bolls $plant^{-1}$			Boll weight (g $boll^{-1}$)		
K	**+**	**Na**	**K: Na ratio**	**NIBGE-2**	**MNH-786**	**mean**	**NIBGE-2**	**MNH-786**	**Mean**
225	+	60	3.75:1	20.4 ns	17.6	19.0 e	3.14 fgh	2.76 ij	2.95 de
240	+	60	4:1	21.4	19.2	20.3 cd	3.24 ef	3.07 fgh	3.16 cd
255	+	60	4.25:1	22.0	19.0	20.5 cd	3.67 bc	3.03 fgh	3.35 bc
270	+	60	4.5:1	21.4	18.6	20.0 d	3.87 ab	2.97 ghi	3.42 abc
210	+	60*	3.5:1	18.6	18.0	18.3 e	2.73 j	2.27 k	2.50 f
225	+	75	3:1	23.2	19.4	21.3 c	3.62 cd	3.13 fgh	3.38 bc
240	+	75	3.2:1	22.6	20.0	21.3 c	3.83 abc	3.17 fg	3.50 ab
255	+	75	3.4:1	25.4	20.2	22.8 b	3.78 abc	3.24 ef	3.51 ab
270	+	75	3.6:1	26.4	22.0	24.2 a	3.89 a	3.43 de	3.66 a
210	+	75	2.8:1	18.0	15.6	16.8 f	2.95 hi	2.81 ij	2.88 e
Mean				**21.94 a**	**18.96 b**		**3.47 a**	**2.99 b**	

*Control, ns = non-significant

Means with different letter(s) differ significantly according to Duncan's Multiple Range Test ($p < 0.05$)

characteristics of such variety should be included in a breeding program to develop cotton varieties with higher yield potentials.

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Table 3: Micronaire ($\mu g\ inch^{-1}$), fiber strength ($g\ tex^{-1}$) and fiber length (mm)of two cotton varieties grown with various rates of K and Na under field conditions

(Values are means of 3 replicates)

Treatment ($kg\ ha^{-1}$)				Micronaire ($\mu g\ inch^{-1}$)			Fiber strength ($g\ tex^{-1}$)			Fiber length (mm)		
K	+	Na	K:Na ratio	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean
225	+	60	3.75:1	4.83ns	4.57	4.70 bc	24.10 a-d	20.80 kl	22.45 b	26.27 d-g	25.47 gh	25.87 cde
240	+	60	4:1	4.80	4.60	4.70 bc	24.03 a-d	23.57 b-f	23.80 a	27.63 bc	25.53 fgh	26.58 bcd
255	+	60	4.25:1	4.97	4.77	4.87 abc	25.17 a	22.77 e-i	23.97 a	28.17 ab	26.33 def	27.25 ab
270	+	60	4.5:1	4.90	4.87	4.88 abc	24.37 abc	23.93 a-e	24.15 a	28.43 a	26.67 de	27.55 a
210	+	60*	3.5:1	4.47	4.20	4.33 d	21.10 jkl	20.67 kl	20.89 c	22.54 i	22.82 i	22.68 f
225	+	75	3:1	5.07	5.00	5.03 a	23.07 d-h	22.47 f-i	22.77 b	27.03 cd	26.07 efg	26.55 bcd
240	+	75	3.2:1	5.13	5.10	5.12 a	24.53 ab	23.23 c-g	23.88 a	25.63 fgh	24.85 h	25.24 e
255	+	75	3.4:1	5.13	4.83	4.98 ab	22.20 g-j	21.77 ijk	21.99 b	26.07 efg	25.43 gh	25.75 de
270	+	75	3.6:1	5.17	4.83	5.00 a	22.63 f-i	22.33 f-j	22.48 b	27.47 bc	25.93 efg	26.70 abc
210	+	75	2.8:1	4.20	4.13	4.17 e	21.83 h-k	20.43 l	21.13 c	23.25 i	22.47 i	22.86 f
Mean				**4.95 a**	**4.78 b**		**23.30 a**	**22.20 b**		**26.25 a**	**25.16 b**	

Table 4: Potassium concentration, sodium concentration ($mg\ g^{-1}$) and K : Na ratio in leaves of two cotton varieties grown with various rates of K and Na under field conditions

(Values are means of 3 replicates)

Treatment $kg\ ha^{-1}$				Potassium concentration ($mg\ g^{-1}$)			Sodium concentration ($mg\ g^{-1}$)			K :Na ratio		
K	+	Na	K:Na ratio	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean	NIBGE-2	MNH-786	Mean
225	+	60	3.75:1	20.70 de	19.17 f	19.93 d	7.00 jk	7.70 i	7.35 e	2.96 d	2.49 e	2.73 c
240	+	60	4:1	21.88 bc	19.63 ef	20.76 c	5.13 m	6.23 l	5.68f	4.27 a	3.15 d	3.71 a
255	+	60	4.25:1	22.80 b	20.18 ef	21.49 b	6.43 kl	5.07 m	5.75 f	3.58 c	3.99 b	3.78 a
270	+	60	4.5:1	25.85 a	21.37 cd	23.61 a	7.17 ij	7.40 ij	7.28 e	3.62 c	2.89 d	3.25 b
210	+	60*	3.5:1	9.27 jk	7.89 lm	8.58 g	9.87 fg	10.83 de	10.35 bc	0.94 hi	0.73 hi	0.84 f
225	+	75	3:1	9.90 ij	8.37 kl	9.13 g	11.50 c	10.30 ef	10.90 b	0.86 hi	0.82 hi	0.84 f
240	+	75	3.2:1	10.73 hi	7.10 m	8.92 g	10.40 ef	11.13 cd	10.77 b	1.03 h	0.64 i	0.83 f
255	+	75	3.4:1	15.71 g	9.15 jk	12.43 f	9.43 g	10.03 fg	9.73 c	1.67 fg	0.91 hi	1.29 e
270	+	75	3.6:1	16.41 g	11.19 h	13.80 e	8.52 h	7.57 ij	8.05 d	1.93 f	1.48 g	1.70 d
210	+	75	2.8:1	2.46 n	2.31 n	2.38 h	15.94 a	12.70 b	14.32 a	0.15 j	0.18 j	0.17g
Mean				**15.57 a**	**12.63 b**		**9.14 a**	**8.90 b**		**2.10 a**	**1.73 b**	

*Control; ns = non-significant; Means with different letter(s) differ significantly according to Duncan's Multiple Range Test ($p<0.05$)

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