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FOLIAR APPLIED POTASSIUM ENHANCES FIBRE QUALITY, WATER RELATIONS AND YIELD OF COTTON

Zahoor Ahmad* [1], Shazia Anjum [2], Muhammad Aamir Iqbal [3] and Hafiz Saeed-ur-Rehman [4]

[1] Assistant Professor,
[2] Professor, Cholistan Institute of Desert Studies, Islamia University of Bahawalpur,
[3] Assistant Professor, Department of Agronomy, University of Poonch, Rawalakot, AJK,
[4] Agronomist, Agronomic Research Institute, Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan.
*Corresponding author e-mail:zahorr.ahmad@iub.edu.pk, zahoorahmadbwp@gmail.com

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ABSTRACT

A study was conducted in the Department of Agronomy, University of Agriculture, Faisalabad, Pakistan to check the effect of different potassium (K) levels on water relations, fibre quality and yield traits of two cotton cultivars (FH-942 and FH-113). Four levels of foliar potassium (0, 1, 1.5 and 2%) were arranged in RCBD replicated thrice with a net plot size of 1.5 m x 5.0 m in farm area. The results revealed significant differences for fibre quality and yield parameters due to foliar applied K levels. However, foliar applied K @ 1.5% performed better than all other treatments. Maximum water (-1.08 and -1.11MPa), osmotic (-1.43 and -1.45 MPa) and turgor potential (0.64 and 0.56 MPa) were noted in K level of 1.5% both at 40 and 60 DAS. The same K level showed maximum fibre strength (28.12g /tex), fibre length (32.24 mm), fineness (6.22 micronaire), uniformity (54.60%) and fibre elongation (5.80%). The yield related parameters i.e. number of sympodial and monopodial branches, bolls number, ginning outturn and yield of seed plus cotton were significant and more at 1.5% foliar applied potassium level. These parameters were better in cultivar FH-942 than FH-113.

KEYWORDS: *Gossypium hirsutum;* cotton; potassium; water relations; fibre quality; yield, Pakistan.

INTRODUCTION

Cotton crop plays an important role in the economy of many countries and also associated with ancient civilizations. These civilizations contribute to economic development of many countries. Cotton has valuable importance such as it is used for oil, fibre and many other products; so it is called as cash crop (Texier, 1993). World-wide approximately 76 countries are growing cotton over an area of 32 million hectares which provides raw material to 1263 ginning units and 503 textile mills (Saranga *et al.,* 2001).

Potassium fertilization significantly improved the biomass production and partitioning between different organs of cotton cultivars (Makhdum *et al.,* 2007). Potassium is one of the important nutrient for cotton which plays a crucial role in dry matter accumulations and quality improvement (Makhdum, *et al.,* 2005, 2007; Pervez, *et al., 2006,* 2007; Zhang *et al.,* 2007). The quality of cotton fibre is affected depending upon the types of cultivars and different management practices (Subhan *et al.,* 2001). Wild cultivars of cotton are used for getting good quality of cotton fibre (McCarty *et al.,* 1998). Lee *et al.* (1967) stated that short fibre of cotton was obtained by crossing the wild cultivars of cotton with commercially used cotton cultivars. The different selected cultivars of cotton are important for the fibre length and fibre micronaire difference under different management practices (Meredith, 1986).

Potassium has the major role in osmoregulation, photosynthesis, transpiration, stomatal opening and closing, synthesis of protein, etc. (Cakmak, 2005; Milford and Johnston, 2007). The growth of crop is reduced when K is not applied sufficiently (Hermans *et al.,* 2006). Foliar potassium fertilization by cotton growers and also at research stations has resulted in consistent and largely unpredictable yield responses (Oosterhuis, 1993). Potassium application significantly increases cotton seed yield per hectare and influences the lint yield of cotton in late growing season. Moreover, positive effects of K on lint have been observed in many studies. Marschner (1995) and Cakmak (2005) stated that potassium is not a component of plant structure and any organic molecule, in many physiological and biochemical processes potassium is involved in yield, quality and plant growth parameters. Demiral and Koseoglu (2005), Lester *et al*. (2005 and 2006) and Jifon and Lester (2009) studied many crops and showed that foliar applied potassium enhanced the quality of fruits more as compared to soil applied potassium. Ebelher and Varsa (2000) evaluated foliar potassium application for increasing cotton lint yield. In this experiment soil applied potassium @ 10, 50, 75 and 100 lb per acre did not increase yield significantly. However, foliar spray of potassium nitrate and urea increased yield @ 5 and 6%, respectively alongwith significant increase in growth rate and fibre quality.

Oosterhuis (1994) conducted physiological research on potassium nutrition in cotton and observed that lint yield, boll weight and number of open bolls at harvest were higher in plants given foliar potassium application. Foliar applied K @ 11.2 kg ha^{-1} during early flowering period, showed better results than that of 13.6 kg ha^{-1} soil application.

The present study was conducted to see the effect of foliar applied potassium on fibre quality water relations of cotton and response of cotton yield parameters to foliar applied potassium.

MATERIALS AND METHODS

Experimental site and treatments

This study was conducted in farm area of Department of Agronomy, University of Agriculture, Faisalabad, Pakistan during the year 2014. After the harvesting of previously sown crop such as wheat, the soil was tested before sowing of cotton crop**.** The soil samples were collected from the experimental site with the help of soil augar at the depth of 0-6 inch and 0-9 inch prior to fertilizer application. Different values of soil characters are given below:-

Table 1. Soil characters of experimental site.

Parameters	Values	Status
0.6 inch depth		
Texture class		Sandy clay soil (medium hard)
EC dSm^{-1}	0.67	Normal
pH	7.52	Alkaline calcareous soil
CO_3^{2-}	0.00	Absent
HCO_3^{1-}	3.48	Normal
Cl^{1-}	1.92	Normal
$Ca^{2+} + Mg^{2+}$	4.62	Normal
0-9 inch depth		
Texture class		Sandy clay soil (medium hard)
EC dSm^{-1}	0.83	Normal
pH	7.80	Alkaline calcareous soil
CO_3^{2-}	0.00	Absent
HCO_3^{1-}	2.04	Normal
Cl^{1-}	4.00	Normal
$Ca^{2+} + Mg^{2+}$	5.48	Normal

Four levels of foliar K (0, 1, 1.5 and 2%) were applied on two cotton varieties (FH-942 and FH-113) in RCBD with factorial arrangement and three replications. The size of plot was 4.75 m x 5 m. The potassium sulphate was used as a source for foliar application.

Crop husbandry

Both cultivars were planted with manual hand sowing at May 24, 2014 in 75 cm row to row distance and 20-25 days after sowing. A 30 cm plant to plant distance was maintained after thinning. At sowing time, whole phosphorous (60 kg ha^{-1}) and potassium (60 kg ha^{-1}) was applied. Three different split doses of nitrogen @ 150 kg ha^{-1} were used. Foliar application of potassium @ 157.895 l ha^{-1} was done 40 and 65 days after sowing (DAS) at field capacity level. During the whole season, the crop was irrigated nine times. The weeds of cotton crop were controlled manually by hoeing. Insecticides were applied five times, as and when required, to control the insect pests of cotton. Seed cotton was picked in one picking after 180 days of sowing.

Collection of data

For data collection, five plants were selected from each plot and tagged. Water relation parameters such as water potential, osmotic potential and turgor pressure were measured using pressure chamber. Osmomtere was used to measure osmotic potential of cotton leaf . The turgor potential was calculated using formula such as;

Turgor potential = Water potential – osmotic potential

The data on quality parameters were taken in High Value Instrument (HIV) Lab, Department of Fibre and Textile Technology, University of Agriculture, Faisalabad. High Volume Instrument (HIV-9008 ASTM) was used for measuring the fibre quality of cotton cultivars using the methods of ASTM standards (1997 a). Before measuring, method of Zellweger (1995) was used for calibration of instrument. The data of all yield related parameters (number of monopodial and sympodial branches, bolls number per plant, boll weight, ginning outturn and yield of seed cotton) were recorded from five tagged plants. The number of monopodial branches, sympodial branches and bolls per plant were calculated by counting from five tagged plants in each plot. GOT was measured according to formula of Singh (2004) as given below:-

$$GOT\ (\%) = \frac{\text{Weight of lint in sample}}{\text{Weight of seed cotton in that sample}} \times 100$$

Statistical analysis

Data were analysed according to Steel *et al.* (1997) using 5 % probability level of LSD test.

Meteorological data

The meteorological data for growing period of the crop were collected from the Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan (Table 2, Fig. 1 and 2).

RESULTS AND DISCUSSION

Water relation parameters

All water relation parameters of cotton were significantly affected at all levels of foliar application of potassium

Table 2. Meteorological data for growing period of crop.

Weeks	Mean Temp.(C°)	Relative humidity (%)	Rainfall (mm)
24 May - 30 May	35.50	29.57	00.0
31 May - 6 June	33.48	35.86	00.0
7 June - 13 June	31.89	42.86	00.0
14 June - 20 June	33.63	36.57	00.0
21 June - 27 June	35.77	40.43	0.04
28 June - 4 July	35.30	47.43	0.72
5 July - 11 July	33.90	54.13	0.14
12 July - 18 July	31.80	67.29	16.80
I 9 July - 25 July	29.10	71.57	19.40
26 July - 1 Aug.	31.10	70.14	2.70
2 Aug. - 8 Aug.	31.20	74.72	15.30
9 Aug. - 15 Aug.	30.90	77.57	8.60
16 Aug. - 22Aug.	30.80	78.57	4.70
23 Aug. - 29 Aug.	28.60	72.57	5.90
30 Aug. - 5 Sep.	31.40	68.14	00.0
6 Sep. - 12 Sep.	29.90	70.57	4.60
13 Sep. - 19 Sep.	26.80	68.13	6.40
20 Sep. - 26Sep.	27.40	68.57	1.40
27 Sep. - 3Oct.	28.50	52.86	00.0
4 Oct. - 10 Oct.	28.50	56.57	00.0
11 Oct. - 17 Oct.	27.60	54.29	00.0
18 Oct. - 24 Oct.	25.60	66.86	00.0
25 Oct. - 31 Oct.	22.20	62.15	00.0
1 Nov. - 6 Nov.	22.00	57.86	00.0
7 Nov. - 13 Nov.	20.30	62.13	00.0
14 Nov. - 20 Nov.	17.90	65.00	00.0
21 Nov. - 27 Nov.	16.70	64.29	00.0

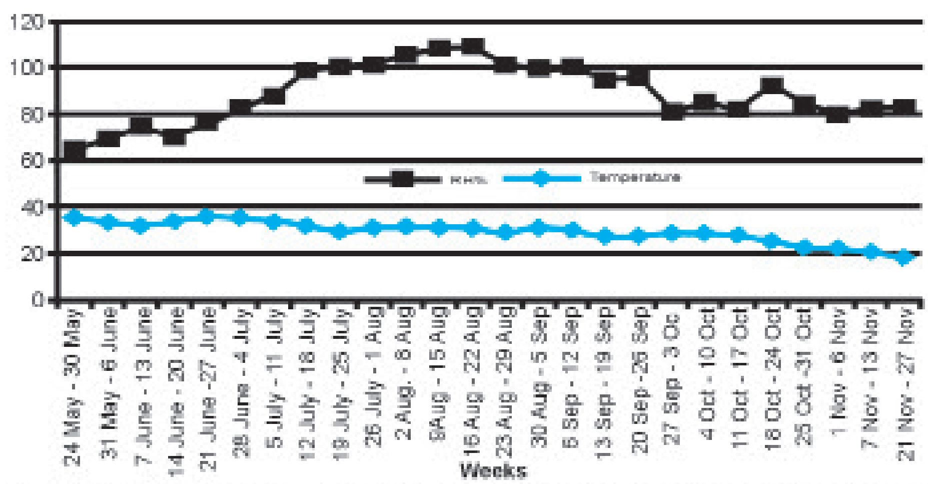

Fig. 1. Mean temperatures(c) and relative humidity(%) during crop growth period.

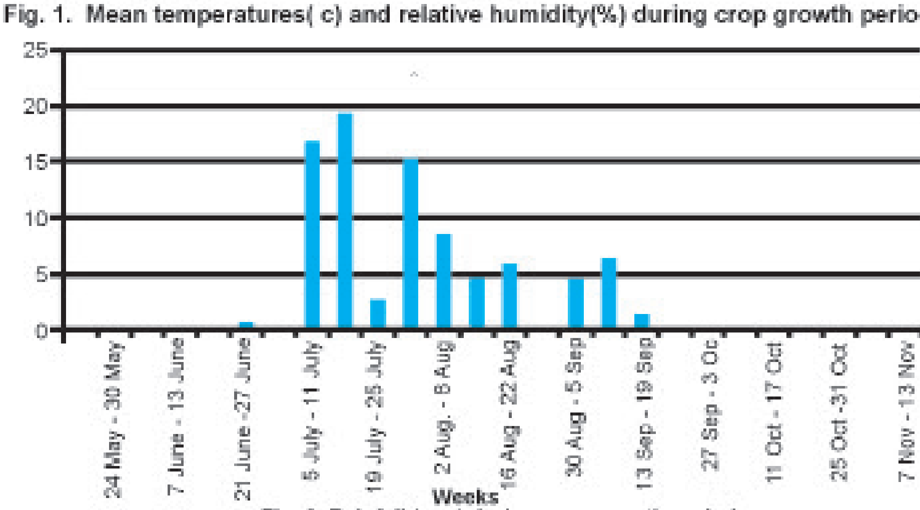

Fig. 2. Rainfall (mm) during crop growth period.

(Table 3). The foliar K application @ 1.5% produced more water potential (-1.08 MPa after 40 DAS and -1.11 MPa after 65 DAS) as compared to other K levels (Table 4). Control treatment produced a water potential of -1.21 after 40 DAS and -1.30 after 65 DAS. Similarly foliar application of potassium applied @ 1.5% produced more osmotic (-1.43 after 40 DAS and -1.45 after 65 DAS), turgor potential (0.648 after 40 DAS and 0.56 a after 65 DAS) and relative water content (0.796 after 65 DAS) as compared to other K levels (Table 4).

Table 3. Mean square values from analysis of variance of water relations parameters of cotton cultivars.

SOV	d.f	Water potential (-MPa)		Osmotic potential (-MPa)		Turgor potential (MPa)	
		40 DAS	65 DAS	40 DAS	65 DAS	40 DAS	65 DAS
Replication	2	0.0008	0.0007	0.00259	0.0008	0.00309	0.00194
Potassium (K)	3	0.0224**	0.0454**	0.19163**	0.2245**	0.10792**	0.0680**
Varieties (V)	1	0.0057^{NS}	0.0002^{NS}	0.00584^{NS}	0.0007^{NS}	8.43^{NS}	0.0001^{NS}
K X V	3	0.0013^{NS}	.0018^{NS}	0.00110^{NS}	0.0162*	0.0020^{NS}	0.00967^{NS}
Error	14	0.0015	0.0018	0.00261	0.0025	0.0031	0.0042

NS = Non-significant, *Significant at 0.05 level of probability. **Significant at 0.01 level of probability.
SOV = Source of variation, d.f = Degree of freedom

Table 4. Effect of different levels of foliar potassium application on water relation parameters of cotton cultivars.

Treatments / Varieties		Water potential (MPa)	Osmotic potential (MPa)	Turgor potential (MPa)
FH-942	at 40 DAS	-1.18	-1.68	0.500
	at 65 DAS	-1.22	-1.69	0.468
FH-113	at 40 DAS	-1.14	-1.64	0.499
	at 65 DAS	-1.23	-1.70	0.464
Concentrations of K_2SO_4 sprayed				
Control	at 40 DAS	-1.21c	-1.86d	0.351d
	at 65 DAS	-1.30c	-1.87c	0.334c
1%	at 40 DAS	-1.20c	-1.63b	0.570b
	at 65 DAS	-1.28c	-1.82c	0.428b
1.5%	at 40 DAS	-1.08a	-1.43a	0.648a
	at 65 DAS	-1.11a	-1.45a	0.56a
2%	at 40 DAS	-1.14b	-1.71c	0.429c
	at 65 DAS	-1.20 b	-1.63b	0.53a
Interaction				
K x V	at 40 DAS	NS	NS	NS
	at 65 DAS	NS	Significant	NS

These findings support the earlier work where improved water potential was noted in different potassium levels. In a study (Siddique *et al.,* (2000) drought stress affected the water relation which is considered to be a reliable parameter for quantifying plant water stress response. The addition of potassium fertilizer in the form of K_2SO_4 showed an edge of 9.5% over KCl in maintaining higher leaf water potential (Pervez *et al.,* 2004). These findings also support the earlier work on enhanced turgor potential by different potassium levels as Outtar *et al.* (1987) observed drought effect on the turgor potential.

Fibre quality parameters

The foliar applied potassium showed significant ($P \geq 0.05$) effect on all fibre quality parameters studied (Table 5). The K applied at lateral stage of cotton performed better which also had important function for development of good fibre. The foliar K application @ 1.5% enhanced the fibre quality of cotton. Shanmugham and Bhat (1991) stated that all the fibre quality parameters of cotton enhanced when foliar potassium applied at flowering stage. During growth of fibre, less supply of K causes certain disorders such as fibre turgor pressure decreases, which results in low elongation of cell and fibre becomes shorter at maturity stage of cotton (Oosterhuis, 1994).

Fibre uniformity: The fibre uniformity of cotton cultivars (FH-942 and FH-113) and their interaction (K x V) was significantly affected by different levels of foliar applied potassium (Table 5). K @ 1.5% showed maximum value of fibre uniformity (54.60%) as compared to all others treatments but similar with foliar applied K @ 2% (53.90%) (Table 6). The cotton cultivar FH-942 performed well and gave maximum value of fibre uniformity (52.15%) as compared to cultivar FH-113 (50.33%) (Table 6). The reason of enhanced fibre uniformity due to foliar applied K is that it is genetically controlled character. Similar results were reported by Dhindas *et al*. (1975) who stated that fibre uniformity was reduced by the deficiency of potassium in cotton. The uniformity of fibre is enhanced by the selection process and it is controlled character (Bednarz *et al.,* 2005).

Fibre length: Data showed that cultivars showed non-significant results while potassium levels and their interaction (K x V) were found to have significant effect on fibre length (Table 5). The foliar application of K @ 1.5% (32.24mm) and 2% (31.24mm) performed better as compared to all other treatments and were statistically at par with each other (Table 6). These results agree to those of Cassman *et al*. (1990) who stated that length of cotton fibre was enhanced by increasing the fertilization of potassium in cotton.

Table 5. Mean square values from analysis of variance of fibre quality traits of cotton cultivars.

SOV	d.f	FU (%)	FL (mm)	FF (%)	FS (g/tex.)	FE (%)
Replication	2	0.016	3.84	0.045	3.47	0.165
Potassium	3	87.48*	18.94*	3.46*	38.60*	3.28*
Varieties	1	20.00*	2.60 NS	0.028 NS	0.405 NS	0.199 NS
K x V	3	15.88*	5.41*	0.023 NS	0.055 NS	0.257 NS
Error	14	1.55	0.91	0.107	0.878	0.220

NS = Non-significant, *Significant at 0.05 level of probability. SOV = Source of variation, d.f = Degree of freedom, FU = Fibre uniformity (%), FL = Fibre length (mm), FF = fibre fineness (micronair), FS = Fibre strength (g/tex), and FE = Fibre elongation (%).

Table 6. Effect of different levels of foliar application potassium on fibre quality parameters of cotton.

Treatments Varieties	Fibre uniformity (%)	Fibre length (mm)	Fibre fineness (micronair)	Fibre strength (g/tex.)	Fibre elongation (%)
FH-942	52.15 a	30.72	5.58	25.78	5.21
FH-113	50.33 b	30.06	5.51	25.52	5.03
Concentrations of K sprayed					
Control	46.33 c	28.12 c	4.55 c	22.44 c	4.19 c
1%	50.13 b	29.97 b	5.38 b	24.87 b	4.88 b
1.5%	54.60 a	32.24 a	6.22 a	28.12 a	5.80 a
2%	53.90 a	31.24 a	6.50 a	27.16 a	5.62 a
Interaction					
K x V	Significant	Ns	Ns	Ns	Ns

Fibre fineness (micronair): The data showed that different levels of K performed significantly better but the interaction between cotton varieties and K levels was non-significant for this character (Table 5). Data further showed that foliar applied K @ 2% gave more value of fibre micronair (6.50%) which was alike with 1.5% foliar application of K (6.22%) as compared to other treatments (Table 6). Davidonis *et al.* (2004) also concluded that fibre micronair enhanced in cotton by application of nutrients.

Fibre strength: The potassium sulphate levels significantly affected also the fibre strength while cultivars and K interaction (K x V) was found to be non-significant (Table 5). Maximum value of fibre strength (28.12 g/tex.) was obtained with 1.5% foliar applied potassium sulphate which was statistically same with 2% (27.16 g/tex.) (Table 6). Fibre strength is an important trait for measuring yarn spin ability of cotton. The different cultivars of cotton have different fibre strength (Faircloth, 2007).

Fibre elongation: Analysis of variance showed that potassium sulphate had significant effect on fibre elongation while cultivars and K interaction (K x V) had non-significant effect (Table 5). Data showed that fibre elongation of cotton increased with the high level of potassium sulphate. Foliar applied K @ 1.5% produced more fibre elongation (5.80%) which was similar with 2% K (5.62%) (Table 6). Likewise Schubert *et al*. (1976) reported that fibre elongation was enhanced by developing water pressure in fibre as potassium application enhanced the water pressure inside the plants.

Yield and yield related components

Number of monopodial branches: Number of monopodial branches per plant was significantly affected by K levels; cultivars and their interaction (Table 7). Maximum number of monopodial branches per plant (6.5) was observed where K was applied @ 1.5% against minimum in control treatment (3.0) (Table 8). Variety FH-942 performed better (7.50) than variety FH-113 (2.25). These findings support the earlier work by Nichols *et al.* (2003) who reported that due to additional nutrition and wide spacing cotton plant showed significant increase in number of monopodial and sympodial branches to bear appropriate fruit on it.

Number of sympodial branches: Data showed that number of sympodial branches per plant and interaction of cultivars was also significantly affected by different K levels, cultivars and their interaction (Table 7). Maximum sympodial branches per plant (50.50) were recorded in foliar K applied @ 1.5% against minimum sympodial branches in control (35.00) (Table 8). The cotton cultivar FH-942 performed better for number of sympodial branches (49.25) than FH-113 (38.00) (Table 8). Nichols *et al.* (2003) also reported that additional nutrition and wide plant spacing significantly increased number of monopodial and sympodial branches to bear appropriate fruit on it. The increased number of sympodial branches in cotton was due to dominant genes (Ayaz and Khan, 2015).

Table 7. Mean square values from analysis of variance of yield and yield related parameters of cotton cultivars.

SOV	d.f	No. of monopodial branches	No. of sympodial branches	No. of bolls/ plant	Boll weight (g)	Ginning out turn (GOT) (%)	Seed cotton yield (g)
Replication	2	1.500	2.375	10.13	1.073	18.447	200.9
Potassium	3	16.375*	282.375*	1061.50*	16.098*	72.888*	23994.5*
Varieties	1	165.375*	759.375*	748.17*	1.286^{NS}	6.365 ^{NS}	1308.5*
K X V	3	3.375*	18.375*	59.28*	2.390 ^{NS}	23.558 ^{NS}	614.2 ^{NS}
Error	14	0.929	4.089	7.70	1.455	9.704	258.4

NS= Non-significant, *Significanct at 0.05 level of probability. SOV= Source of variation, d.f= Degree of freedom

Table 8. Effect of different levels of foliar potassium sulphate application on yield and yield related components of cotton cultivars.

Treatments	No. of monopodial branches	No. of sympodial branches	No. of bolls/ plant	Boll weight (g)	Ginning out- turn (GOT) (%)	Seed cotton yield/plant (g)
Varieties FH-942	7.50 a	49.25 a	42.33 a	16.55 a	27.96 a	241.79 a
FH-113	2.25 b	38.00 b	31.18 b	16.08 a	28.99 a	227.02 b
Concentrations of K sprayed						
Control	3.0 b	35.00 d	21.00 d	14.16 c	24.50 c	154.11 c
1%	4.0 b	41.50 c	32.00 c	15.92 b	26.78 bc	214.96 b
1.5%	6.5 a	50.50 a	52.00 a	17.66 a	32.22 a	274.36 a
2%	6.0 a	47.50 b	42.00 b	17.52 a	30.41 ab	294.19 a
Interaction						
K x V	Significant	Significant	Significant	NS	NS	NS

Number of bolls per plant: Number of open bolls per plant differed significantly in cultivars and among all foliar potassium levels (Table 7). More number of bolls per plant (52.00) was recorded in foliar K applied @ 1.5% than control (Table 8). Cultivar FH-942 produced more number of bolls (42.33) than FH-113 (31.18) (Table 8).

K deficiency causes the low photosynthesis and results in boll shedding. The boll shedding also starts when temperature increases. K application at these stages decreased the boll shedding of cotton (Guinn, 1985; Zeng, 1996a). Oosterhuis (2002) concluded that the bolls of cotton required more K during developing stage. Similarly, Brar and Brar (2004) stated that more K is needed during boll development which enhances the number of bolls and boll weight. Satang *et al.* (2000) also concluded that number of bolls per plant and boll weight had positive correlation with seed cotton yield.

Boll weight (g): Foliar applied potassium significantly affected boll weight while interaction of cultivars and potassium was non-significant (Table 7). The highest weight of boll (17.66 g) was noted where potassium was applied @ 1.5%. Maximum boll weight was in cultivar FH-942 (16.55g) and minimum in FH-113 (16.08g) (Table 8). The boll weight is an important part in cotton for enhancing the yield of seed cotton (Poehlam, 1987). The deficiency of K affects photosynthesis which results in reduced cotton boll weight. Gormus (2002), Aneela *et al*. (2003a) and Pervez *et al.* (2004) reported that boll weight of cotton was enhanced by K application. The K also enhanced the boll mass (Pettigrew *et al.,* 2005). Brar and Brara (2004) have also stated that application of K enhanced the bolls weight and bolls number of cotton.

Ginning outturn (%): Analysis of variance (Table 7) showed that foliar applied potassium significantly improved GOT while interaction between K and cultivars was non-significant (Table 7). Statistically higher GOT (28.99%) was recorded in FH-113 than in FH-942 (27.96%) while foliar applied potassium level (1.5%) showed maximum GOT (32.22 %) (Table 8). These results are in-line with those of Gormus (2002) and Abaye (1998) who stated that ginning outturn increased with increasing potassium concentrations.

Seed cotton yield (g/plant): The foliar applied potassium and both cotton cultivars performed significantly enhancing seed cotton yield but their interaction (K x V) was non-significant (Table 7). Maximum seed cotton yield (274.36 g), was recorded in foliar applied K @ 1.5% against minimum in control treatment (154.11g) (Table 8). Significantly higher yield of seed cotton (241.79 g) was observed in FH-942 while minimum in FH-113 (227.02 g) (Table 8). These results agree to those of Pervez *et al.* (2004) who reported significant effect K and cultivar interaction for seed cotton yield. The positive effect of K_2SO_4 was due to its associated anion (SO_4) of potash. Zeng (1996a) stated that more fertilization of K enhanced the yield and yield related component of cotton. Gormus (2000) concluded that at later stage of cotton, the accumulation of potassium proved helpful for increasing the yield of seed cotton. The foliar K application enhanced the seed cotton yield (Blaise *et al.,* 2009; Donald and Owen, 1998).

CONCLUSION

The study concluded that different K levels of foliar applied potassium enhanced the water relations, fibre quality and yield components of cotton significantly. However, foliar applied potassium @ 1.5% performed better than all other treatments.

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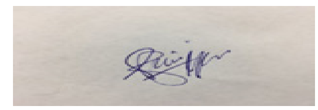
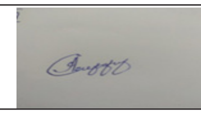
CONTRIBUTION OF AUTHORS

S. No.	Name of author	Contribution	Signatures
1.	Zahoor Ahmad	Conceived, designed the study and write the manuscript	
2.	Shazia Anjum	Critically reviewed manuscript	
3.	Muhammad Aamir Iqbal	Edited the manuscript	
4.	Hafiz Saeed-ur-Rehman	Provided reagents and analyzed results