

Response of rainfed cotton (*Gossypium hirsutum*) to foliar application of potassium

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ABSTRACT

Field studies were conducted (2002-03 to 2004-05) in Nagpur, Maharashtra under rainfed conditions to evaluate the response of upland cotton (*Gossypium hirsutum* L.) to foliar application of potassium (K). Treatments included a control (without K), soil application, soil application along with one foliar spray of K at either early boll or peak boll and two sprays at early and peak boll stages. Averaged across years, yield of the K applied plots were similar (0.97 to 1.07 tonne/ha) and were significantly greater than the control (0.81 tonne/ha). Yield differences were owing to more bolls in the K applied (40.8 to 53.3/m²) than control plots (33.6/m²). Year x treatment interaction was highly significant. In 2002-03 and 2004-05, rainfall was lesser than average and the K applied plots had significantly greater seed cotton yield (0.84 to 1.30 tonne/ha) than the control (0.71 to 0.75 tonne/ha). In 2004-05, treatment with 2 foliar sprays produced 392 kg/ha more seed cotton than soil application and was significantly superior to 1 spray. Total K uptake was greater in the K applied plots (61.3 to 68.8 kg/ha) than the control (39.1 kg/ha). Regardless of treatments, K balance (input - uptake) was negative (-37.1 to -43.8 kg/ha). In general, K application did not impact fibre quality. It was found that K application may be advantageous in years with low rainfall.

Key words: *Gossypium hirsutum*, Fibres, Potassium, Rain, Upland cotton, Vertisols

Cotton (*Gossypium* spp.) is the major commercial crop and is grown on about 5.4 million ha in central India with most of the area being rainfall dependent. Vertisols and associated soil groups are considered rich in K, and because of an inconsistent response to soil applied fertilizer K, it is often not included in the fertilizer recommendation (Kairon and Venugopalan, 1999). The earlier cotton cultivars were low yielding and had low nutrient requirements. Modern high yielding upland cotton (*Gossypium hirsutum*) cultivars and hybrids available in the market have high boll loads, a greater nutrient requirement and are very responsive to fertilizers. During boll formation, K requirement is higher because developing bolls are the largest K sinks on the cotton plant (Oosterhuis, 2002). The period of greater demand for K coincides with cessation of rains in the central India. Consequently, nutrient uptake is reduced. Moreover, cotton is considered inefficient in K absorption due to its poor root activity (Cassman *et al.*, 1989). Foliar supplementation is an option to supply the crop with K when demand is the greatest. Significant improvements in the yield were reported with foliar K

supplementation of 2% muriate of potash under irrigated conditions in north India, Punjab (Brar and Brar, 2004). Significant improvements in fibre quality with soil K application (Pettigrew, 1999) and foliar K supplementation (Pervez *et al.*, 2004) were reported. Presently, little is known about the response of cotton grown on Vertisols under rainfed conditions of central India to foliar K supplementation. To address some of these issues, field studies were conducted to determine the effects of K application through foliar vis-à-vis soil on seed cotton yield and fibre quality. Potassium uptake was measured and balance and use efficiency were also worked out.

MATERIALS AND METHODS

Field studies were conducted from 2002-03 through 2004-05 at the Central Institute for Cotton Research, Nagpur, India (21° 9' N and 17° 7' E). The region is characterized by a dry sub-humid climate with an annual rainfall of 1,050 mm. Most of the rainfall (Fig. 1) is received from June to September. Total rainfall in 2002-03 (918 mm) and 2004-05 (648 mm) was lesser than normal (1,008 mm), whereas normal and well distributed rainfall (1,069 mm) was received in 2003-04. The soil at the site belonged to the order Vertisols, with montmorillonite the dominant clay mineral. The soil was medium deep (60 to

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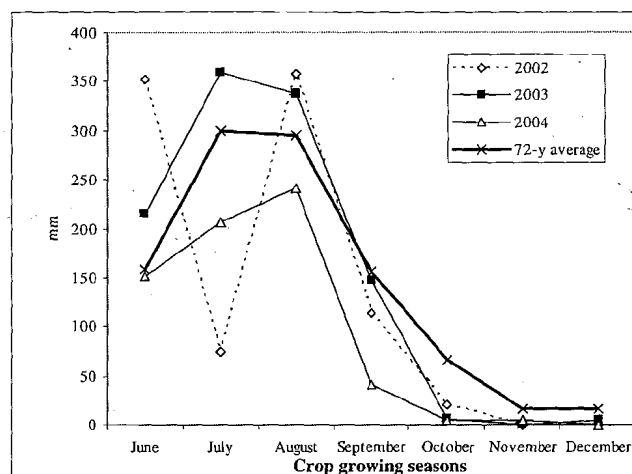


Fig. 1. Rainfall distribution during crop growing seasons

75 cm) and was slightly alkaline (pH 8.0). The surface soil (0-15 cm) was low in organic C (0.5 g/kg), medium in 0.5 M NaHCO_3 extractable P (0.79 mg/kg), and high in exchangeable (369 mg/kg) and non-exchangeable K (1511 mg/kg) content. Water soluble K content was 11.6 mg/kg. Cotton 'Rajat' was sown on 28 June in 2002 and 2003 and on 23 June in 2004, with the onset of rain. Three to four seeds were hand dibbled at 60 cm \times 30 cm and later thinned to a plant/hill at 15-20 days after emergence (DAE).

Potassium treatments included were (i) soil application (K_s), (ii) soil + foliar K application at early boll ($K_s + K_{EB}$), (iii) soil + foliar K application at peak boll ($K_s + K_{PB}$), and (iv) soil + foliar K at early and peak boll formation stages ($K_s + K_{EB+PB}$). A control treatment (K_0) was also included. Recommended amount of K (25 kg/ha) was soil applied in all the K treatments. In each foliar application, 4 kg K/ha was supplied. First spray of K at early boll was done around 80-90 DAE and the second 15 days later. Each treatment had 3 replicates and was arranged in a randomized block design. Each treatment plot had 10 rows, 6 m long. Potassium was supplied through fertilizer grade

muriate of potash. In the foliar K application treatments, K was applied through a knapsack sprayer with a spray volume of 600 litre/ha. In the treatments without foliar K (K_0 and K_s), tap water was sprayed.

In all the plots recommended amount of N (60 kg/ha) and P (13 kg/ha) was added as urea and single super phosphate, respectively. Nitrogen was applied in 3 splits, half after thinning and the remainder in 2 equal splits at squaring (approximately 45-50 DAE) and at boll formation (80-90 DAE). The entire amounts of P and K were applied along with N at thinning.

Cotton was hand picked from 6 central rows and seed cotton yield was recorded. Prior to picking, observations on boll number were recorded on 3 plants tagged at random. A 200-g sample was taken from every plot, ginned and ginning outturn (g lint/200 g seed cotton) was determined. Lint samples were sent to Ginning Training Centre, Nagpur for fibre quality analysis. Plant samples were collected from every plot in 2003-04 and 2004-05. Plant samples were separated into leaves, stem, and reproductive parts and oven dried (65 °C) and ground to pass a 0.5 mm sieve. The samples were wet digested and K content was determined on a flame photometer. For calculating the K balance, K removed by the crop was deducted from the total amount of soil applied K (25 kg/ha). Agronomic, recovery and physiological efficiencies were also calculated.

Data were statistically analysed as a randomized block design combined across years. Years were considered as fixed effects and year \times replication as error. Combined analysis of variance was performed using MSTAT-C (Model No. 15). Least significant difference (LSD) at 5% probability was used to separate out treatment differences.

RESULTS AND DISCUSSION

Seed cotton yield and yield attributes

Seed cotton yield (SCY) did not differ significantly during the 3 years of study (Table 1). Averaged across years, SCY was significantly greater in the K applied plots

Table 1. Seed cotton yield (t/ha) over years, boll number and boll weight averaged over years as affected by application of potassium

Treatment	Seed cotton yield				Boll number (m ²)	Boll weight (g)
	2002-03	2003-04	2004-05	Mean		
K_0	0.75	0.95	0.71	0.81	33.6	2.52
K_s (25 kg K/ha)	0.98	1.04	0.91	0.97	40.8	2.62
$K_s + K_{EB}$ (4 kg K at early boll)	1.14	0.90	1.00	1.01	43.7	2.60
$K_s + K_{PB}$ (4 kg K at peak boll)	1.07	1.13	1.01	1.07	44.3	2.56
$K_s + K_{EB+PB}$ (4 kg K at early and peak boll)	0.84	1.03	1.30	1.06	53.3	2.51
Mean	0.96	1.01	0.99			
	Year	Treatment	Year \times treatment			
SEm \pm	0.08	0.05	0.09		3.9	0.15
CD (P=0.05)	NS	0.15	0.25		11.3	NS

than the K_0 plots. Soil application of K (K_s) resulted in a 168 kg increase in SCY over the K_0 treatment. Although the soils were high in exchangeable-K content, a response to the soil K application was noticed in 2002-03 and 2004-05 but not in 2003-04. Cassman *et al.* (1989) observed yield increases with K application on the vermiculitic soils because of high K-fixing capacity. However, in high rainfall year (2003-04) response was not significant. Soil moisture may modify the K pools and dynamics and consequently availability to plants. Diffusion is the dominant mechanism of K transport to roots. Since K has low mobility, under moist soil conditions, accessibility is higher due to more diffusion to roots (Jungk and Claassen, 1997).

Year x treatment interaction was significant. Differences in yield between treatments were significant in 2002-03 and 2004-05. In 2002-03, yield in the $K_s + K_{EB}$ and $K_s + K_{PB}$ was significantly greater than the K_0 . Yield in the K_0 plots was the least followed by treatments $K_s + K_{EB+PB}$ and K_s . Between the K treatments, yield in the treatment $K_s + K_{EB}$ was significantly greater than the $K_s + K_{EB+PB}$ and was on a par with the K_s and $K_s + K_{PB}$ treatments. In 2004-05, yield in the $K_s + K_{EB+PB}$ treatment was the greatest and produced 392 kg/ha more SCY than the K_s and was significantly greater than the other K applied plots. Yield in the K_0 treatment was the least and was significantly inferior to the K applied plots. The soil alone K treatment was on a par with the $K_s + K_{EB}$ and $K_s + K_{PB}$. Response to soil application (K_s) over treatment K_0 was 29.8 and 27.8% in 2002-03 and 2004-05, respectively, compared to 8.7% in 2003-04. Yield increases recorded on the K applied plots was mainly because of an increase in boll number/m² (Table 1). Boll number and boll weight are main determinants of yield. However, boll weight was not significantly affected by K treatments. Increase in boll number with fertilizer application has been reported earlier (Brar and Brar, 2004).

Present study showed benefit of foliar K spray in years with less than normal rainfall. Between years, a significant response to 2 foliar sprays (early and peak boll stages) was observed in 2004-05. In 2004-05, September rainfall was 41 mm compared to long term average of 155 mm. In 2002-03, 113 mm rainfall was received in September. Probably because of low rainfall in September 2004, the crop may have experienced K stress because of lower K availability either due to (i) little diffusion and/or (ii) high K fixation. Moreover, cotton is relatively inefficient in absorbing K from soil compared to other species (Cassman *et al.*, 1989). Thus greater advantage with 2 foliar sprays was noticed in 2004-05 than the other 2 years.

K content of plant parts

Potassium application significantly enhanced the K

Table 2. Effect of foliar K application on the K concentration of the cotton plant parts (pooled data of two years)

Treatment	K concentration (%)			
	Leaf	Stem	Fruiting parts	Seed cotton
K_0	1.24	1.24	3.56	1.51
K_s (25 kg K/ha)	1.50	1.36	3.86	1.68
$K_s + K_{EB}$ (4 kg K at early boll)	1.58	1.37	3.75	1.64
$K_s + K_{PB}$ (4 kg K at peak boll)	1.54	1.71	3.69	1.69
$K_s + K_{EB+PB}$ (4 kg K at early and peak boll)	1.74	1.56	3.73	1.57
SEm _±	0.10	0.06	0.11	0.06
CD (P=0.05)	0.29	0.17	NS	NS

content of the leaves and stem compared to the control treatment (Table 2). Leaves of the plants in the K_0 treatment had the least K concentration and was at par with treatment K_s . Differences among the K treatments were not significant. With regard to stem K content, foliar spray at peak boll stages ($K_s + K_{PB}$ and $K_s + K_{EB+PB}$) resulted in significantly higher K content than the treatments $K_s + K_{EB}$, K_s and K_0 . Differences among treatments were not significant with regard to the K concentration in fruiting parts and seed cotton. With fertilizer K application, increase in the K concentration of cotton plant parts was reported earlier (Brar and Brar, 2004).

Total K uptake and balance

Fruiting structures including carpel, leaves and stem together account for 57 to 75% of the total K (Fig. 2). Accumulation of K in leaves, stem and seed cotton was significantly greater in the K applied plots when compared with K_0 treatment. Treatment differences were not significant with regard to the fruiting structures. Total K uptake was significantly greater in the K applied plots than the untreated K_0 plots (Table 3). Differences between the K

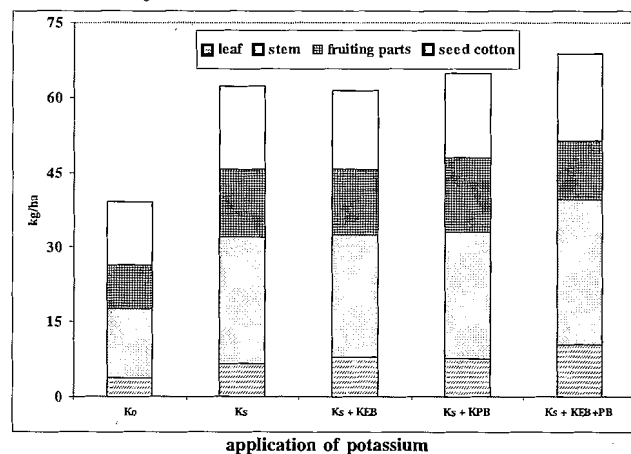


Fig. 2. Effect of K application on K uptake by cotton plant parts

Table 3. Effect of K application on total K uptake, apparent balance and agronomic, recovery and physiological efficiency

Treatment	Total uptake (kg/ha)	Balance ^a (kg/ha)	Agronomic efficiency (kg seed cotton/kg K applied) ^b		Recovery efficiency (kg K/kg K applied) ^c	Physiological efficiency (kg seed cotton/ kg K uptake) ^d
			Soil applied K	Foliar applied K		
K ₀	39.1	-39.1				
K _s (25 kg K/ha)	62.1	-37.1	5.6		0.92	7.3
K _s + K _{EB} (4 kg K at early boll)	61.3	-32.3	7.2	10.0	0.77	9.4
K _s + K _{PB} (4 kg K at peak boll)	64.8	-35.8	9.1	14.0	0.89	10.3
K _s + K _{EB+PB} (4 kg K at early and peak boll)	68.8	-35.8	7.7	10.6	0.90	8.5
SEm ±	5.4	5.1				
CD (P=0.05)	16.1	NS				

^a{Input (kg K soil applied) – total K uptake}

^b{Yield in treatment plot – yield in control}/kg K applied

^c{K uptake in treatment plot – K uptake in control}/kg K applied

^d{Yield in treatment plot – yield in control}/(K uptake in treatment plot – K uptake in control)

treatments were not significant. Significantly greater K uptake in the K applied plots than on the K₀ were observed at this location in an earlier study (Blaise *et al.*, 2005). Irrespective of K application, balance was negative and the treatment differences were not significant (Table 3). Negative K balance recorded in the present study is similar to those observed earlier for this location (Blaise *et al.*, 2005). A negative K balance suggests possible depletion of the soil K.

K use efficiency

Among the K treatments, agronomic efficiency was higher in soil + foliar applied K treatments than the K_s. Comparing the use efficiency of foliar applied K, agronomic efficiency was better in the treatment K_s + K_{PB} than the K_s + K_{EB} and K_s + K_{EB+PB}. Recovery of the soil applied K was 92%. With foliar supplementation, K recovery declined marginally when compared with the treatment K_s. The recovery efficiency values are within the range observed for field crops (Hegde *et al.*, 2007). Physiological efficiency was higher with the foliar K treatments, except treatment K_s + K_{EB+PB} that received 2 sprays, compared to treatment K_s. Despite high K uptake values recorded with the treatment K_s + K_{EB+PB}, averaged over years, yield levels in the foliar treatments were similar. Thus low physiological efficiency values were observed with 2 sprays suggesting poor utilization of applied K. Agronomic efficiency is a product of recovery and physiological efficiencies. Usually, efficiency values decline with an increase in fertilizer rate because yield follows law of diminishing returns. But a better utilization of K in the foliar K treatments resulted in higher agronomic efficiency when compared with K soil applied (Table 3).

Fibre quality

Although fibre quality is genetically controlled, environmental variations have been observed to modulate the quality. Variations were observed between years. In 2002-03, fibre length (23.5 mm), strength (18.8 g/tex) and uniformity (49.8%) were significantly better than in 2003-04 and 2004-05. Micronaire value was the lowest in 2004-05 (3.6). A low micronaire value in 2004-05 was probably because of the extremely dry conditions prevailing during boll development.

Averaged across 3 years, fibre quality traits (length, strength, fineness, and uniformity) and ginning outturn was not significantly affected by K application. Among treatments, 2.5% span length, fibre strength, micronaire and uniformity values ranged from 22.8 to 22.9 mm, 17.7 to 18.1 g/tex, 4.1 to 4.2 and 47 to 49%, respectively. These results are contrary to those reported earlier (Pervez *et al.*, 2004; Pettigrew, 1999). The soils of the present study site are not deficient. Furthermore, it is likely that the amounts of K supplied through foliar spray may not be sufficient to meet plant needs.

It was concluded that cotton responded significantly to K application in years receiving lesser than normal rainfall. Irrespective of K application, K balance was negative. Potassium application, through soil or soil + foliar spray, did not impact the fibre quality. Further studies are needed to determine the optimum number of sprays required and total quantity of K to be supplied through foliar methods.

REFERENCES

- Blaise, D., Bonde, A.N. and Choudhary, R.S. 2005. Nutrient uptake and balance of cotton + pigeonpea strip intercropping on rainfed vertisols of central India. *Nutrient Cycling in Agroecosystems* 73: 135–145.

- Brar, M.S. and Brar, A.S. 2004. Foliar nutrition as a supplement to soil fertilizer application to increase yield of upland cotton. *Indian Journal of Agricultural Sciences* **74**: 472-475.
- Cassman, K.G., Roerts, B.A., Kery, T.K., Bryant, D.C. and Higashi, S.L. 1989. Soil potassium balance and cumulative cotton response to annual potassium additions on a vermiculitic soil. *Soil Science Society of America Journal* **53**: 805-812.
- Hegde, D.M., Sudhakara Babu, S.N., Qureshi, A.A. and Murthy, I.Y.L.N. 2007. Enhancing nutrient-use efficiency in crop production – A review. *Indian Journal of Agronomy* **52**: 261-274.
- Jungk, A. and Claassen, N. 1997. Ion diffusion in soil-root system. *Advances in Agronomy* **61**: 53-110.
- Kairon, M.S. and Venugopalan, M.V. 1999. Nutrient management research in cotton - Achievements under All India Coordinated Cotton Improvement Project. *Fertilizer News* **44**: 137-144.
- Oosterhuis, D.M. 2002. Potassium management of cotton. In: *Potassium for Sustainable Crop Production*. (Pasricha, N.S. and Bansal, S. K., Eds.), International Potash Institute, Basel, Switzerland, pp. 321-346.
- Pervez, H., Ashraf, M. and Makhdum, M.I. 2004. Effects of potassium rates and sources on fiber quality parameters in 4 cultivars of cotton grown in Aridisols. *Journal of Plant Nutrition* **27**: 2235-2257.
- Pettigrew, W.T. 1999. Potassium deficiency increases specific leaf weights and leaf glucose levels in field grown cotton. *Agronomy Journal* **91**: 962-968.