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Plant Nutrient Status during Boll Development and Seed Cotton Yield as Affected by Foliar Application of Different Sources of Potassium

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ABSTRACT

Bt cotton hybrids require large supply of metabolites to support their greater boll load and commonly suffer from premature leaf senescence. A field experiment was conducted to study the nutritional status of Bt cotton leaves during boll development stage and to evaluate the most profitable source of foliar fertilizers. Treatments included basal application of 0 and 60 $kg \cdot K_2O \cdot ha^{-1}$ as muriate of potash (MOP) in main plots and foliar spray treatments viz: 4 & 6 sprays of 2% potassium nitrate (Multi-K, 13-00-45), 4 & 6 sprays of NPK Blend (Polyfed, 19-19-19), 4 sprays of MOP, 4 sprays of MOP + urea (to supply same amount of N & K as in potassium nitrate) and unsprayed control in sub plots. The results revealed that only N and K contents of premature senesced leaves were below the sufficiency range for cotton sufficient levels of P, Fe, Mn, Zn and Cu were observed. Though the concentrations of N and K in both the petiole and leaf blade initially improved with foliar spray, N content declined below the unsprayed control at later stages. Basal application of MOP increased seed cotton yield by 19%. Four foliar sprays of KNO_3, NPK, MOP and MOP + urea recorded yield increase in seed cotton yield of 22.8%, 22.4%, 18.5% and 24.5%, respectively over unsprayed control. Six sprays of KNO_3 and NPK had no yield advantage over four sprays and rather proved economically less viable.

Keywords: Cotton; Foliar Fertilizers; Boll Development; Potassium; Nitrogen

1. Introduction

India is the world's third largest cotton producer, with average production of 2707 TMT. Cotton is the main *kharif* cash crop of southwest Punjab. The area under cotton during 2007 *kharif* was 6.07 lakh hectares and the state had a record production to the tune of 26.8 lakh bales (455.6 TMT) and also a record lint production of 750 kg per hectare, which was three times higher than the national productivity. These figures were 5.6 lakh hectares, 18.5 lakh bales (314.5 TMT) and 562 $kg \cdot ha^{-1}$, respectively, during 2011-2012 [1,2]. Cotton production in the state increased in recent years with the introduction of Bt cotton hybrids that require less expenditure on pesticides because of the resistance to the attack of American Boll worm besides the rise in the price of the produce that helped the farmers to fetch good economic returns. Bt cotton is cultivated on nearly 90 percent of the area under cotton in Punjab, but the crop suffers from premature leaf senescence during boll development. Leaves near the top of the canopy turn bronze/red, which then fall off. The symptoms move down the canopy, defoliating the crop and reducing lint yields. The characteristic rusting and premature senescence of both lower and young cotton leaves at the top of the plant late in the season, resembling potassium deficiency symptoms, have been reported earlier [3-5]. However, unlike the symptoms on the older leaves, researchers have not been able to explain the cause of the upper-canopy deficiency symptoms. A few studies attempted to investigate the reason for premature senescence of Bt cotton. Potassium is required in larger amounts than any other mineral element except nitrogen, but in crops like banana and cotton particularly during the boll formation period, potassium uptake is more than that of nitrogen (www.incitecpivot-fertilisers.com.au/.../PotassiumFS). The occurrence of apparent "potassium deficiency" symptoms in the US

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Cotton Belt had been proposed to be related to soils with K availability problems [6] and the relative inefficiency of cotton at absorbing K from the soil compared to most other crop species [7]. However, the cotton root system is notable by its low density relative to other major row crops [8]. Oosterhuis *et al.* [9] postulated that the wide-spread K deficiency is related to earlier-maturing, higher-yielding, faster fruiting cotton varieties creating a greater demand than the plant root system is capable of supplying. The decrease in root activity after the start of flowering [10] may further aggravate the K deficiency syndrome in high yielding varieties with heavy boll set as the sugars from photosynthesis are translocated to the developing bolls rather than to roots for nutrient absorption. Without energy supply, plant depends upon nutrient reserves already within the plant to maintain high photosynthetic rate, translocation of sugars and boll development. Bednarz and Oosterhuis [11] reported that modern cotton cultivars have higher yields and bigger boll loads but less K in storage prior to boll development, which could account for unpredictable appearance of premature senescence. Wright [12] reported that cotton plants with premature senescence had twice the fruit loads but lower concentrations of potassium and nitrogen in leaves compared to healthy leaves without symptoms in the same field.

Foliar application of nutrients is highly beneficial, as crop benefits are achieved when the roots are unable to meet the nutrient requirement of the crop at a critical stage [13]. Foliar applications of K, especially late in the season when soil application may not be feasible or effective, correct the deficiency quickly and efficiently [14,15]. Brar *et al.* [16] reported improvement in seed cotton yield with foliar application of potassium nitrate, irrespective of the soil status and soil applied K fertilizers. Foliar fertilization of potassium nitrate has been recommended to supplement soil application in the cotton belt of Punjab. However, there is still considerable speculation about the benefits and correct implementation of this practice. Various foliar fertilizers are available that vary in the concentration of nutrients, but the studies on their comparative usefulness for cotton are lacking. In order to suggest the best choice/alternate sources for foliar spray in cotton, there is a need to evaluate the comparative efficacy of various foliar fertilizers and whether their additional sprays can be beneficial. Present investigation aimed to 1) investigate the nutrient status of cotton leaves during boll development and 2) compare the effectiveness of different foliar fertilizers on Bt cotton.

2. Materials and Methods

Field trials were conducted with Bt cotton hybrid RCH 134 at the research farm of Department of Soil Science, PAU, Ludhiana during *Kharif* 2008 and 2009 to compare the effectiveness of different foliar fertilizers. The soil at the experimental site was loamy sand (84% sand and 6% silt), had pH 8.34, EC 0.238 $dS \cdot m^{-1}$ and organic carbon content of 0.25%. Available N, P and K contents were 109.8, 17.1 and 114.2 $kg \cdot ha^{-1}$, respectively. Soil moisture content at field capacity and permanent wilting point was 15% and 4.5% on volume basis, respectively. Treatments included basal application of 0 and 60 $kg \cdot K_2O \cdot ha^{-1}$ muriate of potash (MOP) in main plots and foliar spray treatments viz: 4 & 6 sprays of 2% each of potassium nitrate (Multi-K, 13-00-45) and NPK Blend (Polyfed, 19-19-19), 4 sprays of MOP, 4 sprays of MOP + urea (to supply same amount of N & K as in potassium nitrate treatment) and unsprayed control in sub plots. Sub plot size was 32.8 m^2 having 54 plants. Crop was sown on 27th and 5th May, respectively during 2008 and 2009 cropping seasons, in rows 67.5 cm apart with plant to plant distance of 90 cm. Recommended practices for field preparation, seed treatment, phosphorus and nitrogen fertilizers were followed. Foliar spray treatments were started at flower initiation and repeated at 7 - 12 days interval between treatments.

During 2008, leaf samples showing severe premature senescence as well as healthy leaves in the same field (**Plate 1**) were collected from farmers' field at peak boll formation stage (8th October, 2008) and analyzed for nutrient content (N, P, K, Fe, Cu, Mn and Zn) of leaf blades and petioles. The surface soil of the same field was analyzed and found to contain 0.18% O.C., 8.8 $kg \cdot ha^{-1}$ P and 602.5 $kg \cdot ha^{-1} \cdot K$, had pH 8.5 and EC 0.12 $dS \cdot m^{-1}$. Topmost fully expanded leaves were sampled from each plot of our field experiment at peak boll formation stage (12th September, 2008), separated into leaf blades and petioles, dried at 60˚C and analyzed for N, P and K content. During 2009, leaves from KNO_3 sprayed and control plots were collected on different dates (**Figure 1**) during boll development and analyzed for N and K content. Tissue N content was analyzed by microkjeldahl method and P content by vanadomolybdo-phosphoric yellow colour method on a spectrophotometer after digestion in triacid [17]. Leaf tissue were digested in diacid mixture (HNO_3 and $HClO_4$ in 3:1 ratio); K content of the aqueous ex- tracts determined by flame photometer [18] and concen- tration of micronutrients (Fe, Cu, Zn and Mn) using Atomic Absorption Spectrophotometer (Varian Spectra AA 20 plus).

Weather parameters recorded at an observatory located at a distance of 1.5 km from the experimental site are given in **Table 1**. Monthly average of maximum temperature during the cropping period (May to October) ranged from 31.7˚C to 36.5˚C, and 31.8˚C to 39.9˚C

Table 1. Monthly mean of daily maximum and minimum air temperature (˚C), monthly cumulative pan evaporation (E_p) and rainfall (RF) during the cropping seasons (Kharif 2008 and 2009).

Month	2008				2009			
	Maximum Temp.	Minimum Temp.	E_p, mm	RF, mm	Maximum Temp.	Minimum Temp.	E_p, mm	RF, mm
May	36.5	22.9	263.5	0.0	39.0	23.5	317.7	0.0
June	34.3	25.5	175.9	277.3	39.9	25.2	345.4	36.6
July	34.1	27.1	152.7	152.7	33.8	25.9	141.9	566.1
August	32.8	25.7	127.6	292.8	34.1	26.9	144.2	104.6
September	32.3	22.7	116.2	44.7	32.7	23.7	110.1	83.5
October	31.7	19.4	99.6	39.0	31.8	16.4	99.3	0
Total	-	-	935.5	806.5	-	-	1158.6	790.8

during 2008 and 2009, respectively. Corresponding values for minimum temperature ranged from 19.4˚C to 27.1˚C and 16.4˚C to 26.9˚C. Cropping season rainfall was nearly same during the two years, but its distribution was different. Cumulative pan-E was higher during 2009 (1159 mm) compared to 936 mm during 2008 cropping season. Economics of different foliar spray treatments was worked out as per the latest (Year 2011) market prices of fertilizers, labour and seed cotton.

All data were subjected to statistical analysis of variance as a split-plot design except for the nutrient content of premature senesced and healthy leaves that was analysed as a randomized block design as described by Panse and Sukhatme [19]. Each data was the mean of three replicates. Treatment means and significant differences were evaluated by the Least Significant Difference (LSD) Test at 5% probability level.

3. Results and Discussion

3.1. Nutrient Content of Leaves with Premature Senescence

Premature senesced leaves, collected from farmer's fields, showed symptoms ranging from chlorotic leaf margins, inter veinal chlorosis, reddening and browning of leaf blade tissue that dried in extreme cases whereas healthy leaves were green (**Plate 1**). Nutrient content of cotton leaves (leaf blades and petioles) with and without premature senescence is given in Table 2. The data indicates that N content of leaf blades and petioles declined by 54 and 41% in leaves showing premature senescence as compared to healthy leaves. Premature senesced leaf blades and whole leaf recorded N content below the sufficiency range. Mitchell and Baker [20] compiled the reference sufficient range of various nutrients for cotton leaf tissue at late bloom/maturity stages that were 3.0% - 4.5%, 0.75% - 2.5%, 0.15% - 0.6%, 50 - 300 ppm, 10 - 400 ppm, 50 - 300 ppm and 5 - 25 ppm, respectively for N, K and P, Fe, Mn, Zn and Cu. Petiole K content of premature senesced leaves was 0.55% (much below the critical value) that was only 1/5th of the level recorded in healthy leaves. However, the K content in leaf blades with and without premature senescence was not markedly different. Though P content in both the petiole and leaf blades was in sufficiency range but leaf blade P content was 19% less in senesced leaves. The levels of all the micronutrients (Zn, Cu, Fe and Mn) were in the sufficiency range with little difference among the premature senesced and healthy leaves. The data indicates that in cotton leaves showing premature senescence, depletion of nutients was in the order: K in petiole tissue > N in whole leaf > N in petiole > P in leaf blade. Wright [12] also reported 0.4% or lower K concentration in the leaf blades with symptoms of premature senescence despite high levels of available K in soil, but N concentrations reduced to lesser extent. He attributed the greater depletion of N and K in leaves showing early senescence to higher fruit load. Leffler and Tubertini [21] reported dramatic increase in K requirement at boll setting that is evident from increase in total K in an individual boll from 0.19 mg/boll 10 days after flowering to 1.19 mg/boll 56 days after flowering.

Concentrations of N, P and K in the leaf blade and petiole, estimated at peak boll formation stage during 2008, are given in **Table 3**. Petiole N content was significantly lower with basal K application but leaf blades N content was same with and without basal K. Similarly, all sources of foliar spray lowered petiole N content compared to unsprayed control. However, leaf blade N content increased with foliar application of KNO_3, NPK and MOP + Urea but was unaffected by MOP. Balanced availability of N and K in soil with basal K application as well as in foliar spray treatments increased plant growth and boll formation that resulted in greater absorption and

Table 2. Nutrient content of premature senesced and healthy leaves of cotton.

Nutrients	Leaf blade			Petiole			Whole leaf		
	Premature senesced	Healthy leaves	LSD (0.05)	Premature senesced	Healthy leaves	LSD (0.05)	Premature senesced	Healthy leaves	LSD (0.05)
Nirogen, %	1.57 ± 0.08	3.41 ± 0.18	0.30	0.78 ± 0.06	1.33 ± 0.09	0.09	1.44 ± 0.12	3.15 ± 0.15	0.34
Potassium, %	1.05 ± 0.13	0.87 ± 0.15	NS	0.55 ± 0.05	2.80 ± 0.10	0.33	0.96 ± 0.07	1.08 ± 0.45	NS
Phosphorus, %	0.29 ± 0.02	0.36 ± 0.05	NS	0.28 ± 0.02	0.24 ± 0.04	NS	0.29 ± 0.01	0.34 ± 0.05	NS
Zinc, ppm	22.0 ± 1.0	21.3 ± 3.1	NS	16.0 ± 0.0	9.3 ± 1.2	2.87	21.0 ± 1.2	19.7 ± 1.3	NS
Iron, ppm	464 ± 19.1	425 ± 34.8	NS	127 ± 10.2	121 ± 9.9	NS	385 ± 97.7	408 ± 20.4	NS
Manganese, ppm	49.0 ± 3.6	44.0 ± 5.3	NS	8.0 ± 1.7	20.7 ± 3.1	11.2	42.0 ± 7.2	41.8 ± 11.5	NS
Copper, ppm	5.00 ± 1.0	6.67 ± 0.58	NS	3.00 ± 1.0	4.00 ± 1.0	NS	4.66 ± 0.99	6.35 ± 0.94	NS

Healthy leaves

Premature senesced leaves

Plate 1. Premature senesced and healthy Bt cotton leaves

use of N. Consequently, the N content of petioles estimated at the time of boll development was exhausted or poor compared to unsprayed control and without basal K. Potassium plays an important role in efficient utilization of N. Bijay-Singh and Yadvinder-Singh [22] observed that with adequate amounts of potassium to crops like rice and wheat, the accumulation of NO_3-N in the profile was negligible that suggested greater absorption of N by plants and higher nitrogen use efficiency. Foliar spray of 1% KCl and 1% urea from the jointing stage of both corn and wheat to silking of corn and the full heading stage of wheat increased the N and K content in the plants and stimulated N translocation to the grain [23].

During peak boll formation stage, K content of petiole was higher than the leaf blades (**Table 3**). Foliar spray significantly increased K content of both petiole and leaves with or without basal K application. Oosterhuis *et al.* [24] also reported higher K content in petioles of upper canopy leaves with combined soil applied and foliar K.

Basal K application significantly increased P content of petioles but had no effect on leaf blade P content. All the foliar fertilizers significantly improved P content of leaf blades but the response was variable for petioles compared to unsprayed control. Increased leaf blade P content with basal K as well as foliar fertilization may be attributed to K induced stimulation of root growth as suggested by Hackett [25], thus, resulting in greater nutrient uptake.

Data in **Figure 1** reveal that N concentration of leaf blades was higher (range 2.63% - 3.82%) than that of petioles (range 1.66% - 2.64%) during the course of boll development. However, K concentration was higher (range 1.41% - 5.79%) in petiole than that of leaf blades (range 1.47% - 2.68%). Both the contents of N and K in the leaf were high at the start of boll formation, were maintained or gradually declined during about 5 weeks and then drastically decreased in later samplings. K content in the spray treatment was higher at all sampling dates. However, N content in both the leaf blade and

Table 3. N, P and K content of leaf blade and petiole as affected by soil applied K and foliar fertilizers.

Foliar Fertilizers	Basal K, kg·ha^{-1}			Basal K, kg·ha^{-1}		
	0	60	Mean	0	60	Mean
	% N in leaf blades			% N in petioles		
Unsprayed control	2.00 ± 0.08	2.03 ± 0.15	2.02	1.98 ± 0.19	0.95 ± 0.27	1.46
KNO_3-4 sprays	2.53 ± 0.06	2.28 ± 0.16	2.40	1.20 ± 0.12	1.00 ± 0.14	1.10
KNO_3-6 sprays	2.48 ± 0.09	2.31 ± 0.19	2.39	1.18 ± 0.18	0.94 ± 0.18	1.06
NPK blend-4 sprays	2.41 ± 0.08	2.22 ± 0.10	2.32	1.03 ± 0.10	0.99 ± 0.04	1.01
NPK blend-6 sprays	2.45 ± 0.05	2.40 ± 0.17	2.42	1.16 ± 0.40	1.01 ± 0.06	1.09
MOP-4 sprays	2.18 ± 0.03	2.05 ± 0.08	2.12	1.28 ± 0.42	0.89 ± 0.15	1.09
MOP + Urea-4 sprays	2.34 ± 0.08	2.25 ± 0.09	2.29	1.41 ± 0.01	1.00 ± 0.04	1.20
Mean	2.34	2.22		1.32	0.97	
LSD (0.05)	Basal K	NS			0.140	
	Spray	0.136			0.245	
	Interaction	NS			0.346	
	% K in leaf blades			% K in petioles		
Unsprayed control	0.67 ± 0.08	0.82 ± 0.06	0.74	1.00 ± 0.10	0.97 ± 0.21	0.98
KNO_3-4 sprays	0.78 ± 0.06	1.07 ± 0.08	0.93	1.47 ± 0.08	1.63 ± 0.15	1.55
KNO_3-6 sprays	0.85 ± 0.09	1.17 ± 0.08	1.01	1.40 ± 0.10	1.50 ± 0.40	1.45
NPK blend-4 sprays	0.80 ± 0.10	0.90 ± 0.05	0.85	1.20 ± 0.10	1.37 ± 0.15	1.28
NPK blend-6 sprays	0.92 ± 0.08	0.97 ± 0.10	0.94	1.50 ± 0.05	1.77 ± 0.15	1.63
MOP-4 sprays	0.98 ± 0.10	1.10 ± 0.09	1.04	1.50 ± 0.10	1.53 ± 0.06	1.52
MOP + Urea-4 sprays	0.83 ± 0.06	1.07 ± 0.13	0.95	1.50 ± 0.10	1.58 ± 0.03	1.54
Mean	0.83	1.01		1.37	1.48	
LSD (0.05)	Basal K	NS			NS	
	Spray	0.10			0.18	
	Interaction	NS			NS	
	% P in leaf blades			% P in petioles		
Unsprayed control	0.250 ± 0.001	0.230 ± 0.022	0.240	0.292 ± 0.010	0.292 ± 0.017	0.292
KNO_3-4 sprays	0.316 ± 0.018	0.310 ± 0.022	0.313	0.321 ± 0.009	0.324 ± 0.012	0.323
KNO_3-6 sprays	0.283 ± 0.014	0.285 ± 0.017	0.284	0.279 ± 0.008	0.281 ± 0.014	0.280
NPK blend-4 sprays	0.278 ± 0.004	0.326 ± 0.014	0.302	0.296 ± 0.023	0.306 ± 0.017	0.301
NPK blend-6 sprays	0.317 ± 0.030	0.358 ± 0.018	0.338	0.308 ± 0.012	0.322 ± 0.024	0.315
MOP-4 sprays	0.304 ± 0.021	0.345 ± 0.012	0.324	0.276 ± 0.016	0.316 ± 0.009	0.296
MOP + Urea-4 sprays	0.267 ± 0.005	0.271 ± 0.008	0.269	0.312 ± 0.023	0.337 ± 0.014	0.325
Mean	0.287	0.304		0.298	0.311	
LSD (0.05)	Basal K	NS			0.007	
	Spray	0.021			0.018	
	Interaction	0.030			NS	

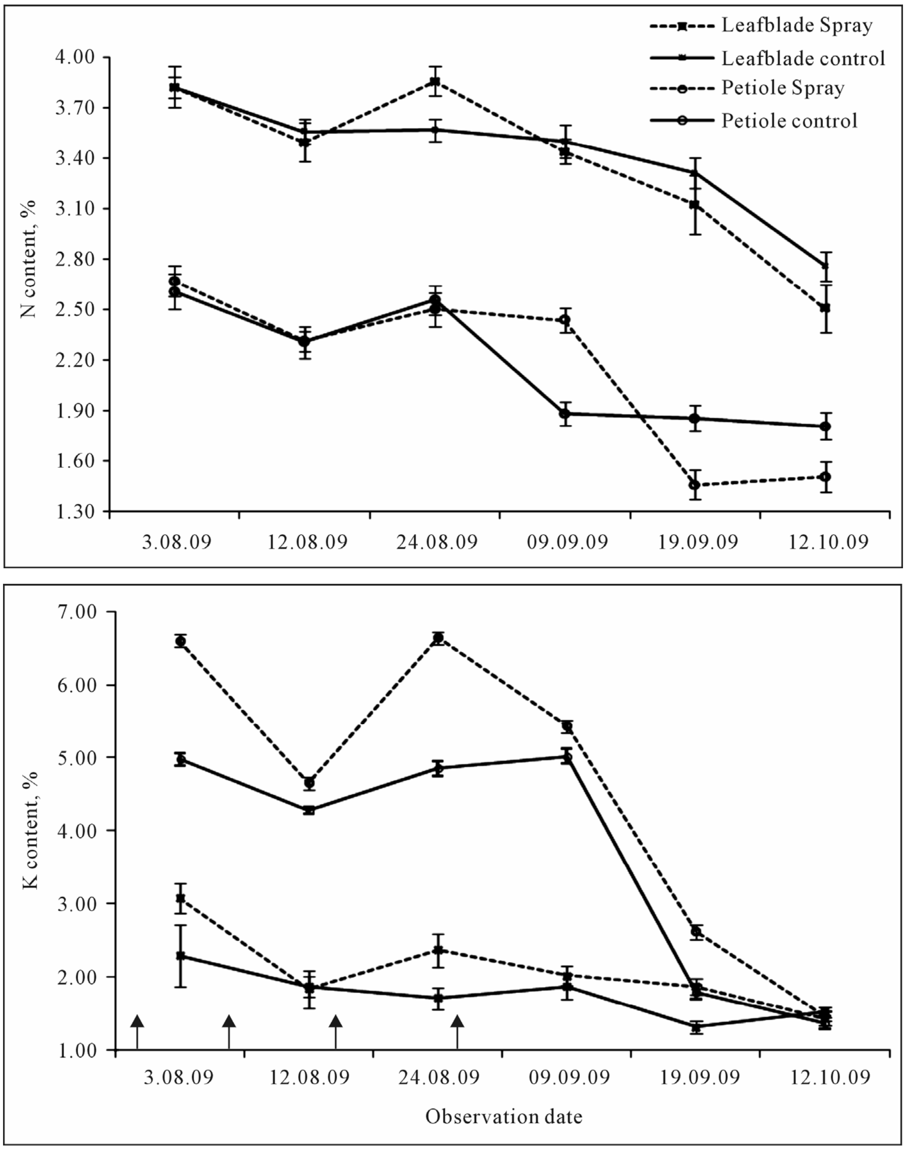

Figure 1. Periodic changes in N and K content of cotton leaf parts during boll development. Vertical bars at different data points indicate standard error values (Arrows indicate foliar sprays).

petiole was either the same or higher with foliar spray compared to unsprayed control but sharply decreased after 9th September. Increased boll formation with foliar spray may be the reason for depletion of leaf N.

Our data indicates that petiole accumulated higher concentrations of K (2.8% as in **Table 2** and upto 5.8% in **Figure 1**) than that required for normal growth and this could be available for use by the developing bolls. Reports are available that cotton plants continue to accumulate K at rates above that needed to produce maximum yields, with the highest K content occurring in older leaves and petioles [26,27]. However, the luxury storage of K is beneficial and a relatively cheap insurance policy against environmental stress [27], although it may be confusing for researchers to accurately predict the onset of K deficiency from tissue analysis as suggested by Bednarz and Oosterhuis [11]. Leffler and Tubertini [21] reported an increase in K concentration during the development of a boll from 19 $g\cdot kg^{-1}$ at 10 days to 55 $g\cdot kg^{-1}$ at maturity. An average cotton crop contains about 150 $kg\cdot K\cdot ha^{-1}$ with about 50% - 65% of the K in the re- productive unit [28-30].

3.2. Seed Cotton Yield

Field experiments conducted to supplement basal K with various foliar fertilizers recorded on an average 330 $kg\cdot ha^{-1}$ (18.6%) higher seed cotton yield with basal K application as compared to control (**Table 4**). However,

Table 4. Seed cotton yield ($q \cdot ha^{-1}$) of Bt-RCH 134 as affected by basal K application and foliar feeding with different fertilizers.

Foliar Fertilizers	Basal K, $kg \cdot ha^{-1}$		
	0	60	Mean
2008			
Unsprayed control	13.7 ± 0.82	16.6 ± 0.23	15.2
KNO_3-4 sprays	17.7 ± 0.34	19.0 ± 1.27	18.4
KNO_3-6 sprays	18.1 ± 1.24	18.6 ± 0.35	18.4
NPK blend-4 sprays	18.8 ± 0.88	20.4 ± 0.38	19.6
NPK blend-6 sprays	18.7 ± 0.21	19.6 ± 1.03	19.2
MOP-4 sprays	16.7 ± 1.38	19.5 ± 0.60	18.1
MOP + Urea-4 sprays	19.3 ± 0.61	19.8 ± 0.89	19.6
Mean	17.6	19.1	18.3
2009			
Unsprayed control	14.8 ± 1.35	19.0 ± 0.67	16.3
KNO_3-4 sprays	20.3 ± 0.15	24.3 ± 0.70	22.3
KNO_3-6 sprays	18.8 ± 0.58	23.0 ± 0.76	20.9
NPK blend-4 sprays	19.6 ± 0.55	22.3 ± 1.60	21.0
NPK blend-6 sprays	18.7 ± 0.37	23.0 ± 1.70	20.9
MOP-4 sprays	14.8 ± 1.15	24.5 ± 0.15	19.7
MOP + Urea-4 sprays	18.4 ± 0.69	24.9 ± 1.91	21.7
Mean	17.9	23.0	20.5
Average of 2008 & 2009			
Unsprayed control	14.2 ± 1.16	17.8 ± 1.38	16.0
KNO_3-4 sprays	19.0 ± 1.44	21.6 ± 3.04	20.3
KNO_3-6 sprays	18.5 ± 0.94	20.8 ± 2.48	19.6
NPK blend-4 sprays	19.2 ±0.78	21.4 ± 1.49	20.3
NPK blend-6 sprays	18.7 ± 0.27	21.3 ± 2.25	20.0
MOP-4 sprays	15.7 ± 1.56	22.0 ± 2.78	18.9
MOP + Urea-4 sprays	18.8 ± 0.78	22.3 ± 3.12	20.6
Mean	17.7	21.0	
LSD (0.05) For pooled data	Crop season = 1.13, Basal K = 0.27, Spray = 0.79, Season × basal K = 0.39, Season × spray = 1.12, Basal K × spray = 1.12, Season × basal K × spray = 1.58		

yield improvement with basal K was more during the relatively hot and drier 2009 crop season (509 $kg \cdot ha^{-1}$) than 2008 (150 $kg \cdot ha^{-1}$) that may be attributed to protective role of K against environmental stress [27]. Although both the seasons received same amount of total rainfall, but early crop growth period (May-June) during 2009 received less rain and had higher temperature and evaporation (**Table 1**). Our observation on greater efficacy of potassium fertilizer in 2009 is supported by the findings of Fanaeia *et al.* [31] for oilseed species and Tohidloo *et al.* [32] for sugar beet that reported much higher increase in yield with potassium fertilizer under low available water than well watered treatment. Brar and Brar [33] reported improvement in seed cotton yield with KNO_3 spray that ranged from 20% to 50% in different seasons. All the foliar spray treatments significantly increased seed cotton yield compared to unsprayed control with and without basal K application (**Table 4**). However, increase in yield with MOP was lowest (18%) compared to 27% with KNO_3 and NPK blend. Six sprays of KNO_3 and NPK blend were at par with 4 sprays. Abaye [34] reported that supplementing potassium by any method increases lint yields but higher lint yield was obtained with the soil applied potassium fertilizers supplemented with foliar KNO_3 treatments and the yield of plants given only K through spray medium was found not as good as those given additional potassium through soil. Brar and Brar [33] also reported that improvement in seed cotton yield with three mid-season foliar applications at weekly intervals of potassium chloride was the lowest (22%), compared to 27% with urea and 36% with potassium nitrate. Brar *et al.* [16] reported that foliar application of potassium nitrate increased the yield of seed cotton irrespective of the soil status and soil applied potassic fertilizers. Brevandan and Hodges [35] have shown that spray of KNO_3 0.5% solution during flowering supplied both N and K which were effectively absorbed as anion and cation by plants, delaying the synthesis of abscisic acid and promoted cytokinin activity resulting an increase in an chlorophyll content for delaying sensecence.

Significant interaction between basal K and foliar spray revealed that when 60 $kg \cdot K_2O \cdot ha^{-1}$ was applied as basal, all the foliar spray treatments increased seed cotton yield compared to control but without basal K application, no response to MOP spray was observed. Lack of response to foliar spray of MOP without soil K application may be due to imbalanced nutrient supply through foliar spray of MOP that contains 49% - 51% K compared to 38% K and 13% N in multi K or potassium nitrate and 19% each of N, P and K in polyfed. Although MOP supplied K through foliage but uptake of K by roots may be reduced due to lower soil K content. On the other hand, with basal K application, same response to potassium chloride spray as other sources (KNO_3, NPK blend or MOP + urea) may be because foliar spray of MOP increased root absorption of nutrients [36] and root

Table 5. Comparative advantages of different foliar fertilizers.

Foliar spray treatment	Additional yield over control, kg·ha^{-1}	Additional income, Rs·ha^{-1}	Cost of foliar spray Rs·ha^{-1}	Net gain with spray Rs·ha^{-1}
KNO_3-4 sprays	433	20,568	4280	16,288
KNO_3-6 sprays	365	17,338	6420	10,918
NPK blend-4 sprays	429	20,378	3920	16,458
NPK blend-6 sprays	400	19,000	5880	13,120
MOP-4 sprays	291	13,823	1100	12,723
MOP + Urea-4 sprays	461	21,898	1093	20,805

Prices: Seed cotton = Rs 4750 per q, Multi-K = Rs 145 per kg, Polyfed = Rs 130 per kg, MOP = Rs 1250 per q, Urea = Rs 537 per q, Labour = Rs 200 ha^{-1} per spray.

absorption, especially of K is expected to be more where soil K is higher. Thus, foliar K may be able to increase mining of nutrients by roots in proportion to their level in the soil *i.e.* more in soil with basal K application and less without soil K application. Hackett [25] also reported retarded root growth and especially the development of laterals under K deficiency.

The economics of different foliar fertilizers is given in **Table 5**. The cost of six foliar sprays of KNO_3 was the highest (Rs 6420/− ha^{-1}) and that of MOP + urea the lowest (Rs 1093/− ha^{-1}). Yield gains and consequently the additional income due to foliar spray were the highest with MOP + urea and minimum with MOP alone. Net gain of rupees 20,805/− per hectare was obtained with the spray of MOP + urea that was nearly 25% more than the other sources. The study suggests that MOP and urea, being easily available, are most suitable and profitable sources of foliar N and K fertilizers for cotton.

Based on this study, it can be concluded that depletion of potassium and nitrogen below the sufficiency range in leaf tissue is responsible for premature senescence commonly observed in Bt cotton. Soil application of potassium as well as foliar spray of fertilizers containing both these nutrients helps to maintain sufficient level of both N and K during boll development resulting in seed cotton yield improvement. Six foliar sprays of NPK blend and KNO_3 had no added advantage over the exist- ing practice of four sprays.

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