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Full Length Article

Economic Analyses of Sole and Combined Foliar Application of Moringa Leaf Extract (MLE) and K in Growth and Yield Improvement of Cotton

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Abstract

The economic feasibility for foliar application of MLE30 (30 times diluted moringa leaf extract) alone and combined with nitrate, murate and sulphate sources of potassium (K) on morphological, growth and yield attributes of *Bt* and non *Bt* cotton cultivars was evaluated. The research study was conducted at two sites i.e., Agronomic Research Area, Bahauddin Zakariya University, Multan and Usmania Agricultural Farm, Shujaabad during kharif season 2013.Results illustrated that all the treatments were effective in enhancing growth, number of bolls per plant and boll weight, which ultimately enhanced the seed cotton yield of *Bt* cotton cultivar CIM 598 yield and fiber quality of both cotton cultivars over the control. The economic analysis revealed that combined foliar application of MLE and potassium nitrate was cost effective for maximizing seed cotton yield and income. © 2018 Friends Science Publishers

Keywords: Moringa leaf extract; Potassium nitrate; Fiber quality; Foliar spray; Economic analysis

Introduction

Among macro-nutrients potassium (K) being mobile in plants has significant roles such as osmoregulation, stomatal movements, nitrogen and phosphorus application has primarily been realized whereas use of potassium is being neglected (Sardans and Peñuelas, 2015). As a mobile in plant, K can be translocated against strong chemical and electrical gradients (Brar and Tiwari, 2004). Furthermore, K is required for transport of phloem solute and maintenance of cation: anion balance in the cytosol and cell vacuole (Chaves *et al*., 2005). It has significant contribution in photosynthesis, food production processes within plant, activation of enzymes, protein synthesis, enhancing resistance to lodging, drought stress, temperature stress, diseases and regulation of moisture inside the plant cell and loss of moisture from plant by transpiration (Marschner, 1995; Brar and Tiwari, 2004; Cherel, 2004; Silva, 2004).

There is a general consensus that clay fraction of soils in Pakistan has adequate proportion of potassium containing illite (Ranjha *et al*., 1990). Presently, introduction of high yielding varieties and enhancement in cropping intensity have rapidly exhausted soil potassium reserves in Pakistan with annual reduction of 0.265 million tons (Akhtar *et al*., 2003). Thus rapid decline in potassium reserves has negatively affected the productivity of cotton by reducing leaf area and photosynthesis which consequences in the reduction of photosynthetic assimilates existing for plant growth (Zhao *et al*., 2001; Wang *et al*., 2012). Assimilate is one of the major negative consequences arose from deficiencies of potassium (Sangakkara *et al*., 2000; Pettigrew, 2008; Aladakatti *et al*., 2011). Its deficiency drastically decreases fiber quality and lower yields as it might have effect on respiration rates, photosynthesis, chlorophyll development and water content of leaves (Sangakkara *et al*., 2000). Foliar application of potassium offers the prospect of correcting matured plant scarceness quickly and proficiently particularly during late season when soil application of potassium may not be effective (Samejima *et al*., 2005; Hassan and Arshad, 2008).

In addition to mineral nutrients, some natural growth enhancers have also been reported to improve growth, yield and quality (Balakumbahan and Rajamani, 2010). Among various natural growth enhancers, moringa leaf extract (MLE), being rich in amino acids, potassium, calcium, iron, ascorbate and growth promoting hormones like zeatin, is proved to be a superlative plant growth enhancer (Fuglie, 2001). Hence, its leaf extract improves the growth of young plants, extends the lifespan, enhances the number of roots, shoots and leaves, produces more and superior fruits, accelerates resistance to diseases and pests and usually boost up yield by approximately 20−35% (Yasmeen *et al.*, 2013a;

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2014; 2016). Previous research findings revealed the potential of MLE in improving crop productivity (Yasmeen *et al.*, 2012) resistance to salinity (Yasmeen *et al.*, 2013a; Rady and Mohamed, 2015), drought (Yasmeen *et al.*, 2013b) and heavy metal stress (Howladar, 2014). Nonetheless, most of above studies reported the use of MLE to improve growth and productivity of different crops in normal and stress conditions little/no work has been done on economic evaluation of MLE30 as compared to other available mineral nutrient element especially in cotton crop.

Keeping in view, the important roles played by MLE30 in growth and development of crop plants it becomes imperative to conduct a research study for determination of economic feasibility of sole and combined foliar application of moringa leaf extract (MLE) and K in growth and yield improvement of cotton.

Materials and Methods

Experimental Sites and Treatments

A field experiment was planned to study the economic efficiency of sole and combined foliar application of moringa leaf extract (MLE) and different sources of K to improve productivity of *Bt* and non-*Bt* cotton cultivars at two locations i.e., Agronomic Research Area, Bahauddin Zakariya University, Multan and Usmania Agricultural Farm, Shujaabad during kharif 2013. The experiment was laid out in randomized complete block with factorial arrangement replicated thrice having net plot size of 4 x 6 m^2. The factors under study were comprised of cotton cultivars viz. CIM-573 (non *Bt*) and CIM-598 (*Bt*), foliar spray of MLE30, potassium nitrate, murate of potash and potassium sulphate keeping distilled water spray as control.

Preparation of MLE

For preparation of moringa leaf extract, three fully grown trees in the Botanical garden of Bahauddin Zakariya University were selected. The young leaves were collected, frozen (-5ºC) overnight pressed for extraction in a locally fabricated machine followed by filtration twice using Whatman No. 1 filter paper (Yasmeen *et al*. 2012). After purification, the extract was centrifuged at 8,000 g for 15 min there after supernant was taken and diluted 30 times (MLE30) for foliar spray.

Foliar application of MLE and Potassium

MLE 30 (Yasmeen *et al*., 2012) and different sources of potassium (nitrate, murate and sulphate @ 2%) were foliar applied twice at 90 and 120 days after blooming.

Soil Analysis

For Pre-sowing physico-chemical analysis, soil samples were collected from experimental area at 0 to 30 cm depth. Experimental soils were silt loam, with organic matter 0.56 and 0.64%, EC 1.14 and 1.03dS m^{-1}, pH 8.13 and 8.03, total N, available P and exchangeable K 0.049 and 0.028%, 0.0068 and 0.0049, 0.158 and 0.177 mg kg^{-1} in Multan and Shujabad, respectively.

Crop Husbandry

Pre-soaking irrigation was applied to the experimental area to produce the favorable seedbed conditions. At workable soil moisture level, seedbed was prepared by cultivator and beds were formed with bed shaper. Delinted cotton seeds of both cultivars were dibbled manually on both sides of beds in the first week of April 2013. The crop was irrigated 3 days followed by dibbling to have successful seed germination and emergence. Subsequent irrigations were applied depending upon the crop requirement till maturity. Recommended dose of nitrogen fertilizer i.e., 145 and 114 kg ha^{-1} for *Bt* and non *Bt*, respectively, was applied in 3 equal splits i.e., sowing, beginning of bloom and peak flowering stages by using urea as source. While triple super phosphate was applied at the rate 56 kg ha^{-1} at the time of sowing as a source of phosphorus. Weeds were controlled with pre emergence herbicide application; two hand weedings at 18 and 28 DAS along with 3 inter cultivations at 40, 55 and 70 DAS. Crop was kept free from insects for both cultivars with regular sprays decisions based on threshold scouting. All other agronomic practices were kept similar for each experimental unit.

Data Collection

Ten plants were randomly selected from each experimental unit and tagged to measure the bolls harvested per plant and boll weight (g). Manual harvesting of seed cotton was done thrice in the middle two rows of each experimental unit at both the locations. The first picking was done when the cotton bolls were about 60% opened, second harvesting was 22 days later and the final picking was in the second week of December at both locations. Net assimilation rate (NAR) and crop growth rate (CGR) was recorded according to the Watson (1952) and Radford (1967), respectively.

Statistical Analysis

The collected data were subjected to the analysis of variance (ANOVA) using the M-STAT software. While Duncan’s Multiple Range Test (DMRt) at 5% probability was used to compare the means of the different treatments (Steel *et al*., 1997).

Results

Exogenous applied MLE and different sources of potassium significantly affected cotton growth, productivity and fiber quality parameters.

Cotton Growth

The crop growth rate (CGR) differed significantly at all growth stages except 71-100 DAS in both locations (Fig. 1). Exogenous application of MLE and potassium nitrate on *Bt* cotton cultivar CIM 598 produced significantly higher CGR against the lower were observed for conventional cotton cultivar CIM 573 from control plots.

The net assimilation rate (NAR) pertaining to different growth stages differed significantly at both locations (Fig. 2). Foliar applied MLE and potassium nitrate produced significantly higher the NAR at all growth stages for *Bt* cotton cultivar CIM 598 except 71−100 DAS. Foliar spray of distilled water produced lower NAR for conventional cotton cultivar CIM 573 at all growth stages except 71−100 DAS.

The leaf area duration (LAD) recorded at different growth stages differed significantly at 41−70 and 131−160 DAS in both locations (Fig. 3). Foliar application of MLE + potassium nitrate and MLE + potassium sulfate on *Bt* cotton cultivar CIM 598 produced significantly higher LAD in Multan and Shujabad, respectively. Minimum LAD was observed for conventional cotton cultivar CIM 573 receiving foliar spray of distilled water.

Cotton Yield

Number of bolls harvested per plant differed significantly due to foliar spray of MLE and various sources of potassium on cotton cultivars in Multan (Table 1). Maximum number of bolls harvested per plant (39.52) was recorded for *Bt* cotton cultivar CIM 598 receiving foliar spray of MLE and potassium nitrate. Minimum number of bolls harvested per plant (28.51) recorded for conventional cotton cultivar CIM 573 receiving foliar spray of distilled water. However, study conducted at Shujabad showed non-significant effect on number of bolls harvested per plant with foliar application of MLE and different sources of potassium on cotton cultivars (Table 1).

Mean boll weight of different cotton cultivars was significantly affected by foliar application of MLE and different sources of potassium in both locations (Table 1). Higher mean boll weight (3.60 g and 3.43 g) were recorded for *Bt* cotton cultivar CIM 598 receiving foliar spray of MLE and potassium nitrate in Multan and Shujabad, respectively. Conventional cotton cv. CIM 573 receiving foliar spray of distilled water and murate of potash produced minimum mean boll weight (2.97 g and 3.03 g) in Multan and Shujabad, respectively.

The seed cotton yield per hectare differed significantly by foliar spray of MLE and different sources of potassium on conventional and *Bt* cotton cultivars in both locations (Table 1). Maximum seed cotton yield per hectare (3194 and 3269 kg ha^{-1}) recorded for *Bt* cotton cultivar CIM 598 receiving foliar spray of MLE and potassium nitrate in Multan and Shujabad. Minimum seed cotton yield (1509 and 2039 kg ha^{-1}) was observed for conventional cotton cultivar CIM 573 receiving foliar spray of distilled water.

Fiber Quality

Interactive effects of foliar applied MLE and different sources of potassium on cotton cultivars had non-significant effect on micronaire value in Multan (Table 1). Study conducted in Shujabad showed significant effect of foliar application of MLE and different sources of potassium on cotton cultivars (Table 1). Maximum micronaire value (3.74 μg $inch^{-1}$) was recorded for conventional cotton cultivar CIM 573 receiving foliar spray of MLE and potassium sulfate. While minimum micronaire (3.49 μg $inch^{-1}$) also observed for conventional cotton cultivar receiving foliar spray of distilled water.

Foliar application of MLE and various sources of potassium on cotton cultivars had significant effect on fiber strength in both locations (Table 1). Maximum fiber strength (37.10 and 37.41 g tex^{-1}) from conventional cotton cultivar receiving combined application of MLE + potassium nitrate and potassium sulfate in Multan and Shujabad. Minimum fiber strength (28.92 and 28.81 g tex^{-1}) observed from *Bt* cotton cultivar receiving foliar spray of distilled water.

Foliar application of MLE and potassium nitrate on *Bt* cotton cultivar CIM 598 gave maximum profit of 0.1402 million Rs. ha^{-1} with benefit cost ratio of 1.77 followed by foliar application of MLE and potassium sulphate on *Bt* cotton cultivar CIM 598 with profit of Rs. 0.1321 million Rs. ha^{-1} with benefit cost ratio of 1.67 in Multan (Table 2). Similarly foliar spray of MLE and potassium nitrate on *Bt* cotton cultivar CIM 598 gave maximum profit of 0.1458 million Rs. ha^{-1} with benefit cost ratio of 2.26 in Shujabad. The minimum net field benefits were associated with control.

Discussion

Potassium is considered one of the principle nutrients which is involved in many physiological processes, photosynthesis, assimilation, transport and enzyme activation, which has direct impact on crop productivity (Taiz and Zeiger, 1991). All the factors affecting the crop growth and development must be integrated at an optimal level to attain maximum production. As the leaves are primary carrier of chlorophyll, a vital material for photosynthesis, their size has a reflective impact on productivity. Leaf beside its efficiency to produce photosynthate, determines the crop growth rate and yield (Ritchie and Burnett, 1971). Foliar application of MLE and different sources of potassium improved the LAD of both cotton cultivars which might be due to improved photosynthesis per unit leaf area that leads to a higher total photosynthetic assimilate pool produced in the plants source tissue (Pettigrew, 2008).

Table 1: Effect of sole and combined foliar application of moringa leaf extract (MLE) and K on fiber yield and fiber quality parametersof conventional and *Bt* cotton cultivars at Multan and Shujaabad

Treatments		Bolls harvested plant^{-1}		Mean boll weight (g)		Seed cotton yield (kg ha^{-1})		Micronaire value (μg inch^{-1})		Fiber strength (g tex^{-1})	
Cotton cultivar	Foliar spray	Multan	Shujabad	Multan	Shujabad	Multan	Shujabad	Multan	Shujabad	Multan	Shujabad
CIM 573	F_1K_1	28.51 d	32.76	2.97 e	3.11 ab	1509 h	2039 d	3.52	3.49 c	35.14 c	35.47 c
	F_1K_2	29.64 d	34.88	3.45 ad	3.25 ab	2068 eg	2617 ad	3.71	3.65 ac	36.79 a	37.33ab
	F_1K_3	30.65cd	33.06	3.07 de	3.03 b	1750 gh	2207 cd	3.70	3.60ac	36.28ab	36.94ab
	F_1K_4	29.90 d	34.54	3.14 be	3.12 ab	1884 fh	2436 bd	3.70	3.71 ab	36.74 a	37.41 a
	F_2K_1	29.42 d	33.34	3.09 ce	3.15 ab	1888fh	2260bd	3.57	3.63 ac	35.66bc	36.13bc
	F_2K_2	32.59bd	36.67	3.48 ad	3.32 ab	2406 ce	2818 ad	3.72	3.7 ac	37.04 a	37.37ab
	F_2K_3	32.05bd	34.95	3.32 ae	3.20 ab	2255dg	2503ad	3.70	3.63 ac	36.65 a	37.05ab
	F_2K_4	32.11bd	34.57	3.42 ad	3.27 ab	2280 cf	2622 ad	3.71	3.74 a	37.10 a	37.24ab
CIM 598	F_1K_1	32.36bd	34.89	3.13be	3.18 ab	1991 eh	2353bd	3.52	3.54ac	28.92 g	28.81 g
	F_1K_2	37.90ab	38.41	3.51 ab	3.37 ab	2791ac	3055ab	3.55	3.57ac	30.03 ef	30.12 df
	F_1K_3	36.63ab	35.38	3.30 ae	3.16 ab	2447 de	2539 ad	3.54	3.53 ac	29.62 fg	29.55eg
	F_1K_4	36.51 ac	36.79	3.41 ad	3.26 ab	2615 bd	2779ad	3.56	3.53 ac	30.03 ef	29.89dg
	F_2K_1	34.14ad	35.35	3.24 ae	3.21 ab	2295 cf	2456 bd	3.53	3.52 bc	29.33 fg	29.12fg
	F_2K_2	39.52 a	40.05	3.60 a	3.43 a	3194a	3269a	3.57	3.58 ac	31.12 d	30.45de
	F_2K_3	37.39ab	36.95	3.42 ad	3.22 ab	2713 ad	2691ad	3.57	3.60 ac	30.77 e	30.54de
	F_2K_4	37.25ab	37.72	3.49ac	3.36 ab	3079ab	2940 ac	3.58	3.56 ac	31.15 d	30.82 d
LSD 0.05*p*		5.16	n.s	0.35	0.30	452.14	689.76	n.s	1.1	0.91	1.11

Table 2: Effect of sole and combined foliar application of moringa leaf extract (MLE) and K on conventional and *Bt* cotton cultivars on net income (Rs. ha^{-1}) and benefit cost ratio (BCR) at Multan and Shujabad

Treatments		Total expenditure (Rs. million ha^{-1})		Gross income (Rs. million ha^{-1})		Net income (Rs. million ha^{-1})		Benefit cost ratio	
Cotton cultivar	Foliar spray	Multan	Shujabad	Multan	Shujabad	Multan	Shujabad	Multan	Shujabad
CIM 573	F_1K_1	0.1181	0.1213	0.1207	0.1631	0.0026	0.0418	1.02	1.49
	F_1K_2	0.1226	0.1259	0.1654	0.2094	0.0428	0.0835	1.35	1.98
	F_1K_3	0.1200	0.1228	0.1400	0.1766	0.0200	0.0538	1.17	1.78
	F_1K_4	0.1211	0.1244	0.1507	0.1949	0.0296	0.0704	1.24	1.88
	F_2K_1	0.1204	0.1226	0.1510	0.1808	0.0306	0.0582	1.25	1.69
	F_2K_2	0.1246	0.1271	0.1925	0.2254	0.0679	0.0983	1.54	2.22
	F_2K_3	0.1230	0.1245	0.1804	0.2002	0.0574	0.0757	1.47	1.94
	F_2K_4	0.1243	0.1256	0.1824	0.2098	0.0581	0.0842	1.47	2.16
CIM **598**	F_1K_1	0.1070	0.1092	0.1593	0.1882	0.0523	0.0791	1.34	1.72
	F_1K_2	0.1129	0.1145	0.2233	0.2444	0.1104	0.1299	1.66	2.13
	F_1K_3	0.1101	0.1107	0.1958	0.2031	0.0856	0.0924	1.44	1.83
	F_1K_4	0.1115	0.1125	0.2092	0.2223	0.0977	0.1099	1.57	1.98
	F_2K_1	0.1088	0.1098	0.1836	0.1965	0.0748	0.0867	1.47	1.79
	F_2K_2	0.1153	0.1158	0.2555	0.2615	0.1402	0.1458	1.77	2.26
	F_2K_3	0.1117	0.1116	0.2170	0.2153	0.1053	0.1037	1.61	1.93
	F_2K_4	0.1143	0.1134	0.2463	0.2352	0.1321	0.1218	1.67	2.07

Where F_1= foliar spray of distilled water, F_2= foliar spray of MLE, K_1= foliar spray of distilled water, K_2= foliar spray of KNO_3, K_3= foliar spray of MOP, K_4= foliar spray of K_2SO_4

Coupling this photoassimilate production with the more assimilates transported from the leaves resulted in more availability of assimilate for the sink tissue (Gwathmey and Howard, 1998; Pettigrew, 2003). Higher growth and its attributes were observed in *Bt* cotton with the foliar application of MLE and potassium might be due to provision of essential nutrients and growth promoting hormone which might have increased the photosynthetic activity, enzyme activity and other biochemical process (Sangakkara *et al.*, 2000; Foidle *et al.*, 2001; Yasmeen *et al*., 2013a). Growth parameters followed an increasing trend at initial stages of crop growth and then decreased thereafter. When the leaves get older and the rate of dry mater accumulation reduced which decreased the growth rate. Reduction of growth attributes at final stages could be due to shedding of leaves which reduced dry matter. Growth parameter depends on canopy photosynthesis per area unit of land. The variation in growth parameters between conventional and *Bt* cotton cultivars attributed to the use of different types of genetic material and efficient utilization of inputs and natural resources (Wang *et al*., 2014).

Higher number of bolls per plant was observed with the application of MLE and potassium nitrate. MLE being rich source of micro- and macronutrients and growth promoting hormone zeatin improved the photosynthesis that accelerate blossoming and fruit formation (Moyo *et al.*, 2011). Foliar spray of potassium nitrate improved the number of bolls per plant which might be due to the favorable effects of potassium on nutrient uptake, photosynthetic activity, improving its mobilization and reduced boll shedding (Zeng, 1996). As boll shedding is a serious problem comes under nutrient deficiency. Similarly, foliar application of MLE and potassium nitrate increased boll weight as compared with the control.

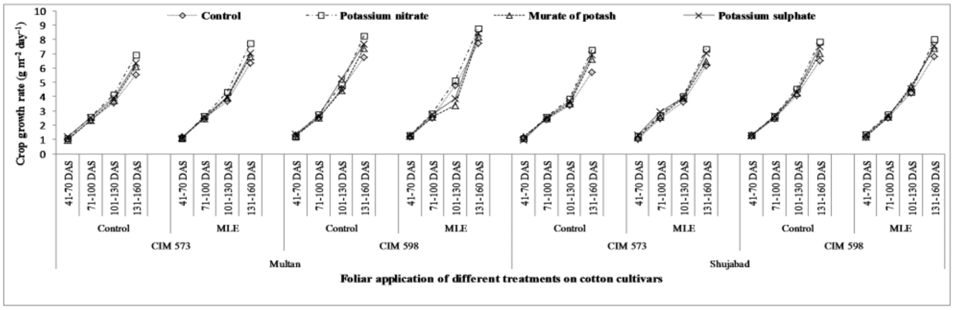

Fig. 1: Effect of sole and combined foliar application of moringa leaf extract (MLE) and K on crop growth rate (g $m^{-2}day^{-1}$) of conventional and *Bt* cotton cultivars at Multan and Shujabad

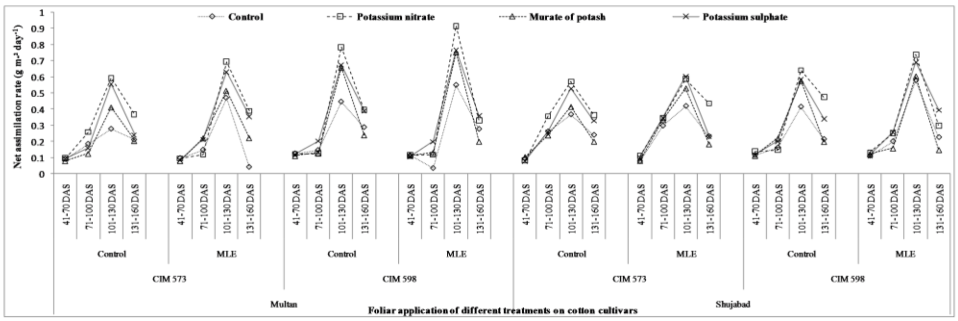

Fig. 2: Effect of sole and combined foliar application of moringa leaf extract (MLE) and K on net assimilation rate (g m^{-2} day^{-1}) of conventional and *Bt* cotton cultivars at Multan and Shujaabad

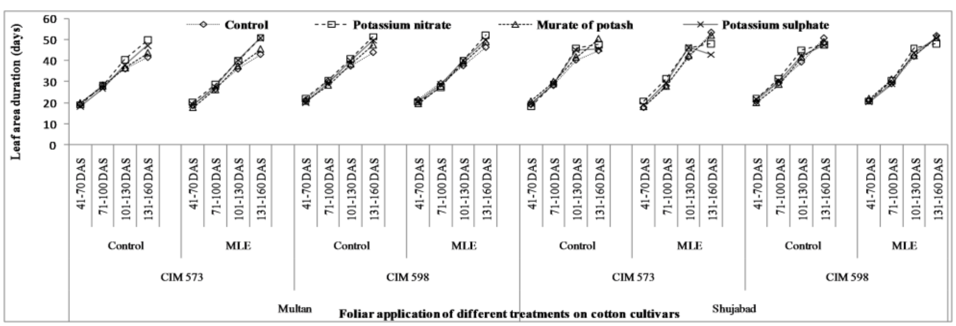

Fig. 3: Effect of sole and combined foliar application of moringa leaf extract (MLE) and K on leaf area duration (days) of conventional and *Bt* cotton cultivars at Multan and Shujaabad

This could be attributed to the fact that application of MLE and potassium nitrate has encouraging effects as an activator of numerous enzymes involved in carbohydrate and nucleic acids metabolism, vitamins, proteins and growth substances (Bisson *et al*., 1994; Bednarz and Oosterhuis, 1999). Potassium positively influenced the synthesis of carbohydrates as bolls are the highest sinks of potassium (Oosterhuis, 2002). It participated in the condensation of simple sugars forms, in complex carbohydrates and their migration to the reserve organs (Bisson *et al.*, 1994). Potassium is required for efficient movement of sugars from leaves, conversion of sugars into starch and improved boll weight (Sabino *et al.,* 1999; Ghourab *et al.,* 2000). Lower boll weight in control plots might be due to less production of photosynthetic assimilates and reduced transport of assimilate out of the leaves to the developing bolls (Pettigrew, 2008).

More number of bolls per plant and higher boll weight with the foliar spray of MLE and potassium might have contributed to higher yields. Foliar spray of these nutrients might have helped in more photosynthetic activity, extended leaf duration, contributing to assimilates' translocation toward bolls to amplify carbohydrate supply during the reproductive phase (Blaise *et al*., 2009). Potassium nitrate produced higher yield as compared to the other potassium sources might be due to the presence of nitrogen which is an imperative nutrient controlling new growth and abscission of squares and bolls (Zeng, 1996). It also plays significant role in creating plant dry matter, as well as part of many energy rich compounds which control the process of photosynthesis and plant production (Mullins *et al*., 1999), thus impacting boll development, improving the number of bolls per plant, boll weight which ultimately increased the final yield. Similarly, *Bt* cotton cultivar CIM 598 produced higher seed cotton yield which might be due to their superiority in genetic potential that finally warped into higher number of branches, squares, flowers and bolls per plant with more weight (Mekki, 1999).

Potassium has its role in fiber development and hence the foliar spray of potassium improved the fiber properties of cotton (Gormus and Yucel, 2002). Development of fiber length, micronaire and fiber strength attributed to foliar spray of potassium which plays a significant role in fiber development and improved cell elongation (Oosterhuis, 2002; Brar and Brar, 2004; Aladakatti *et al*., 2011).

Conclusion

Our results showed inconsistencies in the response of fiber quality parameters to various sources of potassium and MLE. As indeterminate growth habit of cotton, and cultivar variation in development rate, may cause fickle fiber properties (Jones and Wells, 1997; Gormus and Yucel, 2002). Individual bolls may just be starting fiber elongation; others starting fiber thickening and others may be completely mature on the same day. Exogenous application of different sources of potassium improved the cotton productivity and net income. However, combined application of MLE and potassium nitrate returned more net benefits from conventional as well as *Bt* cotton cultivars at both locations.

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