Effects of Nitrogen and Potassium Application on Plant Growth, Yield and Fiber Quality of Cotton (*Gossypium hirsutum* L.)

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Abstract

In a study to investigate different rates of nitrogen (N) and potassium (K) application on growth, yield and fiber quality of cotton (*Gossypium hirsutum* L.), var. Ngwechi-9 and to evaluate the nutrient interactions of N and K in cotton in Pyawbwe Township, Myanmar, two experiments were conducted the first one in pre-monsoon season and the second one in post-monsoon seasons (2015-2016). Four N fertilizer rates (0, 60, 120, and 180 kg N ha^{-1}) and three K fertilizer rates (0, 62.25, and 124.50 kg K ha^{-1}) were set as factor A and B, respectively, using randomized complete block design in two-factor factorial arrangement with three replications. In both seasons plant height, yield and yield components were the highest at 180 kg N ha^{-1}. Potassium fertilizer application of 124.50 kg K ha^{-1} produced the highest seed cotton yield and improved fiber quality. The interaction of N × K application was observed in the number of bolls plant^{-1}, boll weight plant^{-1} and yield. Maximum seed cotton yields were obtained from the treatments combining of 180 kg N ha^{-1} and 124.50 kg K ha^{-1} in both seasons. By the application of K fertilizer at 124.50 kg K ha^{-1}, the fiber quality parameters, such as fiber length, fiber strength, fiber fineness and maturity ratio were the best in both seasons. This study suggested that application of K fertilizer at 124.50 kg K ha^{-1} in combination with 180 kg N ha^{-1} was the best in seed cotton production and its fiber quality for both seasons.

Key words – cotton, fiber quality, nitrogen, potassium, seed cotton yield

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1. Introduction

Cotton (*Gossypium hirsutum* L.) is a major crop grown primarily for fiber and oil seed in the world (Oosterhuis 2001). Historically, cotton played an important role in the national economy of Myanmar and it was essential for local consumption and export for foreign exchange (Pye Tin 2003). In Myanmar, cotton is grown in pre-monsoon, monsoon and post-monsoon seasons.

Nitrogen (N) is an essential macronutrient that is required most consistently and in larger amounts than other nutrients for higher cotton production (Hou et al. 2007). N promotes the growth of the cotton plants, increases the yield and optimizes the quality of the cotton fiber (Bondada et al. 1996). Moreover, N fertilization had significant impacts on plant growth, lint yields and fiber quality. Although N is probably the most important nutrient used on cotton, yet it is the most difficult to manage because both deficiency and excess N may affect cotton yield and quality (Cotton Production Guide 1999).

Similarly, potassium (K) is also an important nutrient in cotton production. K plays a vital role in cotton growth and metabolism, although it is not a constituent of any known plant components (Read et al. 2006). It also plays in significant role in the maintenance of osmotic potential and water uptake during fiber development, and its shortage will result in poorer fiber quality and lowered yields (Oosterhuis 2001). Pye Tin (1995) stated that although N is primary nutrient for increasing cotton yield, it is necessary to add adequate amount of other nutrients particularly phosphate and potash to activate a response of N. Plants adequately supplied with K and other macro and micronutrients are more tolerant to pests and diseases incidence than N nutrient alone (Perrenoud 1990).

Fiber is the primarily and economically important product of the cotton crop. Maintaining fiber quality is one of the great challenges to the farmers. Most mills now use high-speed spinning equipment, which favors higher quality fiber. Fiber properties of cotton may be affected by temperature, humidity, soil moisture (Killi et al. 2005) and fertilizers (Abid et al. 2007).

Impact of N and K fertilization on yield and yield components were well documented in literatures but their combined effects on cotton cultivation are poorly understood in Myanmar. Moreover, little information has been reported how combined effect of N and K fertilization would influence cotton growth, yield and fiber quality. Therefore, this experiment was carried out with the following objectives:

1. to investigate the effects of different rates of N and K fertilizers on the growth and yield components of cotton;
2. to examine the effects of different rates of N and K fertilizers on the fiber quality of cotton, and
3. to evaluate the interaction of N and K nutrition on seed cotton yield.

2. Materials and Methods

2.1 Site description

Two-season-continuous field study was conducted from March to August (pre-monsoon season) and from August to January (post-monsoon season) in year 2015-2016 at the Cotton Seed Farm (Pyawbwe), Pyawbwe Township, Mandalay Region, Myanmar. It is located between 20° 23' N and 20° 47' N, and between 95° 96' E and 96° 6' E at 304 meters above sea level.

Soil samples were taken as composite samples from 0-20 cm surface layer before the experiment. The physicochemical properties of soil samples were analyzed at Soil and Water Utilization Division, Department of Agricultural Research (DAR), Yezin, Nay Pyi Taw, Myanmar. The soil analysis results are shown in Table 1. Meteorological data were collected from Yamethin meteorological station which is located near the experimental site (Figure 1).

Table 1. Physicochemical properties of the experimental soil

Parameters	Amount (rating)
Soil Texture	Silt loam
Texture% (sand, silt, clay)	20.8,52.3,26.9
Soil pH	6.8 (neutral)
Available N (mg kg^{-1})	76 (medium)
Available P (mg kg^{-1})	19 (medium)
Available K (mg kg^{-1})	343 (high)
Bulk density (g cm^{-3})	1.3
Cation Exchange capacity (CEC) $cmol_{(+)}$ kg^{-1}	24 (medium)
Organic matter (%)	1.6 (low)
EC (dS m^{-1})	0.14 (Non saline)
Exchangeable Ca $cmol_{(+)}$ kg^{-1}	12 (high)
Exchangeable Mg $cmol_{(+)}$ kg^{-1}	9 (high)
SAR	0.58

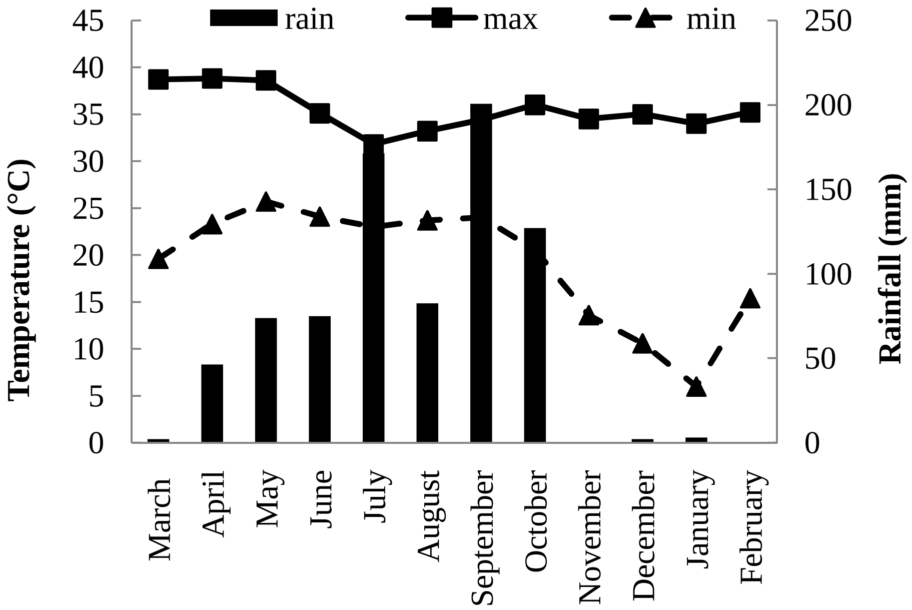

Figure 1. Monthly means rainfall, minimum and maximum temperature during the experimental period (March 2015 – January 2016)

2.2 Experimental design

In each season, the field cultivation experiment was laid out as two-factor factorial randomized complete block design (RCBD) with 3 replications. Ngwechi-9 cotton cultivar was used as a test crop. Four different rates of N (N_0 = 0 kg N ha^{-1}, N_1 = 60 kg N ha^{-1}, N_2 = 120 kg N ha^{-1} and N_3 = 180 kg N ha^{-1}) were assigned as factor (A) and three different rates of K (K_0 = 0 kg K ha^{-1}, K_1 = 62.25 kg K ha^{-1} and K_2 = 124.50 kg K ha^{-1}) as factor (B). N and K fertilizers were equally split into three times at basal, squaring stage (about 30 days after emergence) and the first flowering stage (about 60 days after emergence). All plots were provided a basal rate of phosphorus (P) 26.4 kg P ha^{-1} (60 kg P_2O_5). Source of N, P and K were obtained from urea, triple super phosphate and muriate of potash, respectively.

2.3 Data collection and analysis

For both seasons, the spacing was 0.75 m × 0.75 m and the space between two plots was 1.52 m. The net total experimental area was 60 × 32 m^2. Each treatment plot was 6.82 × 5.3 m^2 and consisted of 7 rows of plants. Ten sample plants were randomly selected and used to measure the growth characters, yield and yield components and fiber quality from each treatment plot.

For growth characters, plant height (cm), number of main-stem nodes plant^{-1}, number of monopodial branches plant^{-1} and number of sympodial branches plant^{-1} were collected. Plant height and number of main-stem nodes were collected at two weeks interval. Plant height was taken as the distance between the terminal bud and the cotyledon nodes. Number of monopodial branches and sympodial branches were counted at harvest time.

Yield and yield components, such as number of squares plant^{-1},number of flowers plant^{-1}, number of boll plant^{-1},boll weight (g), boll weight plant^{-1} (g) and seed cotton yield (kg ha^{-1}) were collected. Number of squares, flowers and bolls were collected as two weeks interval. Boll weight (g), boll weight plant^{-1} (g) and seed cotton yield (kg ha^{-1}) were recorded at harvest time.

Fiber quality parameters, such as fiber length (mm), fiber strength (lb mg^{-1}), fiber fineness (micronaire), fiber maturity ratio and ginning percentage were analyzed at Cotton Fiber and Yarn Testing Laboratory, Meiktila Township, Myanmar. Ten open bolls were picked to conduct quality tests for each treatment in both seasons, and analyzed for fiber quality.

Statistical analyses of the data were carried out according to randomized complete block design. All the parameters were subjected to analysis of variance (ANOVA) and the data were analyzed by using Statistix 8.0 software. The differences between means were compared using the least significant difference (LSD) test at 5% level.

3. Results and Discussion

3.1 Plant growth characters

In pre-monsoon seasons, there was highly significant difference in plant height among the different N treatments ($P<0.01$) (Figure 2a). The plant height in all treatments increased rapidly from 44 days after sowing (DAS) to 100 DAS and high N application treatments gave generally higher plant height than low N treatments. The tallest plant height (79.30 cm) was obtained from N_3 treatments and the shortest plant height (47.38 cm) was observed in N_0 treatments. Similarly, plant heights were significantly different among the different N treatments for post-monsoon season ($P<0.01$) (Figure 2b). In post-monsoon season, the highest plant height (75.83 cm) was found in N_3, followed by N_2 (65.75 cm) while the shortest plant height (46.08 cm) was observed in N_0. Plant height in pre-monsoon season was generally higher than that of post-monsoon season. This finding was consistent with the results reported by Soomro and Waring (1987) who reported that the significant difference was observed in plant height with different levels of N application. It can be assumed that the increase in plant height with increased N application might be due to N fertilization primarily enhanced greater vegetative growth. However, no significant different was observed among K treatments for both seasons (Figure 2a and 2b). No interaction effect between N and K application was observed in both seasons.

There were highly significant differences in number of sympodial branches plant^{-1} among the different N treatments in both seasons (*P<0.01*) (Table 2). The sympodial branch is one of the important parameters which directly affect the cotton yield and it is assumed in many literatures as the fruiting branches. The highest N application gave the largest sympodial branches plant^{-1} in both seasons while the lowest number was observed in N_0 treatments. Similar finding has been reported by Baraich et al. (2012). In both seasons, number of sympodial branches plant^{-1} differed significantly at various levels of applied K (*P<0.05*), but the interaction between various levels of N and K application was not significant (Table 2). For pre- and post-monsoon seasons, the highest numbers of sympodial branches plant^{-1} were resulted in K_2 treatments. The lowest number of sympodial branches plant^{-1} was obtained from K_0 treatments in both seasons. According to Aladakatti et al. (2011) who observed that soil and foliar application of K had significant effect on number of sympodial branches plant^{-1}.

In the case of monopodial branches, higher numbers were observed in high N application levels in both seasons and they were significantly different among the N treatments. However, in the K application treatments, higher rates of K gave the lower number of monopodial branches (Table 2). K_2 gave significantly lowest monopodial branches in pre-monsoon season. According to Alitabar et al. 2013, the number of monopodial branches plant^{-1} in a cotton plant depend on genotype as well as management practices like as the use of N fertilizer. However, monopodial branches were found to produce three to nine percent of the total yield production (Jenkins et al. 1990). And it can be assumed that increasing sympodial branches at the same time with reducing monopodial branches may be the most suitable practice with the control of N and K fertilizers.

3.2 Yield components

Number of bolls plant^{-1} were significantly affected among the N as well as K fertilizer treatments for both seasons (*P<0.01*). The highest N treatments N_3 gave the highest number of bolls plant^{-1} in both seasons and those were significantly higher than other N treatments (Table 2). Rashidi et al. (2011) reported that 200 kg ha^{-1} N application rate resulted significant increased in the boll number (19.8), and boll weight (6.26 g) compared to low N rates. Sawan (2014) suggested that N is an important nutrient which control growth and prevents abscission of squares and bolls, essential for photosynthetic activity and stimulate the mobilization and accumulation of metabolites in newly developed bolls and thus their number and weight are increased. For K application, the highest numbers of boll plant^{-1} were found in K_2 treatments. Aladakatti et al. (2011) in their study on cotton reported that K application had significant effect on total number of bolls plant^{-1}. N × K interaction effect was significant at 1% level for both seasons.

The highly significant differences were observed in boll weight for N application for both seasons (*P<0.01*) (Table 2). In pre-monsoon season, the highest boll weight 3.74 g was achieved from N_3 treatments but it was not significant from N_2 treatments which gave 3.66 g boll weight. The lowest boll weight 3.38 g was obtained from N_0 treatments and it was not significant from N_1 treatments which gave 3.43 g boll weight. In post-monsoon season, the highest boll weight 4.10 g was obtained from N_3 treatments although it was not significant from N_2 treatments while the lowest in N_0 treatments. Similarly, significant effect of different levels of N application on boll weight was reported by Khan et al. (1993). Boll weight was significantly affected by K application at 5% level for pre-monsoon season but not significant in post-monsoon season. In pre-monsoon season, K_2 treatments gave the highest boll weight (3.63 g) which was significantly higher than K_1 and K_0 treatments. According to Azab et al. (1993), boll weight was significantly increased by adding K. And the current results clearly showed that boll weight of cotton still responded to K application up to 124.50 kg K ha^{-1}. However, no significant interaction was observed between N and K application for both seasons.

3.3 Seed cotton yield (kg ha^{-1})

In both seasons, seed cotton yields were highly significantly different among the tested N and K treatments (*P<0.01)* (Table 2). Highest seed cotton yields were obtained in N_3 in both seasons. N_0 treatments produced the lowest value (801.70 kg ha^{-1}) of seed cotton yield however, that was not significantly different from N_1 (893.00 kg ha^{-1}) in pre-monsoon season. It showed that low response to N was observed at 60 kg N ha^{-1} for seed cotton yield compared to 180 kg N ha^{-1} which gave the highest yield. In post-monsoon season, the lowest yield 764.50 kg ha^{-1} was obtained from N_0 treatments and which was significantly different from others. Sawan et al. (1988) proved that seed cotton yield increased linearly with increasing N fertilizer treatments. The highest seed cotton yield in pre-monsoon season

(1413.40 kg ha^{-1}) and in post-monsoon season (1524.90 kg ha^{-1}) were resulted from K_2 treatments which were significantly different from others (Table 2). In pre-monsoon season, there were no significant differences in seed cotton yields between K_1 and K_0 treatments and those were the lowest in seed cotton yield produced. According to Fan et al. (1999), yield increases could be attributed to the effect of K on growth and nutrient uptake, which caused favorable effects on the number of bolls $plant^{-1}$ and boll weight leading to higher cotton yield. The significant interaction of N × K at 5% level was observed in both seasons. This result indicated that the response of seed cotton yield to N was influenced by K application, vice versa. Many literatures indicated that the rapid NO_3 uptake depends on adequate K supply in soil solution. Moreover, crops respond to higher K levels when N is sufficient, and greater yield response to N fertilizer occurs when K is sufficient as well (Better crop 1998).

3.4 Fiber quality

Nitrogen application at 180 kg N ha^{-1} (N_3) gave longest fiber length in both seasons however no significant difference was observed (Table 3). Grimes et al. (1969) reported that it was no or inconsistent effects of the N application rate on fiber length. However, Read et al. (2006) reported that N deficiency decreased the fiber length. Therefore, N application is important but, essential to have the major attention to be suitable amount and timing. In case of K application, although no significant difference was observed in pre-monsoon season, fiber length was significantly different at 1% level among the K levels for post-monsoon season. For both seasons, the longest fiber lengths were recorded at K_2 treatments. This finding was in line with Dhindsa et al. (1975) who observed that when K supply was insufficient or low, fiber elongation was reduced. Dewdar and Rady (2013) also reported that enough supply of K during active fiber growth period may cause an increase in the turgor pressure of the fiber, resulting in higher cell elongation and longer fibers at maturity. The combined analysis showed no significant interaction between N and K application treatments on fiber length for both seasons.

The highest N rate (N_3) gave the highest fiber strength values (8.03 lb mg^{-1}) in post-monsoon season but no significant difference was obtained among N treatments for both seasons (Table 3). These results are similar to those of Boman and Westerman (1994), who did not observed any significant relationship between fiber strength and N treatment. In pre-monsoon season, the highest fiber strength value (8.01 lb mg^{-1}) was observed in K_2 however, it was not significantly different with other K application treatments. In post-monsoon season, highly significant differences were observed among K application treatments ($P<0.01$) and the highest fiber strength value (8.08 lb mg^{-1}) was obtained from K_2 treatments. Similarly, a reduction in fiber strength at K omission treatment was observed by Gormus (2002). The combined analysis showed no significant interaction between N and K application treatments for both seasons.

The higher values of micronaire represent the lower fineness of the cotton fiber while the lower micronaire value means the higher fiber fineness. No significant difference in fiber fineness (micronaire) was observed for N or K application and their interaction effect for both seasons (Table 3). In pre-monsoon season, the maximum micronaire value was observed in N_0 treatments and minimum micronaire value was observed in K_2 treatments. It has been reported by Reddy et al. (2004) who found that N deficiency increased the micronaire value. By increasing N and K application, the micronaire value was decreased (Table 3). Therefore proper N and K application is necessary since more fine fiber is a desired trait.

In both season, no significant differences were observed in maturity ratio among N rates while it was significantly different at 5% level among K treatments (Table 3). The maximum maturity ratio value was found in K_2 treatments and the minimum value was observed in K_0 treatments. Pettigrew et al. (1996) found that fiber maturity was reduced when K levels were insufficient. The values of maturity ratio in post-monsoon season were higher than those in pre-monsoon season for all N and K treatments.

In both seasons, significant difference was not found in the ginning percentage among the tested N and K application treatments (Table 3). Results in this study indicated that ginning percentage were higher in post-monsoon season compared to pre-monsoon season. Interaction between N and K application on ginning percentage was not observed in both seasons.

4. General Discussion

The results indicated that N and K application gave higher yield and better fiber quality value in post-monsoon season compared to pre-monsoon season. The decrease in yield and quality in pre-monsoon season might be due to the effect of high temperature and low rainfall at the early growth stages (Figure 1). The cotton production can be reduced by the limitation of irrigation water especially during germination and early growth stages (Bielorai 1973). In this study, seed cotton yield increased linearly with increased N and K application rates. It can be observed that N application clearly affect on seed cotton yield. Increased K application rates produced longer fiber length with a smoother and stronger yarn, higher fiber strength value—an important parameter in determining yarn spinning value—in the post-monsoon season. Similarly, high K application produced high value of maturity ratio which is one of the important fiber quality parameters, especially in pre-monsoon season. It can be suggested that K application increased not only seed cotton yield but also fiber quality significantly and so it is necessary to apply optimum amount of K fertilizer to optimize cotton production. Moreover, supply of adequate balanced ratio of N and K fertilizer combination is also important and further systematic study is needed with more N and K ratios.

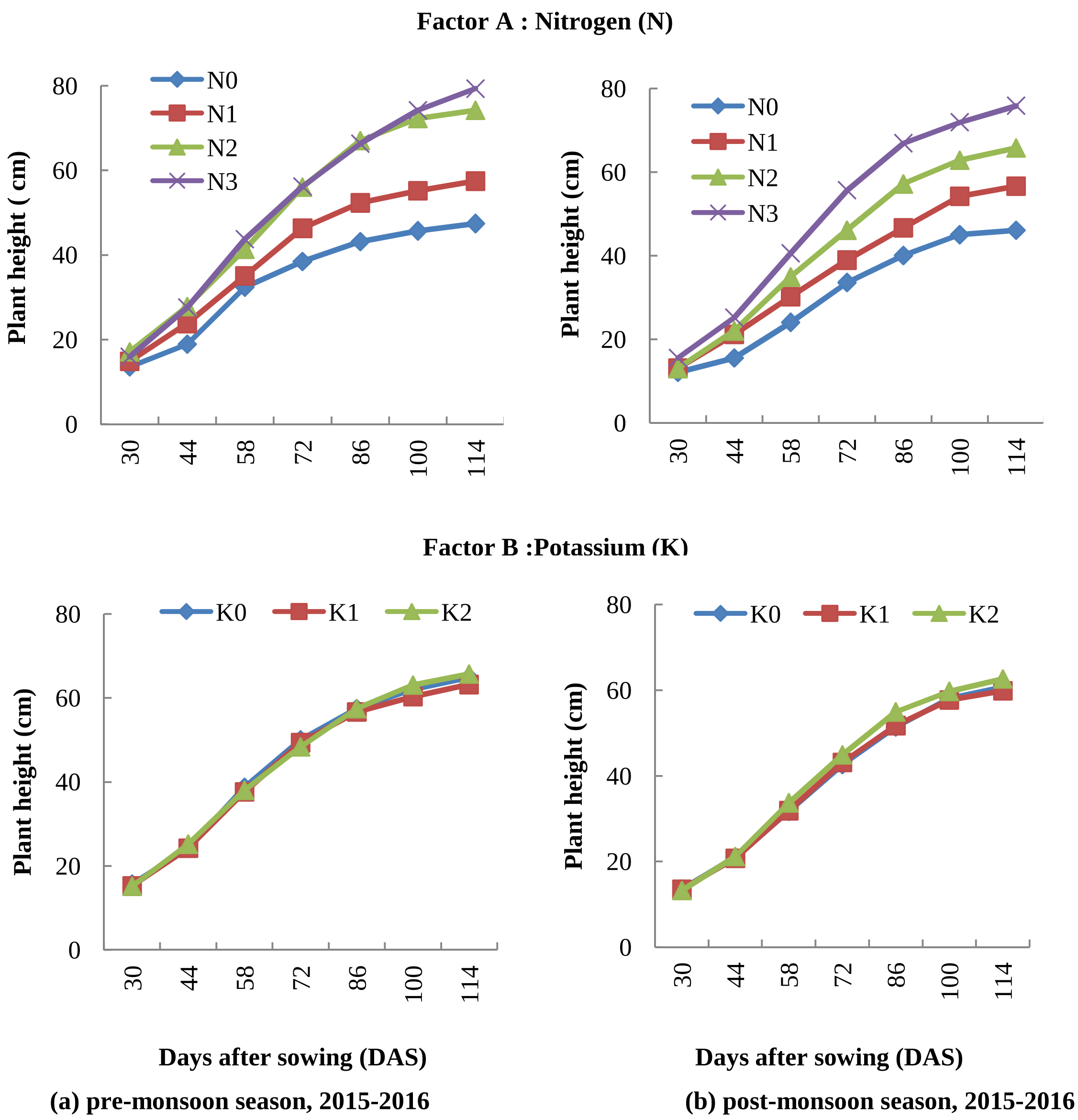

Figure 2. Plant height of cotton as affected by nitrogen and potassium applications at 14-days interval in pre- and post-monsoon season, 2015-2016

5. Conclusion

This investigation indicated that maximum seed cotton yield was observed in the highest N and K application treatments for both seasons. N fertilization mostly influenced on growth and yield of seed cotton although it had no effect on fiber quality, whereas K fertilization was more pronounced for number of sympodial branches, yield and fiber quality. The results from all quality characteristics can be assumed that K fertilization is a key to increase the better fiber quality rather than N fertilization alone. Based on this research finding, it can be concluded that application of 180 kg N ha^{-1} with 124.50 kg K ha^{-1} would be the best fertilizer ratio for higher seed cotton yield and quality under the present experimental conditions. Further investigations will be necessary to understand the response of N and K fertilization on cotton yield and quality under different soil fertility and climate conditions using different cultivars.

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Table 2. Effects of nitrogen and potassium application on growth, yield components and yield in pre- and post-monsoon season (2015-2016)

Treatment	No. of sympodial branches plant^{-1}		No. of monopodial branches plant^{-1}		No. of bolls plant^{-1}		Boll weight (g)		Seed cotton yield (kg ha^{-1})	
	pre-	**post-**	**pre-**	**post-**	**pre-**	**post-**	**pre-**	**post-**	**pre-**	**post-**
Nitrogen (N kg ha^{-1})										
0	12.48b	12.77c	0.90c	0.86c	8.64d	8.59d	3.38b	3.26c	801.70c	764.50d
60	13.73a	14.57b	1.13b	1.04b	10.49c	10.57c	3.43b	3.54b	893.00c	986.40c
120	13.60a	14.71ab	1.27ab	1.24a	12.57b	13.70b	3.66a	3.83a	1242.10b	1345.50b
180	14.28a	15.73a	1.37a	1.27a	14.72a	17.63a	3.74a	4.10a	1468.30a	1835.80a
$LSD_{0.05}$	0.93	1.15	0.14	0.16	0.86	1.50	0.13	0.28	161.64	193.98
Potassium (K kg ha^{-1})										
0	13.05b	13.76b	1.26a	1.17	10.32b	10.63c	3.51b	3.61	900.40b	994.60c
62.25	13.28b	14.40ab	1.13b	1.08	10.96b	12.03b	3.52b	3.62	990.00b	1179.70b
124.50	14.23a	15.17a	1.11b	1.06	13.54a	15.21a	3.63a	3.83	1413.40a	1524.90a
$LSD_{0.05}$	0.80	0.99	0.12	0.14	0.75	1.30	0.11	0.24	139.99	167.99
Pr>F										
N	**	**	**	**	**	**	**	**	**	**
K	*	*	*	ns	**	**	*	ns	**	**
N × K	ns	ns	ns	ns	**	*	ns	ns	*	*
CV%	7.01	8.18	12.24	14.55	7.61	12.19	3.63	7.73	15.01	16.09

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level

*= significant at 5% level

ns = non- significant

Table 3. Effects of nitrogen and potassium application on fiber qualities of cotton in pre- and post-monsoon season (2015-2016)

Treatment	Fiber length (mm)		Fiber strength (lb mg^{-1})		Fiber fineness (micronair)		Maturity ratio		Ginning %	
	pre-	post-	pre-	post-	pre-	post-	pre-	post-	pre-	post-
Nitrogen (N kg ha^{-1})										
0	28.44	30.44	7.93	7.97	4.70	4.72	0.87	1.07	34.12	38.79
60	28.44	31.11	7.98	7.96	4.56	4.93	0.89	1.13	34.39	38.01
120	28.33	30.44	7.97	8.01	4.29	4.86	0.87	1.13	33.31	38.36
180	28.89	30.78	7.96	8.03	4.44	4.70	0.86	1.09	33.71	37.76
$LSD_{0.05}$	0.60	0.63	0.13	0.11	0.32	0.39	0.03	0.07	1.15	1.27
Potassium (K kg ha^{-1})										
0	28.25	30.25b	7.91	7.95b	4.50	5.01	0.86b	1.07b	33.97	38.39
62.25	28.58	30.58b	7.96	7.94b	4.52	4.74	0.87ab	1.09b	33.94	38.26
124.50	28.75	31.25a	8.01	8.08a	4.45	4.66	0.89a	1.16a	33.74	38.03
$LSD_{0.05}$	0.52	0.55	0.11	0.09	0.27	0.34	0.03	0.06	0.99	1.10
Pr>F										
N	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
K	ns	**	ns	**	ns	ns	*	*	ns	ns
N × K	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	2.15	2.12	1.67	1.40	7.2	8.45	3.22	6.44	3.47	3.41

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level

*= significant at 5% level

ns = non- significant

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