Research Article

Cotton Response to Tillage and Soil and Foliar Applied Potassium Fertilization

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Abstract | In the scenario of recent energy crises, enhancement of yield at a reduced tillage cost and site specific potassium nutrition is much important for higher cotton yield and lint quality. The experiment was in a split-plot design and replicated thrice. Tillage system (i.e. reduced and conventional) was main plot treatment and potassium levels (0, 50, 100, 150, 200 & 250 kg ha^{-1}) sub-plot. K-levels were applied 50, 100, 150, 200, and 200 kg ha^{-1} as soil application treatments and 1, 2, 3, 4, and 5 as a foliar application of 2% K_2SO_4 solution at peak boll formation stage. Results revealed that tillage did not influence yield and quality attributes of cotton; however, potassium levels significantly affected yield and quality traits except fiber micronaire. Potassium fertilizer (soil-applied) at 250 kg ha^{-1} along with five foliar sprays of K_2SO_4 produced higher plant height, sympodial branches plant^{-1}, bolls plant^{-1}, 100 cotton seed weight, seed cotton yield, ginning outturn, fiber length, and fiber strength compared to other K-levels. Moreover, tillage × potassium interaction indicated that reduced tillage along with 250 kg K ha^{-1} plus 5 foliar sprays was superior to conventional tillage for producing higher sympodial branches, bolls plant^{-1}, seed cotton yield, and ginning outturn (%).

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Keywords | Reduced tillage, Conventional tillage, Seed cotton yield, Quality, GOT

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the major cash crops of Pakistan (Razzaq *et al*., 2021). It is very important to the national economy for its fiber from lint and oil from seeds to contribute to the gross domestic product (Shuli *et al*., 2018). Cotton involvement in the total foreign exchange from Agriculture is 55% (MINFAL, 2001). Unfortunately, cotton production has been declining with the subsequent increase in imports since 2018 (USDA, 2021). India and China are the world-leading cotton producers, with about 6 million tonnes each, followed by the USA, Brazil, Pakistan, and Australia with 4.55, 1.9, 1.8, and 1.05 million tonnes, respectively (Statista, 2018). Average cotton lint yield is low (810 kg ha^{-1}) in Pakistan compared to the world's cotton leading country like China (1484 kg ha^{-1}) (Shuli *et al*., 2018). There may be several reasons for lower cotton yield, such as insect pests and diseases; however, land degrading tillage practices and poor crop fertilization, especially with potassium, cannot be avoided. Cotton has inconsistent response to tillage (Boquet *et al*., 2004). Some people talk in favor of conventional tillage that it effectively controls weeds; prepares the land well in time, while others say against it in terms of the higher cost of cultivation and long-term degradation of soil. Feng and Balkcom (2017) reported that the main benefit of reduced tillage is to sustain crop productivity besides additional soil benefits. Reduced tillage saves time and energy. It also enhances the water and soil resources. Reduced tillage declines evaporation from topsoil, lowers soil temperature, and increases the yield of the cotton crop. During the growth stage, it increases water retention and paves the way for roots to penetrate against soil resistance (De Vita *et al*., 2007; Fabrizzi *et al*., 2005). However, some researchers reported that conservation tillage produced a low yield of cotton and water productivity while conventional tillage had a higher crop yield (Jalota *et al*., 2008). Therefore, the present research deals with the comparative performance of the two tillage systems in terms of yield and quality attributes.

Table 1: *Weather conditions during 2019 and 2020 growing seasons.*

Trial year	Trial month	Temperature (°C)			Total rainfall (mm)
		Maximum	Minimum	Mean	
2019	April	35	10	23	54
	May	36	22	29	27
	June	41	28	35	15
	July	38	27	33	02
	August	36	23	29	49
	September	36	21	28	28
	October	27	9	18	15
	November	28	14	21	6
2020	April	30	17	24	99
	May	38	12	25	6
	June	39	22	31	21
	July	39	20	30	17
	August	38	22	30	60
	September	36	21	28	20
	October	27	10	19	10
	November	29	15	22	0

Potassium is a quality element and increases both the yield and quality of cotton. It makes the plant tolerant against insect pests, diseases, produces resistance against environmental and drought stress (Ashfaq *et al*., 2015). Low use of potassium in the cotton crop may have serious concerns as the crop may be highly responsive to potassium deficiency compared with other agronomic crops because of the less dense root system of cotton than other crops (Meshram *et al*., 2021). Potassium fertilizer had a strong influence on the quality parameters of the cotton crop (Reddy *et al*., 2000). Potassium deficiency reduced the lint quality and yield (Yang *et al*., 2011). The optimum level of K significantly improved the yield components in cotton crops (Hussain *et al*., 2021). There is limited information about the tillage and K effect on seed cotton yield and lint quality in the heavy textured soil of D.I. Khan. Therefore, research was carried out with the objectives; 1) to compare reduced tillage with conventional tillage regarding cotton yield and lint quality, and 2) to evaluate the impact of K-levels on cotton yield and lint quality.

Materials and Methods

The experiments were conducted in Gomal University, D.I. Khan for two consecutive years (2019-2020). The site is categorized by warm and heavy textured soil (hyperthermic, and Typic Torrifluvents as said by Soil Survey Staff (2009)) with 180-200 mm annual rainfall. The weather conditions of the two growing seasons were almost similar; however, the 2020 growing season was a bit wetter than the 2019 growing season (Table 1). Cotton was planted on the field that previously remained under wheat crop. The field was irrigated (shallow irrigation) just after wheat harvesting. Main plot treatments were two tillage *i.e.* reduced (2 tillage passes; one cultivator and one moldboard plow) tillage and conventional (local tillage trend: disc plow followed by cultivator and rotavator) tillage, while subplot treatments were 6 potassium levels (0, 50, 100, 150, 200 & 250 kg ha^{-1}). The subplot size was 3 × 3 meters. There were 4-rows in each subplot with a 0.75-meter row-row distance and 0.30-meter plant-plant distance. There was a 1 m separation bund between two adjacent plots. N was applied at 200 kg N ha^{-1} in 2-splits, one half at first irrigation after thinning stage and the other half at bloom stage. Fertilizers were Urea, Di-ammonium phosphate, and potassium sulfate. P (150 kilograms P_2O_5 ha^{-1}) was given with sowing. Potassium foliar spray at the rate of 20 g per liter water (2%) was applied 1, 2, 3, 4, and 5 times (with 10 days interval) on the plot treated with 50, 100, 150, 200, and 250 kg ha^{-1} soil-applied K, respectively during boll formation stage. The first foliar spray of potassium was initiated on 25th July in both years of the study. The cotton crop was planted manually in dry condition followed by irrigation on 29th and 30th April during 2019 and 2020, respectively. Four seeds per hill were initially sown of the Bt cotton (Cv. IUB-13) and thin-out to single healthy seedling after 20 days after emergence. Irrigation was given on weekly basis during the establishment stage while after the square stage (6 weeks after emergence) irrigation interval was extended to three weeks till one month before maturity. The irrigation depth was 7.5 cm. Cotton was harvested on 25th and 26th November in 2019 and 2020, respectively. Weeds were controlled manually while sucking types of insects such as whitefly, thrips, and jassids were controlled with insecticide, Polo (Diafentiuron with a formulation of 500 suspension concentrate). Data recording parameters were plant height (cm), sympodial branches plant^{-1}, bolls plant^{-1}, 100 cotton seed weight (g), seed cotton yield (kg ha^{-1}), ginning outturn (GOT %), fiber length (mm), fiber strength (g tex^{-1}), and micronaire (µg inch^{-1}). Field data were recorded at crop maturity while fiber quality traits were studied in CCRI, Multan.

Statistical analysis

Data recorded were statistically analyzed with computer software, Statistix 8.1 to determine the analysis of variance according to ANOVA procedure (Steel *et al*., 1997) and subsequent LSD at a 5% level of probability for significant means.

Results and Discussion

Plant height (cm)

Plant height showed a significant response to potassium levels (K); neverthless, tillage (T) and the T × K interaction were not significant both in 2019 and 2020 (Table 2). The results reveal that plant height increased with the incremental increase in K-level and reached a maximum height at 250 kg K ha^{-1} plus five foliar sprays of K_2SO_4. Plant height response to various K levels was similar in 2019 and 2020. The results indicate that a lower level of K reduced plant height while a higher level increased plant height. It means that cotton is more responsive to K than other crops, probably due to poor soil exploitation and a less dense rooting system as also communicated by Yang *et al*. (2011) who reported that both genotype and K application affected plant height.

Sympodial branches plant^{-1}

Sympodial branches plant^{-1} showed a significant response to various K-levels; however, tillage and tillage × potassium interaction was not significant in 2019 (Table 2). In 2020, Sympodial branches plant^{-1} responded significantly to various potassium rates and T × K interaction while tillage alone had no significant effect on sympodial branches plant^{-1} (Figure 1). Sympodial branches plant^{-1} increased regularly with the increase in potassium rates, viz., more K-rates had a constant trend towards producing more sympodial branches plant^{-1} and vice versa. Other researchers also reported more sympodial branches with higher doses of K (Pettigrew, 2004). In 2020, the T × K interaction showed that sympodial branches plant^{-1} decreased with decreasing potassium levels in both tillage systems. T × K interaction showed that reduced tillage plots produced significantly more sympodial branches at every K level than conventional tillage with corresponding potassium levels. Results showed that excessive tillage as in the case of conventional tillage is not important for getting greater sympodial branches, provided there are no nutrients deficiencies, as reported by Tsonev *et al*. (2011). Higher sympodial branches under reduced tillage with each potassium level indicate an efficient use of resources in reduced tillage than in conventional tillage.

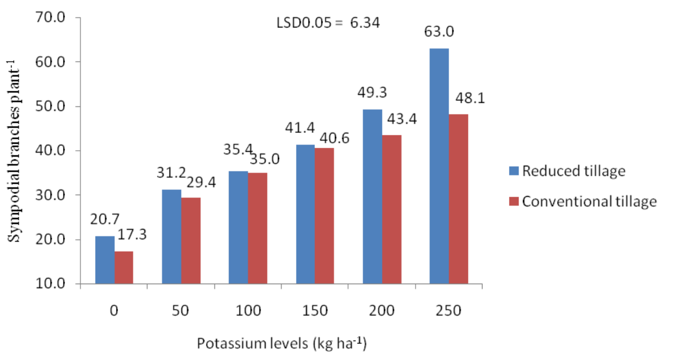

Figure 1: *Sympodial branches plant^{-1} as affected by tillage and potassium interaction during 2020 growing season.*

Number of bolls plant^{-1}

Bolls plant^{-1} responded significantly to various potassium rates, while T was neither significant in 2019 nor 2020 (Table 3); however, T × K interaction was significant in 2020 only (Figure 2). Pervez *et al*. (2005a) reported that plants treated with higher K level shifted earlier from vegetative stage to reproductive stage and also produced more harvestable bolls than plants treated with lower K or no K. The results reveal that higher K level produced more number of bolls that survived till harvesting while lower K level produced

Table 2: *Plant height (cm), sympodial branches plant^{-1}, and bolls plant^{-1} as affected by tillage and potassium levels during 2019 and 2020 growing seasons.*

Tillage	Plant height (cm)		Sympodial branches plant^{-1}		Bolls plant^{-1}	
	2019	2020	2019	2020	2019	2020
Reduced tillage	125	108	35.3	40.0	29.0	26.1
Conventional tillage	104	103	36.8	35.8	23.1	27.2
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns
Potassium levels						
K_0	103 de	89 d	23.7 d	19.0 f	19.0 d	16.2 d
K_{50} + 1 foliar spray*	92 e	93 cd	28.0 d	30.3 e	19.5 d	19.5 d
K_{100} + 2 foliar spray	111 cd	101 bc	34.9 c	35.2 d	24.6 c	23.9 c
K_{150} + 3 foliar spray	119 bc	108 b	37.7 bc	40.9 c	27.1 bc	26.8 c
K_{200} + 4 foliar spray	127 ab	119 a	43.4 ab	46.3 b	30.8 b	32.7 b
K_{250} + 5 foliar spray	133 a	125 a	48.8 a	55.6 a	35.9 a	42.0 a
$LSD_{0.05}$	12	8	6.2	4.5	4.52	3.65
Interaction $(T \times K)_{0.05}$	ns	ns	ns	*	ns	*

Foliar spray @ 2% K_2SO_4 initiating at peak boll formation stage

Table 3: *100 cotton seed weight (g), seed cotton yield (kg ha^{-1}), and GOT (%) as affected by tillage and potassium levels during 2019 and 2020 growing seasons.*

Tillage	100 cotton seed weight (g)		Seed cotton yield (kg ha^{-1})		GOT (%)	
	2019	2020	2019	2020	2019	2020
Reduced tillage	5.78 a	4.59	1630	1621	69.2	68.2
Conventional tillage	5.61 b	4.82	1341	1351	66.7	65.7
$LSD_{0.05}$	0.15	ns	ns	ns	ns	ns
Potassium levels						
K_0	5.06 e	3.96 e	523 c	672 d	62.8 c	61.8 c
K_{50} + 1 foliar spray*	5.24 de	4.20 de	689 c	928 cd	65.5 bc	64.5 bc
K_{100} + 2 foliar spray	5.44 d	4.41 cd	950 c	1241 c	68.9 ab	67.9 ab
K_{150} + 3 foliar spray	5.77 c	4.72 c	1196 bc	1763 b	69.2 ab	68.2 ab
K_{200} + 4 foliar spray	6.14 b	5.18 b	1983 b	2108 ab	69.6 ab	68.6 ab
K_{250} + 5 foliar spray	6.53 a	5.77 a	3572 a	2323 a	71.7 a	70.7 a
$LSD_{0.05}$	0.32	0.31	810	397	4.28	4.29
Interaction $(T \times K)_{0.05}$	ns	ns	*	ns	*	*

Foliar spray @ 2% K_2SO_4 initiating at peak boll formation stage

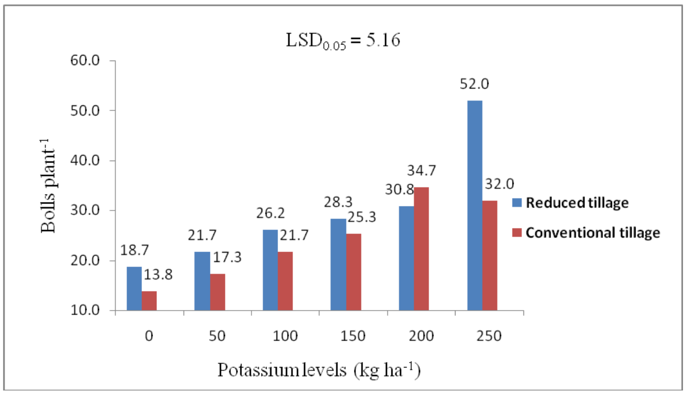

Figure 2: *Bolls plant^{-1} as affected by tillage and potassium interaction during 2020 growing season.*

a lower number of bolls majority of which could not survive till harvesting and thus resulted in a reduced number of harvestable bolls. Makhdum et al. (2001) reported analogous results who conveyed that potassium fertilizer significantly increased bolls plant^{-1}.

100 cotton seed weight (g)

Hundred cotton seed weight responded significantly to various K levels in 2019 and 2020; nevertheless, tillage was significant only in 2019, while interaction (T × K) was not significant (Table 3). Means for tillage revealed that reduced tillage had a higher 100

Table 4: *Fiber length (mm), fiber strength (g tex^{-1}), micronaire (µg inch^{-1}) as affected by tillage and potassium levels during 2019 and 2020 growing seasons.*

Tillage	Fiber length (mm)		Fiber strength (g tex^{-1})		Micronaire (µg inch^{-1})	
	2019	2020	2019	2020	2019	2020
Reduced	25.6	24.1	25.6	24.6	4.2	4.5
Conventional	25.2	23.7	25.4	24.4	4.2	4.5
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns
Potassium levels						
K_0	24.9 e	23.4 e	24.8 e	23.8 e	4.1	4.4
K_{50} + 1 foliar spray*	25.1 de	23.6 de	25.0 de	24.0 de	4.1	4.4
K_{100} + 2 foliar spray	25.3 cd	23.8 cd	25.3 cd	24.3 cd	4.2	4.5
K_{150} + 3 foliar spray	25.4 bc	23.9 bc	25.6 bc	24.6 bc	4.2	4.5
K_{200} + 4 foliar spray	25.6 b	24.1 b	25.9 ab	24.9 ab	4.2	4.5
K_{250} + 5 foliar spray	25.9 a	24.4 a	26.4 a	25.4 a	4.3	4.6
$LSD_{0.05}$	0.23	0.23	0.49	0.49	ns	ns
Interaction $(T \times K)_{0.05}$	ns	ns	ns	ns	ns	ns

Foliar spray @ 2% K_2SO_4 initiating at peak boll formation stage

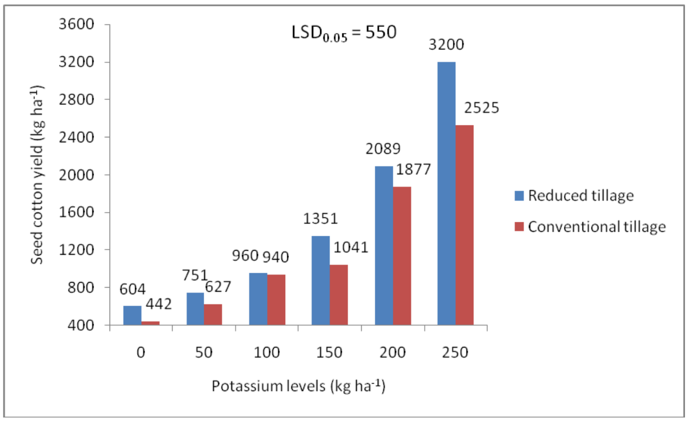

Figure 3: *Seed cotton yield (kg ha^{-1}) as affected by tillage and potassium interaction during 2019 growing season.*

cotton seed weight than conventional tillage. Similarly, higher levels of K produced heavier seed weight compared to lower levels of K. The highest 100 cotton seed weight at 250 kg K ha^{-1} indicates that probably this level was the optimum level which resulted in the heaviest seed weight among all other K levels. The K deficient plots had lower seed weight. Sawan (2016) reported similar results.

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

Seed cotton yield was significantly affected by K in both the years and T × K interaction in 2019 only, however, the main effect of tillage was not significant in both years (Table 3). Results showed that seed cotton yield was higher with a higher level of potassium (250 kg K ha^{-1}) than lower levels of K both in 2019 and 2020. Mean values for T × K interaction in 2019 revealed that reduced tillage had higher seed cotton yield with each K-level than the conventional tillage with the corresponding K-level (Figure 3). This may be due to the efficient use of resources under reduced tillage than in conventional tillage. The added potassium doses from 0 - 250 kilogram ha^{-1} resulted in higher seed cotton yield. The control plot or lower level of potassium plots have lower seed cotton yield probably due to K deficiency. Potassium deficiency affects plant growth and subsequent seed cotton yield as reported by Adeli and Varco (2002). The cotton crop needs greater potassium at flowering. That perhaps might not be achieved in the experimental site for decreased nutrient uptake and severe potassium deficiencies that lead to reduced cotton yields (Oosterhuis, 2002). Conversely, there was increased seed cotton yield in potassium enrich-plots perhaps because of potassium's active role in improving seed cotton yield (Lu *et al*. 2016).

Ginning out turn (GOT %)

GOT responded significantly to K and T× K interaction while tillage alone was not significant both in 2019 and 2020 (Table 3). Potassium levels revealed that higher K-level produced higher GOT than other K levels in both years. The results showed that ginning outturn improved with increased K level and the highest GOT was achieved from the plot treated with 250 kg K ha^{-1} whereas the smallest value from the control plot. Greater GOT obtained from 250 kg K ha^{-1} under reduced tillage (Figure 4) was perhaps due to the well-documented role of K in increasing lint yield (Hasan-uz-zaman *et al.* 2018). Prabhu *et al.* (2007)

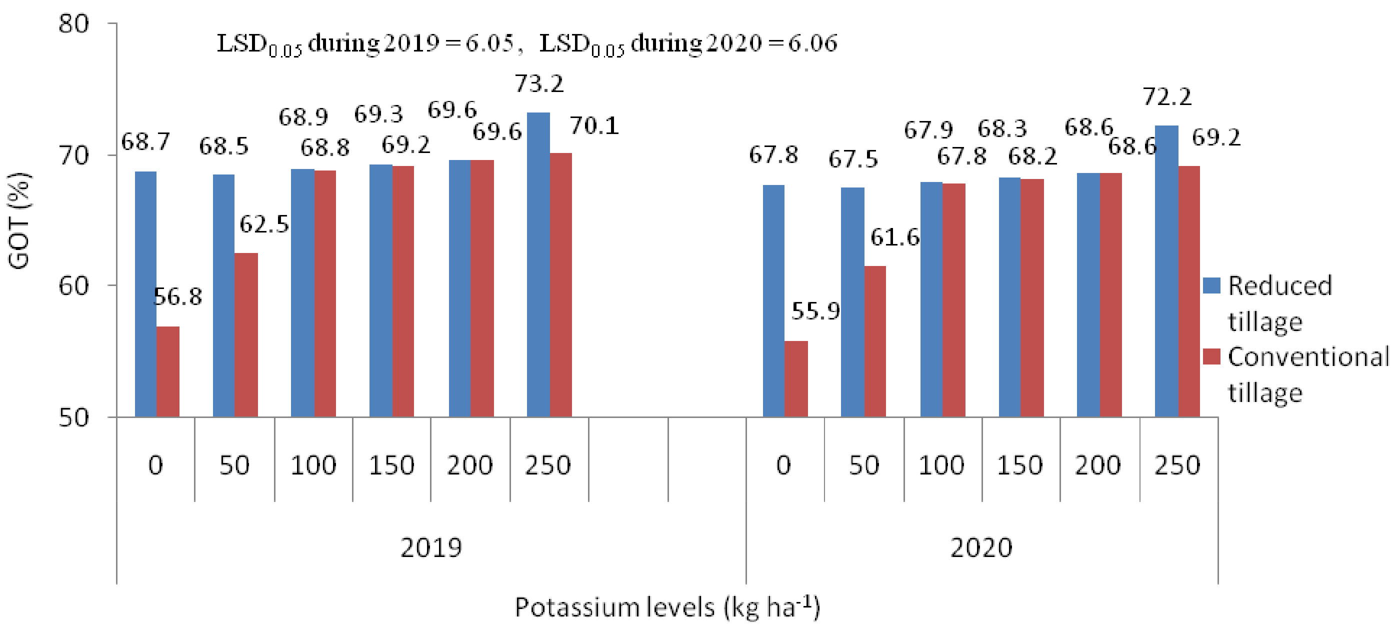

Figure 4: *GOT (%) as affected by tillage and potassium levels during 2019 and 2020 growing seasons.*

reported that a higher level of K made crop resistant to pests, drought, and diseases, which ultimately lead to greater ginning outturn.

Fiber length (mm)

Fiber length had a significant response to K levels, whereas T and T × K interaction were not significant both in 2019 and 2020 (Table 4). Potassium means revealed that increasing level of K increased fiber length both in 2019 and 2020. Potassium at 250 kg ha^{-1} plus 5 foliar sprays produced the lengthiest fibers, while plots with no potassium had the shortest fibers in 2019 and 2020. K deficiency might have reduced fiber length in zero potassium plots. The poor source-sink relation in the K-deficient plot, probably reduced nutrients supply to sink organs, which negatively affected fiber length (Pervez *et al*. 2005b). Argiolas *et al*. (2016) also reported analogous results that K deficient plants had reduced fiber length.

Fiber Strength (g tex^{-1})

Fiber strength response was significant for K-levels; however, it was not significant for T and T × K interaction (Table 4). The highest fiber strength was achieved from the plot treated with 250 kg K ha^{-1} while the lowest fiber strength was achieved from the control plot. The results displayed that a regular increase in K level improved fiber strength significantly. K deficient plots resulted in reduced crop growth which might have formed weaker bolls for decreased translocation of sugar from source organs to sink reducing fibers strength (Pettigrew, 2008).

Micronaire (µg $inch^{-1}$)

Micronaire indicates whether the fiber is fine or coarse. One can judge the monetary value of a bale from the fiber micronaire. Micronaire was not significant for T, K, and T × K interaction (Table 4). However, the micronaire values achieved for T and K were in the acceptable range, indicating fiber fineness. It means that T and K did not deteriorate the fiber fineness. Micronaire values were in the range of 4.13 to 4.33 and 4.43-4.63 in 2019 and 2020, respectively. Lokhande and Reddy (2015) narrated that increasing K levels did not deteriorate fiber fineness but rather improved fiber fineness compared to control, where no K was applied.

Conclusions and recommendations

Application of 250 kg K ha^{-1} plus five foliar sprays @ 2% K_2SO_4 solution with ten days, interval is highly productive regarding cotton yield and quality attributes. Reduced tillage is superior to conventional tillage for producing higher sympodial branches, bolls $plant^{-1}$, seed cotton yield, and ginning outturn at 250 kg K ha^{-1} plus 5 foliar sprays of K_2SO_4 solution. Since the study area is hard, compact, and naturally low in organic matter, therefore, reduced tillage which accumulates more organic matter in the soil compared to intensive/conventional tillage should be practiced. The cotton field should be treated with 200-250 kg K ha^{-1} plus 4-5 foliar sprays of K_2SO_4 solution during the boll formation stage with ten days intervals.

Novelty Statement

Cotton crop grown in a silty clay soil of Dera Ismail Khan needs 200-250 kg potassium ha^{-1} plus 4-5 foliar sprays of K2SO4 solution during the peak boll formation stage with ten days irrigation intervals.

Author's Contribution

Muhammad Waqas Imam Malik: Conducted this research and prepared draft of the paper.
Khalid Usman: Supervisor of the research scholar and corresponding author who gave final shape to the manuscript.
Amir Hamza: Helped in recording field data and literature collection.
Muhammad Saad: Helped in lab analysis and literature collection.
Said Ghulam: Helped in initial draft of the paper.
Azmatullah: Helped in data analysis.

Conflict of interest
There is no conflict of interest.

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