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Response of Cotton to Tillage Plus Wheat Residue and Potassium Management in Wheat-Cotton System

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Abstract
Conservation tillage with straw retention and optimizing potassium is an important strategy to enhance soil quality and cotton yield in the wheat-cotton system. Field experiments were conducted to study the effect of six tillage methods (zero tillage straw as such on the soil surface (ZTsas), ZTstraw removed (ZTsr), reduced tillage straw incorporated (RTsi), RT straw removed (RTsr), conventional tillage straw incorporated (CTsi), CT straw removed (CTsr)) and three potassium rates (30, 60 and 90 kg ha^{-1}) on cotton yield and quality. Results showed that RTsi produced higher boll count, weight per boll, seed cotton yield, ginning out turn than all other tillage methods. Mean bolls $plant^{-1}$, boll weight, seed cotton yield, ginning out-turn, and fiber length were optimum at 60-90 kg K ha^{-1}. Interaction showed optimum bolls, boll weight, yield and GOT with 60 kg K ha^{-1} under conservation tillage. RTsi with 60 kg K ha^{-1} also performed better in terms of fibre length and strength. ZTsas and RTsi with 60 kg K ha^{-1} produced higher total soil K at the end of two year experimentation. In conclusion, conservation tillage plus straw retention with 60 kg K ha^{-1} may be a sustainable and environmentally safe strategy to enhance cotton yield and quality.

Keywords: *cotton, potassium, tillage, yield, quality*

Introduction

Wheat– cotton system occupies a large part in the arid region of northwestern Pakistan, as it is a source of food for the increasing population, provide raw materials to the textile industry and ensure foreign earning (Usman *et al*. 2010; APTMA, 2015). Wheat straw is not incorporated, either removed used as burning or as animal feed. Burning and/or removal cause huge losses of carbon and other nutrients (Beri et al. 2003). As a result, cotton yield in the wheat-cotton system has become stagnant or started declining. The decreasing soil fertility, particularly potassium, is one of the important factors responsible for this decline (Olk et al. 1996; Pasricha and Bansal, 2002). Hence there is a stress on the accumulation of potassium and other nutrients, and to improve it in the soil, crop residues are normally advocated. Burning of wheat residue negatively affects soil eco-system along with nutrient sources (Singh et al. 2002). Residues on the surface of soil act as a mulch that protect the soil from structural degradation and has a positive effect on soil productivity, storage, and supply of water and potassium use efficiency (Díaz-Zorita et al. 2002). Residues retention may affect soil fertility, soil physico-chemical properties and yield of the crop (Hulugalle et al. 2004). Potassium in crop residues and soil improvements are more accessible to crops if they are retained into the soil rather than burnt. Keeping in view significance of straw incorporation/ retention into field one should adopt suitable tillage method. One of the farmer's adopted and environmentally acceptable methods of residue disposal is residue incorporation with conventional tillage-CT), which can enhance soil potassium, develop physical/biological conditions of the soil, and prevent soil degradation (Blaise, 2003; Mert et al. 2006). However, CT that involves several tillage operations/ plowings and disturbs the entire surface of sthe oil (CTIC 1998; Endale et al. 2002) for incorporation of wheat residues is neither feasible nor economical in case of wthe heat-cotton system. Both wheat and cotton are exhaustive crops and there is constant removal of nutrients from the soil (Wang et al., 2014; Usman et al., 2014). On the other hand ,much use of fertilizers especially potassium in conventional tillage method may not beproductive and not economical besides environmental hazards (Nehra et al., 2005; Ning et al., 2014) Therefore, conservation tillage with optimum K may be alternative to optimize cotton yield, fibre quality and soil health. Conservation tillage (ZT or RT) with straw retention enhances total soil potassium and therefore induces major changes in k management. Zero tillage and reduced tillage performed better than exhaustive tillage if k management is optimized (Howard et al., 2000; Pettigrew and Jones, 2001) .ZT with straw on the soil surface as such ma reduce soil crusting, increase water infiltration, reduce runoff, increase potassium use efficiency and gave higher seed cotton yield than tilled soils(Ning et al., 2014). Since there are contrasting results in literature that whether higher K (Girma et al. 2007), or lower K rates are required (Aladakatti et al. 2009) to crops sown in previous crop residues, the aim of the present study was to determine the best method of tillage and to explore optimum K rate in cotton sown after wheat.

Materials and methods

Experimental Site

A field experiment was conducted over two years from 2016 and 2017 cotton growing seasons at Cotton Research Station, Dera Ismail Khan, Pakistan. The climate of the area is arid and subtropical, mean minimum and maximum temperature ranges from16 and 40^{o}C during the cotton growing season, respectively. Annual average precipitation was >200mm, about 70% of which occurs during the cotton growing season. Soil samples were taken from the experimental field from 0 to 30 cm depth before and after sowing of the crop and analyzed for physic-chemical traits. The soil was clay loam with 6.6 g kg^{-1} organic matter-OM by Walkley and Black procedure (Nelson and Sommers, 1996), total N (0.3 g kg^{-1}), AB-DTPA extractable P (7.6 mg kg^{-1} soil) and available K (192 mg kg^{-1} soil). The climate data were obtained from Arid Zone Research Council (AZRC), D. I. khan, Pakistan, near the experimental site (Table 1)

Crop management practices

The experiment was laid out in RCB design with split-plot arrangements, repeated thrice. Tillage methods (ZTsas, ZTsr, RTsi, RTsr, CTsi, and CTsr) were kept in main plots, and three potassium rates (30, 60 and 90 kg K ha^{-1}) were allotted to sub-plots. Wheat was the based crop at the trial area during the study years. Wheat (CV. Hasheem-9) was sown in 1st week of December. Net plot size was 10m×3m and separated by 30 cm high dicks to facilitate application of the accurate amount of potassium to each treatment**.** After wheat harvest, cottonseed was sown into standing a wheat straw in ZT plots by dibbling method (making holes with a wooden stick) without seedbed preparation. RT plots comprised of one tiller followed by rotavator and cotton was sown by the dibbling method. In CT plots, wheat residues were incorporated or removed, and seedbed was prepared with plowing operations including disc plow followed tiller and rotavator. After well-prepared seedbed, CIM-616, Bt. cotton genotype was sown by the dibbling system. Phosphorus (60 kg P_2O_5) and Potassium were applied in the form of TSP & SOP before sowing, while N: 150 kg per hectare in the form of Urea was given at thinning, flowering and boll formation stage. The cotton received up to 6 irrigations depending upon precipitation during the years. Weeds were controlled by broad spectrum herbicides namely Haloxyfop-R-Methyl @ 109 g. a.i. per/hec and lactofen 26 EC, @ 167 g. a.i. per ha. All the agronomic practices and protective measures were used as needed. The crop was harvested on November 20, 2016, and November 24, 17 respectively.

Data collection

Seed cotton in each sub-treatment was handpicked two times and then converted into kg per hectare. Data on matured bolls per plant was taken from randomly selected ten plants in each sub-plots then averaged and calculated. Fifty opened bolls were picked from the selected ten plants, dried, and weighed then weight per boll was calculated. GOT = Lint weight in sample/weight of seed cotton in total sample × 100. Fiber properties of each sample were determined with the help of fiber quality determining instrument (HVI). Fiber length (mm) was measured as the average length of the longer one-half of the fibers (upper half mean length).

Statistical Analysis

Data were analyzed using a randomized complete block design with split plot combined over the years according to MSTATC (Steel & Torrie 1980). When the F-values were significant for main and interaction effects, means were compared using the least significant difference test at 0.05 level of probability.

Results

Number of bolls plant^{-1}

A number of bolls plant^{-1} was significantly affected by year (Y), tillage (T), Potassium (K), and T × K interaction (Table 2). Higher bolls per plant were recorded in 2017 than in 2016 (Table 3) probably due to variations in temperature and moisture between the two growing seasons. Conservation tillage such as zero tillage with straw as such on the soil surface and reduced tillage plus straw retained had more bolls per plant compared with the corresponding tillage treatments. Mean values for potassium revealed that application of K fertilizer at a rate of 60-90 kg ha^{-1} produced higher bolls compared 30 kg ha^{-1}. T × K interaction revealed that RTsi with 60 kg K ha^{-1} produced a greater number of boll count among all the other treatment combinations.

Weight per boll

Boll weight had a significant response to Y, T, K and year × tillage interactions (Table 2). Reduced tillage with straw incorporated (RTsi) showed heavier boll weight than the other tillage treatments (Table 4). Potassium increased weight per boll with incremental dose and reached a maximum at 60 kg K ha^{-1}. Year × tillage interactions revealed that optimum boll weight could be realized with RTsi in 2017.

Seed cotton yield

Seed cotton yield was significantly affected by Y, T, K, Y× T and Y× K interaction (Table 2). Seed cotton yield was higher in 2017 than that in 2016 (Table 5). The maximum yield in 2017 might be due to favorable growing conditions such as temperature and rainfall. In RTsi treatment, higher seed cotton yield was recorded compared to other tillage treatments. Mean values for potassium revealed that seed cotton yield increased initially with an increase in potassium and peaked at 60 kg K ha^{-1} but thereafter its decline with a further increase in potassium. Interaction effects indicated that RTsi with 60 kg K ha^{-1} produced higher seed cotton yield in 2017.

Ginning out-turn

GOT had a significant response to year (Y), tillage (T), Potassium (K), and T × K interaction (Table 2). Main effects of tillage revealed that reduced tillage with straw incorporated resulted in highest ginning out-turn than the other tillage plus wheat straw management practices (Table 6). Mean values for potassium revealed that 60-90 kg K ha^{-1} showed highest GOT followed by 30 kg K ha^{-1}. The results revealed that conservation tillage such as ZTsas and RTsi with 60-90 kg K ha^{-1} produced greatest ginning out turn among all the other treatment interactions.

Fiber length

Fiber length was affected significantly by potassium, while other main and interaction effects were found to be non significant (Table 2). Mean values for potassium revealed that highest fiber length could be achieved from 60-90 kg K ha^{-1}(Table 7). Conservation tillage could be optimized fiber length at a higher rate of potassium.

Fiber strength

Fibre strength had a positive response to tillage, potassium and their interactions (Table 2). Main effects of tillage revealed that RTsi gave the highest fiber length as compared to other tillage methods (Table 8). Mean values for potassium indicated that greater fiber strength was obtained from 90 kg K ha^{-1}**.**In T×K interactions; potassium at 90 kg ha^{-1} had higher fiber strength in conservation tillage (ZTsas and RTsi).

Total soil potassium (mg kg^{-1} soil)

Tillage and K had significant effects on total soil potassium content (TSK). TSK was the highest in ZTsas and RTsi among all other tillage systems (Table 9). Mean values for K revealed that higher TSK was recorded with 90 kg K ha^{-1}.

Discussion

The sowing of cotton with conservation tillage plus residue retention is still in experimental stages in Pakistan. However, cotton growers take a keen interest in this technology because of the lower cost of cultivation and higher cotton yield (Endale et al. 2002; Nehra et al. 2005; Gürsoy et al. 2010). In the study, cotton yield was significantly promoted by conservation tillage plus residue retained/incorporated as compared to conventional tillage plus straw burnt/removed. Correspondingly, potassium at the rate of 60 kg per hectare had the highest yield and quality of cotton compared to other K rate. Higher seed cotton was because of more number of bolls and boll weight (Girma et al. 2007; Zhang et al. 2007; Wang et al. 2014). Cotton yield in straw removed and K deficient plots were lowered as against straw incorporated/retained plots might be due to a distinct reduction in bolls and boll weight (Adeli et al. 2002; Akhtar et al. 2003). The probable cause of lower cotton yield in residue removed plots might be a due loss of nutrients especially potassium (K) and a decrease of beneficial soil micro-organisms (Liu and Ji 2003; Ahmad et al. 2013; Hulugalle et al. 2004). The increased cotton yield in straw incorporated/ retained plots might be due to improved nutrients in residues and soil, because, abundant micro-organisms are returning to the soil with residues (Unger et al. 1997; Ishaq et al. 2001; Nehra et al. 2005). In 2016, the micro-organisms might have consumed more nutrients such as K and C to meet their own growth requirement (Bordovsky et al. 1994; Díaz-Zorita et al. 2002; Blaise and Ravindran, 2003). The cotton plant produced less number of bolls and boll weight. In the 2nd year, the decomposed wheat straw released K nutrient to accelerate the process of initiation of yield and attributes resulting in seed cotton yield. Optimum K management conservation tillage plots with straw as such on soil surface/incorporated might have accelerated enzymatic activities in boll formation phase, which increased the translocation of photo assimilates to bolls and promoted the cotton (Kennedy and Hutchinson, 2001; Brar and Tiwari, 2004). Nehra et al (2005) observed that wheat straw has pa ositive influence on soil fertility, soil K dynamics, and recovery and cotton productivity. Furthermore, K stress in conventional tillage plus straw removed resulted in decreased yield through early termination reproductive growth (Brar and Brar 2008; Aladakatti et al; 2009; Kumar et al., 2011; Wang et al., 2014). Howard et al. (2000) suggested that highest lint yield was recorded from optimum K rates under zero tillage plus wheat straw on sthe oil surface as such. They concluded that crop residue is a significant factor for cotton productivity through their effects on soil physical, chemical and biological properties as well as moisture and soil aggregates stability. The results of the present study revealed that wheat residues retained/incorporated into the soil rather than burnt/removed had increased total soil potassium and cotton yield. Conservation tillage functions and balancing soil K nutrient are taken over by micro-organisms. Extensive tillage disturbs this process. Therefore, conservation tillage (zero or reduced) is an important tillage method that improved soil resources and cotton yield (Wiese et al 1994; Howard et al. 2000; Usman et al 2014). Wheat and cotton rotation is also beneficial to avoid diseases and insect-pest problems. In our present study, ZTsas and RTsi produced the highest total soil potassium besides encouraging better cotton yield. Optimum cotton productivity could be achieved from collective efforts of zero tillage with straw on the soil surface as such and reduced tillage plus wheat straw incorporated and potassium fertilizer application at rthe ate of 60-90 kg K ha^{-1}. This shows that straw retention/incorporation has guided to the increase in carbon and potassium contents in soil and microbe's activity is clear indication of soil heath (Howard et al. 2000; Ning et al. 2014). However, ZTsas and RTsi soils with no or limited potassium resulted in lower cotton yield. Because, nutrients released by residues or low K supply might have consumed by microbes for their own growth and the crop will face K deficiency that may result in lesser cotton yield. In the previous study, it was investigated that fibre characteristics were not influenced by tillage practices (Pettigrew and Jones 2001; Boquet et al. 2004; Blaise, 2006) supporting the findings of the present study. However, lower lint percentage and higher fibre strength were reported under zero tillage with wheat straw retention (Pettigrew and Jones 2001).

Potassium fertilizer management is integral for high yield cultivation of cotton. However, the effects of the combination of residue management under different tillage systems and K fertilization on cotton grown after wheat were less studied. In the present study, we tried to optimize K management under different tillage methods in order to improve cotton yield and quality in the wheat-cotton system.

Conclusion

The study included six tillage systems (ZTsas, ZTsr, RTsi, RTsr, CTsi, and CTsr) and three potassium rates (30, 60 and 90 kg K ha^{-1}. Results show that RTsi with 60 kg K ha^{-1} produced a number of boll count; weight per boll; seed cotton yield and ginning out-turn, fiber length and strength as compared to other treatments. Cotton yield was higher in straw retained/incorporated plots than plots with either straw removed. Moreover, ZTsas and RTsi had a positive influence on total soil K compared to other tillage systems. In summary, conservation tillage with 60 kg K ha^{-1} can improve cotton yield and fibre characteristics through conservation of resources.

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Table 1: Monthly seasonal precipitation, temperature and relative humidity (%) at Cotton Research Station, Dera Ismail Khan during 2016and 2017 growing seasons

Month	2016								2017							
	Temp (°C)			Relative humidity (%)				Rainfall (mm)	Temp (°C)			Relative humidity (%)				Rainfall (mm)
				800hrs		1400 hrs						800hrs		1400 hrs		
	Max	Min	Mean	Max	Min	Max	Min		Max	Min	Mean	Max	Min	Max	Min	
April	41	13	27	92	52	77	23	38	38	6	22	75	36	56	29	-
May	42	19	31	75	39	63	20	12	45	7	26	57	30	36	23	17
June	44	21	33	81	46	58	27	16.5	45	12	29	65	34	50	26	6.0
July	42	24	33	81	48	68	36	34	45	18	32	73	30	42	23	111
August	40	23	32					35	41	20	31	73	42	49	26	43
September	39	20	30	82	65	71	28	-	40	18	29	73	42	41	22	40.0

October	34	19	27				4	36	18	27	72	52	52	25	-
November	30	6	18	90	59	91	65	-	31	10	21	81	69	78	53	-
Total rainfall							139.5								217.0

Source: *Arid Zone Research Council (AZRC), D.I.Khan, Pakistan.*

Table 2 Analysis of variance (mean squares) of Bolls plant^{-1}, Weight per boll, Seed cotton yield (kg ha^{-1}), ginning out turn(%), fibre length (mm) and fiber strength ((g tex^{-1}) as affected by tillage plus crop residue management and K application rate during 2016 and 2017 growing seasons of cotton

Source	D.F	Bolls plant^{-1}	Weight per boll	Seed cotton yield	GOT	Fibre length	Fiber strength
Year (Y)	1	192.00**	0.60**	3448624**	4.02*	0.04 ^{Ns}	0.75**
Rep (y*)	2	1.82	0.02	32511	0.70	0.75	0.03
Tillage (T)	5	97.75**	0.29**	814203**	15.29*	0.12 ^{Ns}	10.64**
Potassium (K)	2	73.59**	1.53**	1897911**	2.99*	2.18**	42.74**
Y × T	5	2.46^{NS}	0.04**	104068**	1.13^{Ns}	0.02 ^{Ns}	5.66 ^{Ns}
Y × K	2	3.31^{NS}	0.00 ^{NS}	124646*	1.31^{Ns}	0.03 ^{Ns}	1.42 ^{Ns}
T × K	10	9.99**	0.01 ^{NS}	34808 ^{NS}	1.55*	0.15 ^{Ns}	0.80**
Y × T × K	10	7.15^{NS}	0.01 ^{NS}	42527 ^{NS}	0.41^{Ns}	0.03 ^{Ns}	9.37 ^{Ns}
Error	70	1.31	0.01	32283	0.75	0.22	0.03

Notes: NS, non significant; D.F., degree of freedom; Rep (y*) = represent replication over year.
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 3 Bolls plant^{-1}of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Bolls per plant						Year × potassium means
		Tillage plus straw management (T)[a]						
		ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	
2016	30	19.3	15.0	18.7	16.0	16.0	13.3	16.4
	60	21.7	17.3	23.3	18.3	18.3	13.7	18.8
	90	20.3	19.0	19.7	18.0	20.7	16.0	18.9
2017	30	22.0	17.7	21.3	18.7	18.7	16.0	19.1
	60	24.3	20.0	26.0	21.0	21.0	16.3	21.4
	90	23.0	21.7	22.3	20.7	23.3	18.7	21.6
								Potassium means
Mean (2 yr)	30	20.7 def	16.3 i	20.0 efg	17.3 i	17.3 i	14.7 J	17.7 b
	60	23.0 b	18.7 h	24.7 a	19.7 fgh	19.7 fgh	15.0 J	20.1 a
	90	21.7 cd	20.3 efg	21.0 cde	19.3 gh	22.0 bc	17.3 i	20.3 a
2016		20.4	17.1	20.6	17.4	18.3	14.3	18.0 b
2017		23.1	19.8	23.2	20.1	21.0	17.0	20.7 a
Tillage means		21.8 a	18.4 c	21.9 a	18.8 c	19.7 b	15.7 d	

Tillage (T) (average over years) = 0.7609, Potassium (K) (average over years) = 0.5381, Tillage × Potassium = 1.3180

Table 4 Weight per boll of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Weight per boll						Year × potassium means
		Tillage plus straw management (T)[a]						
		ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	
2016	30	2.23	2.24	2.40	2.24	2.21	2.26	2.26
	60	2.80	2.60	2.80	2.60	2.48	2.53	2.64
	90	2.37	2.27	2.50	2.32	2.24	2.30	2.33
2017	30	2.41	2.33	2.67	2.34	2.35	2.30	2.40
	60	2.90	2.67	3.13	2.67	2.83	2.62	2.80
	90	2.55	2.35	2.80	2.41	2.41	2.33	2.47
								Potassium means
Mean (2 yr)	30	2.32	2.29	2.53	2.29	2.28	2.28	2.33 c
	60	2.85	2.63	2.97	2.63	2.66	2.58	2.72 a
	90	2.46	2.31	2.65	2.37	2.33	2.31	2.40 b
2016		2.47 de	2.37 fg	2.57 bc	2.39 efg	2.31 g	2.36 fg	2.41 b
2017		2.62 b	2.45 def	2.87 a	2.47 cde	2.53 bcd	2.42 ef	2.56 a
Tillage means		2.54 b	2.41 c	2.72 a	2.43 c	2.42 c	2.39 c	

Tillage (mean of 2 years) = 0.0685, Potassium (mean of 2 years) =0.0484, Year × Tillage =0.0968

Table 5 Seed cotton yield of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Seed cotton yield (kg ha^{-1}) Tillage plus straw management (T) ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	Year × potassium means
2016	30	1419	1311.7	1804.7	1382	1522.7	1330	1462 e
	60	1926	1626.7	2118	1740	1704	1693	1801 bc
	90	1556.3	1408	1918	1531	1663.7	1482	1593 d
2017	30	1808	1660	2048	1597	1813	1419	1724 c
	60	2530	2004	2844	1937	2620	1808	2290 a
	90	2000	1900	2118	1774	2019	1670.7	1914 b
								Potassium means
Mean (2 yr)	30	1614	1486	1927	1490	1668	1375	1593 c
	60	2228	1815.3	2481	1838.3	2162	1750	2046 a
	90	1778	1654	2018	1653	1841.5	1576	1754 b
2016		1634 fg	1449 h	1947 cd	1551 gh	1630 fg	1502 gh	1619 b
2017		2113 bc	1855 de	2337 a	1769 ef	2151 b	1632 fg	1976 a
Tillage means		1873 b	1652 c	2142 a	1660 c	1890 b	1567 c	

Notes: LSD0.05 for tillage (T) (mean of 2 years) Tillage=119.45, Potassium (mean of 2 years)= 84.464, Year × Tillage= 168.93, Year × Potassium= 119.45

Table 6 Ginning out turn of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Ginning out turn (%) Tillage plus straw management (T)[a] ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	Year × potassium means
2016	30	37.40	37.30	38.80	36.76	37.67	36.70	37.44
	60	38.72	37.83	39.20	37.53	37.79	37.22	38.05
	90	39.63	37.80	39.15	38.39	37.79	37.53	38.38
2017	30	38.10	38.10	39.60	37.500	39.263	36.87	38.24
	60	39.80	37.17	40.23	37.67	38.113	37.19	38.36
	90	39.63	36.70	40.57	38.33	37.89	37.46	38.43
								Potassium means
Mean (2 yr)	30	37.75cde	37.70 cde	39.20 ab	37.13 de	38.47 bc	36.78 e	37.84 b
	60	39.26 ab	37.50 cde	39.72 a	37.60 cde	37.95 cd	37.21 de	38.21 a
	90	39.63 a	37.25 de	39.86 a	38.36 bc	37.84 cd	37.50 cde	38.41 a
2016		38.59	37.64	39.05	37.56	37.75	37.15	38.34 a
2017		39.18	37.32	40.13	37.83	38.42	37.17	37.96 b
Tillage means		38.88 b	37.48 d	39.59 a	37.70 cd	38.09 c	37.16 d	

Tillage (mean of 2 years) =0.5761, Potassium (mean of 2 years) = 0.4074, Tillage × Potassium=0.9979

Table 7 Fibre length of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Fibre length (mm) Tillage plus straw management (T)[a] ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	Year × potassium means
2016	30	28.43	28.33	28.27	28.27	28.17	27.97	28.24
	60	28.87	28.40	28.73	28.37	28.63	28.30	28.55
	90	28.57	28.57	28.40	28.73	28.83	28.83	28.66
2017	30	28.13	28.13	28.20	28.13	28.17	28.07	28.14
	60	28.77	28.33	28.77	28.33	28.63	28.30	28.52
	90	28.57	28.77	28.63	28.63	28.80	28.63	28.67
								Potassium means
Mean (2 yr)	30	28.28	28.23	28.23	28.20	28.17	28.02	28.19 b
	60	28.82	28.37	28.75	28.35	28.63	28.30	28.54 a
	90	28.57	28.67	28.52	28.68	28.82	28.73	28.66 a
2016		28.62	28.43	28.47	28.46	28.54	28.37	28.48
2017		28.49	28.41	28.53	28.37	28.53	28.33	28.44
Tillage means		28.56	28.42	28.50	28.41	28.54	28.35	

Potassium (mean of 2 years) =0.2211

Table 8 Fibre Strength of cotton as affected by tillage plus crop residue management and K rate during two growing seasons (2016 and 2017)

Year	K (kg ha^{-1})	Fibre Strength (g/tex) Tillage plus straw management (T)[a]						Year × potassium means
		ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	
2016	30	28.50	27.50	28.50	27.10	27.60	27.10	27.72
	60	29.40	28.40	30.60	28.23	29.50	28.30	29.07
	90	30.50	29.40	30.70	29.50	30.60	28.53	29.87
2017	30	28.67	27.67	28.67	27.267	27.77	27.267	27.88
	60	29.57	28.57	30.77	28.40	29.67	28.47	29.24
	90	30.67	29.57	30.87	29.67	30.77	28.70	30.04
								Potassium means
Mean (2 yr)	30	28.58 cd	27.58 f	28.58 cd	27.18 g	27.68 f	27.18 g	27.80 c
	60	29.48 b	28.48 cde	30.68 a	28.32 e	29.58 b	28.38 de	29.16 b
	90	30.58 a	29.48 b	30.78 a	29.58 b	30.68 a	28.62 c	29.96 a
2016		29.47	28.43	29.93	28.28	29.23	27.98	28.89 b
2017		29.63	28.60	30.10	28.44	29.40	28.14	29.05 a
Tillage means		29.55 b	28.52 d	30.02 a	28.36 e	29.32 c	28.06 f	

Tillage (mean of 2 years) =0.1163, Potassium (mean of 2 years) =0.0823, Tillage × Potassium=0.2015

Table 9 Total soil potassium (mg kg^{-1}) at the end of 2 yr of experimentation as affected by different tillage plus crop residue management and K rate

K (kg ha^{-1})	Total soil potassium (mg kg^{-1} soil) Tillage plus straw management						Potassium means
	ZTsas	ZTsr	RTsi	RTsr	CTsi	CTsr	
30	187.00	175.00	187.00	177.33	181.33	174.00	180.28 c
60	192.00	178.00	192.00	180.00	187.33	179.00	184.72 b
90	193.67	180.00	196.00	182.00	191.00	180.33	187.17 a
Tillage means	190.89 a	177.67 c	191.67 a	179.78 c	186.56 b	177.78 c	

Tillage = 2.1152, Potassium=1.7565