Research Article

Response of Upland Cotton (*Gossypium hirsutum* L.) to Tillage and Nitrogen in Wheat Based Cropping System

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Abstract | Ridge tillage system is one approach to ensure better plant population, save irrigation water, cut cultivation costs and increases cotton yield and quality on sustainable basis. Field trial was conducted in 2013 and 2014 at Cotton Research Station, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan to study the effect of tillage systems [ridge tillage (RT) and flat tillage (FT)] and 5 nitrogen levels (0, 50, 100, 150, 200 kgN. ha-1) on cotton lint yields, quality and earliness. Experiment was laid out in a RCB design with split plot arrangements replicated thrice. Tillage methods were allotted to main plots while nitrogen levels were kept in sub plots. Results showed that RT produced higher bolls per plant, weight per bolls, lint yields, earliness % and benefit cost ratio (BCR) than FT. Ridge tillage gave lower percent of lodging. Results for nitrogen indicated that bolls numbers per plant, bolls weight, lint yield, earliness, lodging, BCR, fibre length and fineness were highest at 150-200 kg N/hectare. The fibre characteristics Indicated that RT had no unfavorable influence on fiber length and fineness compared to FT. In conclusion, RT is a resourceful alternative tillage method for rising earliness %, cotton yield and fiber characteristics in D.I. Khan, Pakistan environments.

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Introduction

Cotton contributes a major role in the economy of Pakistan as it provides raw materials to the textile industry, secures food for a growing population, and ensures foreign exchange earnings (APTMA, 2016). Among fibers, cotton fibers (used for clothing and finishing) have 56% market share in the world (Javed et al., 2009). The role of producing cotton is likely to grow significantly in future because our country has a big potential to lead the worldwide cotton and textile market (MINTEX, 2015). In Pakistan, cotton is sown on area of about 3.11 million hectares with the total production of14.04 million bales (PCCC, 2016). The area under cotton in the country needs to be further expanded to boost up the economy through export commodities. In Pakistan, flat tillage (dibbling on flat surface of soil) is used in cotton belt resulted in poor cotton-seed germination and decreased cotton yield (Hussain et al., 2003). After planting and before emergence of cotton seedlings in FT, a light shower of rain results in crust formation which restricts the emergence of seedlings and causes poor plant population. Ridge tillage system, sowing of cotton on raised beds or ridges ensured adequate plant population due to better seed germination and emergence of seedlings even during unusual rains (Anwar et al., 2003; Krause et al., 2009). Ridge tillage system guarantees better plant population, saves 32% irrigation water as compared to flat tillage. It also saves the cotton from lodging occurred by heavy rains (Mert et al., 2006). RT afforded labor saving, improved soil fertility, enhanced water management, increased water use efficiency, controlled erosion, enrich rooting depth and better pest management (Lal, 1990). Well developed root system due to greater soil volume by ridge tillage has been renowned as an important adaptation of plants to ensure sufficient water and nutrient uptake (Horst et al., 2001). Blaise and Ravindran (2003) reported higher cotton yields in ridge tillage than flat tillage (FT). RT planting system gave higher lint yield and fibre quality than flat tillage system (Ali et al., 2010). The highest lint yield was obtained in ridge tillage (Anon, 2006). Cotton sown with ridge tillage produced sustainable production and better water economy (Iftikhar et al., 2010). Wheeler et al. (1997) reported that RT produced equal lint yield as compared to FT. Researchers investigated that N is the most significant fertilizer for cotton crop. Both vegetative and reproductive growth can be reduced due to deficiency of N in cotton which may induce square shedding resultting in yield loss (Girma et al., 2010). Cultivation of cotton under flat tillage using high inputs of N fertilizer is a common practice in northwestern Pakistan. N management in FT is highly inefficient, not productive and un-economical besides environmental hazards (Boquet et al., 2004). Therefore, alternative tillage methods and proper N management practices are important to ensure long-term viability of cotton production in the region. Ridge tillage is a appropriate alternative to maintain soil quality, conserve soil moisture, save 25–30% of irrigation water, improve nutrient availability through placement of fertilizer, reduced soil salinity, reduced production costs and obtain similar or higher yields compared with FT (Usman et al., 2013).The aim of the present study was to test the hypothesis for optimum N rates under ridge tillage that induce earliness and produce high cotton yield and quality. More specifically the aim research explores the influence of tillage and N rates on cotton yield, fiber quality and earliness in wheat–cotton system of Dera Ismail Khan Pakistan.

Materials and Methods

Experimental site

The soil of the study area is slightly saline, fewer fertile and requirements irrigations for crop production (Soil Survey Staff 2009). The area is situated in arid region where canal water is used for irrigation. It is hot and dry in summer with moderate rain during monsoon season; March, July, and August (Table 1).

Treatments and crop management

Field trials were carried out during 2013 and 2014 at Cotton Research Station, D.I. Khan, Pakistan. The experimental site was situated at 31°49'N, 70°55'E, 165 m elevation from sea level. It is characterized by low rainfall less than 200 mm per year, hot and dry summer. The design of the experiment was Randomized Complete Block with split-plot having three replications. Ridge tillage (RT) and flat tillage (FT) were kept in main treatments, while 5 nitrogen rates (0, 50, 100, 150 and 200 kg N ha^{-1}) were applied to sub treatment. Net plot size was 10 m × 3 m. After the harvest of wheat, the field was irrigated. When field came in proper moisture condition, previous wheat straw was incorporated into the soil with plowing operations including tiller, disc plow and rotavator. After well prepared seed bed, cotton was sown with dibbling method on flat land (flat tillage, FT). In ridge tillage (RT) soil was prepared with disc plow followed by tiller and rotavator, and ridges were made with help of Ridger, 75cm apart from each other. The height of each ridge was 12cm.Cotton cv. CIM-616 (standard Bt. cotton variety) was sown with dibbling method on May 15, 2013 and May 18, 2014, respectively. 2-3 seeds were dibbled manually at 75 cm row to row and 30 cm plant to plant distances. Thinning was done after 20 days (weak and disease affected plants were pulled out). All experimental plots received 150 kg N ha^{-1} as urea and 60 kg P ha^{-1} as triple super phosphate. All the phosphorous was applied at sowing, while N was applied in three split doses, 50 kg at sowing, 50 kg at 1st irrigation, and 50 kg at 3rd irrigation during both the years. In both the years, cotton was grown under irrigated conditions with other inputs applied uniformly. Six irrigations were applied at about 14 days' intervals from the beginning of square stage to boll maturity during the growing season each year. Weeds were controlled with herbicide application [Coast 10.8 EC (a.i. Haloxyfop-R-Methyl 108 g l^{-1}, dosage 1 L ha^{-1}, manufacturer, Four Brothers AgriServices, Pakistan)] + [Conquest 24 EC (a.i. Lactofen 168 g l^{-1}, dosage 450 ml $acre^{-1}$, manufacturer, Kanzo Chemicals, Pakistan)].Seed cotton was picked in the 2nd week of November. All cultural and protection practices were equally adopted. The detail of physic-chemical properties of the experimental site is given in Table 1. Weather data was monitored on Meteorological Station located near the study site. Detailed data about temperature and rainfall is in Table 2.

Table 1: *Physico-chemical properties of the experimental soil.*

Characteristics	Values
Sand	151 g kg^{-1}
Silt	450 g kg^{-1}
Clay	400 g kg^{-1}
Electrical conductivity (EC)	2.66 dSm^{-1}
Soil pH (1:1)	7.80
Organic Matter	0.89 %
NO_3-N	5.52 mg kg^{-1}
Available K (mg kg^{-1})	180 mg kg^{-1} soil
AB-DTPA extractable P	7.8 mg kg^{-1} soil
Total N	0.99 g kg^{-1} soil

Measurement of crop parameters

Data on bolls number per plant, weight per boll (g), lint yield, lodging (%), earliness, fiber length (mm), micronaire value (µg inch-1) and BCR were recorded using standard procedures. For bolls, five plants were tagged randomly from each plot and mature (opened) bolls per plant were counted. Fifty mature bolls were picked from each treatment, sun dried, weighed and then calculated on per boll basis. Lint yield was recorded in kg ha-1 for each treatment. For fiber quality a sample of 100 gram seed cotton was ginned to separate the lint from the seed. The lint samples were sent to CCRI, Multan, for fibre length (mm) and micronaire tests. BCR = total income/total expenditure *100 (Xian et al., 2014).Lodging % = lodged plants/ total plants×100. Earliness in percentt was calculated as first pick yield/ total seed yield (Bourland et al., 2001).

Statistical analysis

Data of the two years was analyzed statistically (Steel and Torrie, 1997) used MSTATC- software. LSD test was used for difference in means. Regression analyses were also done.

Results and Discussion

Bolls plant^{-1}

Number of bolls per plant had significant response to tillage (T), nitrogen (N), however, interaction effects were not significant (Table 3). Mean values for tillage revealed that ridge tillage (RT) produced higher number of bolls $plan^{-1}$ than flat tillage (FT) during the study years (Table 4). Mean values for N rates revealed that the application of N fertilizer at a rate of 200 kg ha^{-1} produced the highest number of bolls plant compared to control. RT showed higher bolls plant than flat tillage system probably due to more favorable soil micro-climate with regard to soil moisture conservation, nutrients supply and light transmission.

Table 2: *Average air temperature and rainfall at Cotton Research Station, Dera Ismail Khan during 2013and 2014 growing seasons.*

Months	2013				2014			
	Temperature ^{0}C				Temperature ^{0}C			
	Minimum	Maximum	Mean	Rainfall (mm)	Minimum	Maximum	Mean	Rainfall (mm)
January	2	19	11	-	4	11	7.5	-
February	4	19	12	4.5	8	20	14	100.5
March	11	27	19	1.0	10	27	18.5	2
April	18	32	25	40.5	19	32	25.5	29
May	23	38	31	2.5	22	39	30.5	3.5
June	26	40	33	3.0	26	41	33.5	80
July	27	37	32	49	29	40	34.5	22
August	26	35	31	36	27	37	32	-
September	23	33	28	75	25	37	31	16
October	16	32	24	-	21	33	27	5.5
November	11	27	19	-	10	26	18	6
December	6	22	14	13.5	6	22	14	1
Total				225				265.5

Table 3: *Analysis of variance (mean squares) of bolls plant^{-1}, boll weight, lint yield, fiber length, micronaire, BCRand earliness % as affected by tillage and nitrogen during two growing seasons.*

Source	D.F	Bolls plant^{-1}	Boll weight	Lint yield (kg ha^{-1})	Fiber length	Micronaire	Earliness %	Lodging %	BCR
Year (2013)									
Replication	2	1.3000	0.00484	858	0.06533	0.01633	1.430	3.276	0.04633
Tillage (T)	1	61.6*	0.1*	52836*	0.0^{ns}	0.01^{ns}	30.442*	594.97**	3.67500*
Nitrogen (N)	4	89.1**	0.1*	294168**	0.0**	1.41**	208.281**	117.87**	1.90950**
T×N	4	1.6^{ns}	0.0^{ns}	233^{ns}	0.0^{ns}	0.14^{ns}	6.722**	2.117^{ns}	0.14750^{ns}
Error	16	1.1417	0.00390	854	0.01542	0.01433	0.891	0.759	0.05500
Year (2014)									
Replication	2	0.1000	0.00688	2842	0.13300	0.01900	0.435	0.104	0.2230
T	1	93.6*	0.1^{ns}	94304*	0.0^{ns}	0.048ns	117.77*	777.65**	10.6803**
N	4	98.8**	0.16**	303931**	0.0*	0.57967*	266.36**	143.69**	2.3612**
T×N	4	0.6^{ns}	0.0^{ns}	1007^{ns}	0.0^{ns}	0.01133^{ns}	0.324^{ns}	3.47^{ns}	0.0445^{ns}
Error	8	0.4083	0.00253	1248	0.02192	0.00683	0.559	1.57	0.0461
Year (2yr)									
Replication	2	0.3000	0.00579	1631	0.09608	0.01733	0.156	0.582	0.11808
T	1	76.8**	0.1*	72423*	0.0^{ns}	0.003^{ns}	67.04*	683.26**	6.72133**
N	4	93.6**	0.1**	298744**	0.0**	0.56758**	236.02**	130.23**	2.11117**
T×N	4	0.7^{ns}	0.0^{ns}	90^{ns}	0.0^{ns}	0.01008^{ns}	1.633**	2.506*	0.06342^{ns}
Error	16	0.5167	0.00232	822	0.01358	0.01383	0.475	0.623	0.03648

*, **: *significant at 5% and 1% level of probability, respectively;* ^{ns}: *no significant difference at P<5%.*

Table 4: *Bolls of cotton as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage		Mean
		Ridge	Flat	
		Bolls plant^{-1}		
Y1 (2013)	0	21.0	17.0	19.0 d
	50	25.0	21.3	23.2 c
	100	25.7	24.0	24.8 b
	150	27.0	25.0	26.0 b
	200	31.0	28.0	29.5 a
	Mean	25.93 a	23.07 b	
	LSD$_{0.05}$ for T= 0.7589, N =1.3078.			
Y2 (2014)	0	23.0	19.0	21.0 e
	50	26.3	22.3	24. d
	100	29.0	25.0	27.0 c
	150	30.0	27.0	28.5 b
	200	33.0	30.3	31.7 a
	Mean	28.27 a	24.73 b	
	LSD$_{0.05}$ for T= 3.5248, N =0.9948			
Mean (2 yr)	0	22.0	18.0	20.0 e
	50	25.7	21.8	23.8 d
	100	27.3	24.5	26.0 c
	150	28.5	26.0	27.3 b
	200	32.0	29.2	30.6 a
	Mean	27.1a	23.9 b	
	LSD$_{0.05}$ for T= 1.4905 =0.8798.			

Note: *Any two means not sharing a letter in a common differ significantly at P ≤ 0.05.*

The optimum utilization of resources by crop plants might have caused higher bolls plant in RT compared to FT(Daniel et al., 1999; Triplett et al., 2006). Regression results shwoed that there was a quadratic trend in bolls plant^{-1} in response to increasing N rate ($y = -4E\text{-}05x^2 + 0.0555x + 20.6$, $R^2 = 0.9769$). The results are in line with Wiatrak et al. (2005) who reported greater bolls per plant with higher N rates.

Weight boll^{-1} (g)

Weight boll^{-1}(g) was significantly affected by tillage, nitrogen, while tillage× N interactions were not significant (Table 3). Nitrogen increased boll weight with each incremental dose and reached a maximum at 200 kg. N. ha^{-1}. Main effect of tillage indicated that RT had heavier boll weight than FT (Table 5). The better performance of RT at 150 kg N per hectare may be attributed toward better establishment of crop stand in comparatively favorable soil environment and more allocation of resources to boll formation compared to FT (McAlavy, 2004). Boquet et al. (2004) reported heavier boll weight at higher N rates. Regression analysis revealed that there was a quadratic decline in boll weight with the increase in N rate ($y = -4E\text{-}06x^2 + 0.0025x + 2.924$, $R^2 = 0.9627$).

Table 5: *Boll weight as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage (T)		Mean
		Ridge	Flat	
		Boll weight (g)		
Y1 (2013)	0	2.9	2.9	2.9 d
	50	3.1	3.0	3.0 c
	100	3.2	3.1	3.1 b
	150	3.3	3.1	3.2 ab
	200	3.3	3.1	3.3 a
	Mean	3.16 a	3.04 b	
	$LSD_{0.05}$ for T= 0.1143, N =0.0765.			
Y2 (2014)	0	2.9	2.9	2.9 c
	50	3.1	3.1	3.1 b
	100	3.3	3.2	3.2 a
	150	3.1	3.1	3.2 a
	200	3.3	3.2	3.2 a
	Mean	3.1 a	3.1 a	
	$LSD_{0.05}$ for T= 0.1214, N = 0.0596			
Mean (2 yr)	0	2.94	2.88	2.90 d
	50	3.06	3.01	3.0 d
	100	3.23	3.10	3.16 b
	150	3.28	3.11	3.19 ab
	200	3.31	3.17	3.24 a
	Mean	3.1a	3.2b	
	$LSD_{0.05}$ for T= 0.0952, N= 0.0590.			

Note: *Means followed by same letter or no letter do not differ significantly at 5% level of probability.*

Lint yield kg per hectare

Tillage and nitrogen significantly influenced lint yield, while interaction effects were not significant (Table 3). Tillage means revealed that RT gave higher lint yield as compared to FT during both the study years (Table 6). Mean values for N averaged over tillage revealed that graded doses of N enhanced the cotton lint yield compared to the control with the highest yield recorded at 200 kg N ha^{-1}. The higher cotton lint yield at greater N dosewasdue to higher number of bolls plant and higher boll weight (Hulugalle et al., 2004). The results are in line with Ali et al. (2012) who observed that cotton yield would be higher if cotton bolls are higher. Other researchers also reported higher lint yield with higher N rate (Zhang et al., 2012). Lint yield responded positively to the different N rates and had quadratic response to N rates ($y = -0.0037x^2 + 3.4133x + 733.84$, $R^2 = 0.9932$).

Fiber length (mm)

Fibre length had positive response to N rates, while tillage and their interaction effects was not significant (Table 3). RT gavelonger fiber length than FT (Table 7). Our results are analogous with the findings of Hulugalle et al. (2004) who observed no differences in fiber length by tillage systems. Nitrogen means revealed that fiber length increased with increase in N rate and thus highest fiber length could be achieved from highest N level (100-200 kg N ha^{-1}). Fiber length is largely determined by genotype such as cultivars with the highest length and strength break points in lint and more cross linkages between fibers (Hake et al., 1996; Jordan, 2001; Wiese et al. 2005), however, some environmental factors such as temperature can also effect fibre length. Reed (2004) reportedthat N levels substantially impacted fiber length compared to control. Girma et al. (2007) reported that fiber length was higher at higher N level. Regression analysis revealed that fibre length had quadratic response to N rates ($y = -3E\text{-}06x^2 + 0.001x + 25.064R^2 = 0.9349$).

Table 6: *Lint yield as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage (T)		Mean
		Ridge	Flat	
		Lint yield (kg ha^{-1})		
Y1 (2013)	0	729.0	639.3	684.2 e
	50	917.3	839.0	878.2 d
	100	1076.3	984.0	1030.2 c
	150	1181.7	1087.0	1134.3 b
	200	1282.7	1218.0	1250.3 a
	Mean	1037.4 a	953.5 b	
	$LSD_{0.05}$ for T= 58.316, N = 35.762.			
Y2 (2014)	0	767.3	674.3	720.8 e
	50	958.3	853.33	905.8 d
	100	1125.0	1020.3	1072.7 c
	150	1214.0	113.7	1163.8 b
	200	1377.0	1219.3	1298.2 a
	Mean	1088.3 a	976.2 b	
	$LSD_{0.05}$ for T= 66.260, N = 43.234			
Mean (2 yr)	0	748.7	656.7	702.7 e
	50	9338.0	846.0	892.0 d
	100	1100.7	1002.0	1051.3 c
	150	1198.0	1100.3	1149.2 b
	200	1329.7	1218.7	1274.2 a
	Mean	1063.0 a	964.7 b	
	$LSD_{0.05}$ for T= 62.287, N=35.101.			

Note: *Means followed by same letter or no letter do not differ significantly at 5% level of probability.*

Table 7: *Fiber length as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage (T)		Mean
		Ridge	Flat	
		Fiber length (mm)		
Y1 (2013)	0	25.03	25.03	25.03 c
	50	25.11	25.10	25.11 b
	100	25.13	25.12	25.12 ab
	150	25.15	25.13	25.14 a
	200	25.16	25.14	25.15 a
	Mean	25.12	25.11	
	$LSD_{0.05}$ for T= 0.0160, N = 0.0292.			
Y2 (2014)	0	25.07	25.03	25.05 b
	50	25.12	25.11	25.12 b
	100	25.14	25.14	25.14 ab
	150	25.16	25.15	25.16 ab
	200	25.17	25.49	25.33 a
	Mean	25.19	25.13	
	$LSD_{0.05}$ for T= 0.2535, N = 0.2309			
Mean (2 yr)	0	25.05	25.03	25.04 d
	50	25.12	25.11	25.11 c
	100	25.14	25.13	25.14 bc
	150	25.16	25.15	25.15 ab
	200	25.17	25.15	25.16 a
	Mean	25.13	25.12	
	$LSD_{0.05}$ for T= 0.0207, N= 0.0221.			

Note: *Means followed by same letter or no letter do not differ significantly at 5% level of probability.*

Mincronaire

Micronaire was significantly influenced by nitrogen rates, however, tillage and tillage × nitrogen interactions were not significant (Table 3). Nitrogen showed that the micronaire values increased with the increase in N rate indicating that the fiber fineness declined with each incremental dose of N (Bauer and Roof 2004). Nitrogen rate at 200 kg ha^{-1} resulted in significantly coarser fibers (higher micronaire value) than the other treatments (Table 8). Our results are in line with the findings of Zhang et al. (2012) who reported higher micronaire value at higher N rate. Micronaire had quadratic response to nitrogen ($y = -3E\text{-}05x^2 + 0.0099x + 4.684$, $R^2 = 0.8422$).

Earliness of harvesting (percent first-pick)

Earliness of harvesting was significantly affected by tillage, nitrogen, and tillage × nitrogen interactions were significant (Table 3). Results revealed that RT enhanced earliness than FT (Table 9). N means revealed that earliness of harvesting in percent increased with increasing N rates and produced maximum under 150 kg·N·ha^{-1} compared to control. Interaction indicated that RT at 150-200 kg N ha^{-1} produced maximum earliness in percent. RT enhanced earliness by improving soil water and temperature in the root zone, leading to earlier boll set. Earliness (%) induced by CT (Blaise and Ravindran, 2003). Earliness of harvesting showed quadratic response to increasing N rates($y = -0.000x2 + 0.173x + 59.48$, $R^2 = 0.966$).

Table 8: *Micronaire as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage (T)		Mean
		Ridge	Flat	
		Micronaire		
Y1 (2013)	0	4.8	4.1	4.73 c
	50	5.2	4.3	5.27 b
	100	5.3	4.4	5.28 b
	150	5.5	4.6	5.45 a
	200	5.6	4.6	5.50 a
	Mean	5.27	5.27	
	$LSD_{0.05}$ for N = 0.1465			
Y2 (2014)		4.4	4.0	4.72 c
		4.6	4.3	5.25 b
		4.8	4.4	5.28 ab
		4.8	4.7	5.47 a
		4.8	4.7	5.48 a
		4.28	4.20	
	$LSD_{0.05}$ for N = 0.2133			
Mean (2 yr)		4.73	4.72	4.37 c
		5.20	5.37	5.26 b
		5.27	5.25	5.28 b
		5.50	5.48	5.46 a
		5.47	5.45	5.49 a
		5.25	5.25	
	$LSD_{0.05}$ for T= 0.1721, N= 0.1440.			

Note: *Means followed by same letter or no letter do not differ significantly at 5% level of probability.*

Lodging (%)

Lodging was significantly affected by T, N and T × N interactions (Table 3). RT had lower lodging in percent during the study years (Table 10). Mean values for N averaged over tillage revealed that graded levels of N increased lodging compared to the control with the highest yield recorded at 200 kg N/hec. The higher lodging at higher N rate might be due to higher vegetative growth (Kennedy and Hutchinson, 2001). The results are in line with Mert et al. (2006). Communicated analogous results who reported that lower lodging occurred under ridge tillage compared FT. Other researchers also reported lower lodging with lower N rate (Zhang et al., 2012). Lodging responded positively to the different N rates and had linear response to N rates ($y = 3.4133x + 733.84$, $R^2 = 0.9932$).

Table 9: *Earliness as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage (T)		Mean
		RT	CT	
		Earliness %		
Y1 (2013)	0	57.94 g	58.72 g	58.33 e
	50	69.55 df	64.63 f	67.09 d
	100	71.37 bc	68.56 e	69.97 c
	150	72.69 ab	70.56 cd	71.63 b
	200	73.74 a	72.75 ab	73.25 a
	Mean	69.06 a	67.04 b	68.05
	LSD0.05 for T=1.6462, N= 1.1550 T× N=1.6335			
Y2 (2014)	0	41.27	41.67	59.09 e
	50	42.40	42.50	70.13 d
	100	42.55	42.51	72.65 c
	150	42.57	42.54	74.39 b
	200	42.58	42.55	75.77 a
	Mean	72.39 a	68.43 b	70.41
	$LSD_{0.05}$ for T= 1.7479, 1.0974			
Mean (2 yr)	0	59.40 h	58.03 h	58.71 e
	50	70.72 ef	66.50 g	68.61 d
	100	73.02 cd	69.60 f	71.31 c
	150	74.57 b	71.45 de	73.01 b
	200	75.91 a	73.09 bc	74.50 a
	Mean	70.72 a	67.73 b	69.23
	$LSD_{0.05}$ for T= 1.6259, N= 0.8432 T× N= 1.1925			

Note: *Means followed by same letter or no letter do not differ significantly at 5% level of probability.*

Benefit cost ratio

BCR is an important economic parameter. BCR was significantly influenced by tillage, nitrogen and their interactions were not significant (Table 3). Mean values for tillage revealed that RT had higher BCR than FT (Table 11). THighest BCR was recorded at 150-200 kg·N·ha–1. Higher BCR in RT at highest nitrogen dose was due to lower cost of cultivation, and better consumption of soil resources. Highest benefit cost ratio in ridge tillage than flat tillage was reported by Sharma et al. (2011) who investigated higher BCR at higher N rate under RT. BCR had quadratic response to increasing N rates ($y = -2E\text{-}05x^2 + 0.0104x + 2.124$, $R^2 = 0.9861$).

Table 10: *Lodging of cotton as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage		Mean
		Ridge	Flat	
		Lodging %		
Y1 (2013)	0	11.567	20.733	16.15e
	50	16.600	24.300	20.45 d
	100	18.067	26.167	22.12 c
	150	20.300	29.100	24.70 b
	200	22.533	33.300	27.92 a
	Mean	17.81 b	26.72 a	
	$LSD_{0.05}$ for T= 02.7895, N= 1.0659			
Y2 (2014)	0	12.863	22.030	17.45 e
	50	16.600	25.597	21.10 d
	100	18.547	28.813	23.68 c
	150	21.597	31.330	26.46 b
	200	23.830	36.580	30.21 a
	Mean	18.69 b	28.87 a	
	$LSD_{0.05}$ for T= 1.4947, N= 1.5329			
Mean (2 yr)	0	12.22 i	21.38 ef	16.80 e
	50	16.60 h	24.95 d	20.77 d
	100	18.31 g	27.49 c	22.90 c
	150	20.94 f	30.22 b	25.58 b
	200	23.18 de	34.94 a	29.06 a
	Mean	18.25 b	27.80 a	
	$LSD_{0.05}$ for T= 1.5454, N= 0.9663, T×N=1.3665			

Note: *Any two means not sharing a letter in a common differ significantly at P ≤ 0.05.*

Conclusions

Ridge tillage gave maximum lint yield and earliness with suitable fiber quality. These results showed that RT is a proficient alternative tillage method for rising lint yield, earliness (%) with suitable fiber characteristics in D.I. Khan. Lower lodging occurred under RT. N also significantly influenced lint yields, earliness, lodging and fibre characteristics. Therefore, ridge system with 150–200 kg N ha–1 is recommended for the arid region of Dera Ismail Khan, Pakistan.

Table 11: *BCR of cotton as affected by tillage and nitrogen levels during two growing seasons.*

Year	N (kg ha^{-1})	Tillage		Mean
		Ridge	Flat	
		Benefit cost ratio		
Y1 (2013)	0	1.97	1.75	1.82 c
	50	2.83	2.23	2.53 b
	100	3.16	2.50	2.78 b
	150	3.60	2.63	3.12 a
	200	3.85	2.70	3.23 a
	Mean	3.12 a	2.35 b	2.74
	$LSD_{0.05}$ for T= 0.4067, N= 0.2870.			
Y2 (2014)	0	2.85	1.50	2.13 d
	50	3.25	2.70	2.68 c
	100	3.85	2.63	3.20 b
	150	4.00	2.83	3.42 b
	200	4.43	3.00	3.72 a
	Mean	3.63 a	2.43 b	3.03
	$LSD_{0.05}$ for T= 0.4059, N= 0.2627.			
Mean (2 yr)	0	2.42	1.58	1.98 d
	50	3.00	2.22	2.61 c
	100	3.42	2.57	2.99 b
	150	3.80	2.73	3.31 a
	200	4.10	2.85	3.53 a
	Mean	3.34 a	2.40 b	2.87
	$LSD_{0.05}$ for T= 0.0633, N= 0.2338.			

Note: *Any two means not sharing a letter in a common differ significantly at $P \leq 0.05$.*

Author's Contribution

NUK designed, conducted research, measured observation and prepared draft. AAK helped in structuring the manuscript with editing. SU and NU helped in preparation of methodology, data collection. IU and AR helped in statistical analysis.

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