Research Article

Cotton Yield and Lint Response to Tillage System and Irrigation Interval under Wheat Based Cropping System

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Abstract | Water shortage is becoming a serious concern for all crops and particularly for cotton, which has been a major export contributor of Pakistan. In this scenario, reduced tillage could be the best option. A field experiment was conducted during 2019 to study the impact of two tillage systems [reduced (10 cm depth, one tiller followed by rotavator) and conventional (20 cm depth, including disc plough, cultivator, rotavator, and levelling operations)] and five irrigation intervals (10, 15, 20, 25 and 30 days) on cotton yield and lint percentage. Total irrigation water used in irrigation treatments, 10, 15, 20, 25 and 30 days intervals were 1125, 750, 560, 450 and 360 mm, respectively. Results indicated that reduced tillage had higher plant population (32454), plant height (114.8cm), bolls per plant[s] (18.9), bolls weight (2.42g), seed cotton yield (1812 kg ha^{-1}) and lint percentage (36.72%) than conventional tillage. Likewise, frequent irrigation interval of 10 days produced taller plants compared to less frequent irrigations (20-25 days). Irrigation at 20 days interval improved seed cotton yield (48.7%) and lint %age (21.1%). Interaction effects (tillage x irrigation) revealed that reduced tillage with 20 days irrigation interval conserved 60 % more water, produced 60.4% more bolls per plant, 45.8 % heavier boll weight, 21.1% higher lint %age and 41.6% higher seed cotton yield compared to all other combinations. In conclusion, reduced tillage with 20 days irrigation interval is more advantageous and adaptable in agro-ecological conditions of Dera Ismail Khan.

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Introduction

Cotton (*Gossypium hirsutum* L.) is an important cash crop of Pakistan (Ashraf *et al*., 2018). It supplies raw materials to textile industries and is called silver-fiber due to its unique quality. Cotton is used in garments, medicines and furnishings of homes. Pakistan is the 5th biggest cotton producers after India, China, United States, and Brazil (Statista, 2018). However, Pakistan is not producing sufficient raw materials for national textile mills. Accordingly, Pakistan is the first among leading cotton importing countries of the world such as Bangladesh, Turkey, Vietnam, China, and Indonesia (APTMA, 2018). In Pakistan cotton cultivated area has reached to 3 million hectares; share in GDP to 1.5% and value added to agriculture 7.0% (MNFSR, 2015). The present area under cotton cultivation with low production per unit area cannot meet even the domestic requirement of the growing population. Since extension of the existing area under cotton may not be possible as already occupied by major crops such as wheat, rice, maize,

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and sugarcane, the possible alternative is to increase cotton yield on the existing area. There are several factors that affect cotton productivity; however, tillage and water are the two key factors that can affect cotton more seriously than all other factors (Ashraf *et al*., 2018).

Cotton yield can be optimized with suitable tillage and optimum use of irrigation water; however, there is an acute shortage of irrigation water and numerous tillage practices commonly applied for cotton production are not productive. Current water crisis in agriculture gives emphasis on efficient use of water resources (Azevedo *et al*., 2019). Cotton is a deep rooted crop and the growers consider soil inversion deep tillage necessary for the previous crop residues management. With this practice they also intend to create favourable environment for cotton roots penetration. This practice not only incurs the tillage cost but also causes more use of irrigation water by increasing soil water evaporation. Unlike the prevailing practice, cotton grown with reduced/minimum tillage in the standing stubbles of the previous wheat crop improves water management for cotton by reducing soil water evaporation (Omololu *et al*., 2020). Roots of the previous wheat crop decompose and create channels through compacted soil layers, which enable subsequent crop roots to grow through the compacted zone and thus improve infiltration (Farooq *et al*., 2020). Since, water conservation is more in reduced tillage than in conventional tillage (Coates *et al*., 2021); cotton grown with reduced tillage practices may give economic yield with limited irrigation water at reduced cost of cultivation. Increasing water use efficiency by potential cotton grown with reduced tillage can be an important criterion for enhancing yield under water stressful environment. Several researchers have confirmed positive impact of reduced tillage system on cotton yield, economics and water use efficiency. More recent studies revealed that increased cotton yield and lint percentage under reduced tillage system might be due to improved water use efficiency (WUE), soil fertility, and nutrient status (Tan *et al*., 2018; Hulugalle *et al*., 2019).

Cotton is a warm season crop that needs regular supply of water, either from irrigation or rainfall. Successful cotton production depends on availability of water. The world scientists are in search of low inputs agriculture including wise use of irrigation water to optimize production from existing limited water (Thorp *et al*., 2020). Using inadequate water for enhancing cotton productivity is one of the major challenges for agriculturists (Siskani *et al*., 2015; Sahito *et al*., 2019). WUE can be improved by adopting best irrigation management practices (Yang *et al*., 2016; Idowu *et al*., 2019). Effective agronomic practice needs to be explored which has the potential to enhance WUE and cotton yield (Li *et al*., 2019). Since the study area, Dera Ismail Khan, is an arid region and has limited rainfall in addition to low organic matter status of the soil, reduced tillage could be a viable option for efficient use of inadequate irrigation water. Since a little research was done before to investigate the effect of irrigation intervals on cotton under reduced tillage; therefore, the present research was aimed to examine the response of cotton yield and lint under reduced tillage for limited water condition.

Materials and Methods

Experimental site

An experiment was carried out at Agriculture Research Institute, Dera Ismail Khan in 2016. Five soil samples were collected randomly from 0-30cm soil depth from the study area. The soil samples were analyzed for physico-chemical characteristics. The mstudy area is characterized by hard calcareous soils, high summer temperature (35-40°C), low annual rainfall 180-250 mm) and a pH (>7.0). Total rainfall during the study year was 215 mm (Table 1).

Table 1: *Meteorological data recorded at Cotton Research Station, Dera Ismail Khan during 2019.*

Month	Temperature °C			Rainfall (mm)
	Maximum	Minimum	Mean	
April	45	17	37.5	-
May	43	25	38	-
June	44	27	39.25	35
July	39	27	35.5	124
August	38	29	34.75	173
September	37	25	33.5	20
October	34	19	29.5	-
November	29	14	24.5	-
Total	352			

Source: *Arid Zone Research Institute, Dera Ismail Khan, Pakistan.*

Experimental procedure

The experiment was laid out in a randomized complete block design with split-plot arrangement replicated thrice. Tillage treatments were reduced tillage

(10 cm depth, one tiller followed by rotavator) and conventional tillage (20 cm depth, including disc plough, cultivator, rotavator, and leveling operations). Reduced and conventional tillage were the main plot treatments and irrigation interval (i.e. 10, 15, 20, & 25 days intervals) the sub plots. Total irrigation water used in irrigation treatments, 10, 15, 20, 25 and 30 days intervals were 1125, 750, 560, 450 and 360 mm, respectively. Each subplot consisted of four rows of 10 m length and 0.75 m intra row width. All the subplots were isolated from each other by making bunds around them so that the amount of irrigation for one subplot did not affect the amount of irrigation for another subplot. After wheat harvesting, previous crop residues were incorporated into the soil, with ploughing, operations including tiller, disc plough and rotavator and after well prepared seed bed, cotton was sown with dibbling method (conventional tillage system, CT). The reduced tillage (RT) system consisted of a tiller followed by rotavator, Cotton (*cv.* Ali Akbar, a standard Bt.variety of cotton for the region) was sown at 75 cm inter-row and 22.5 cm intra-row spacing with dibbling method on May 28, 2019. Irrigation was given through canals. Thinning was done 20 days after emergence by leaving one seedling hill^{-1}. Weeds such as *Cynodon dactylon*, *Conyza canadensis*, *Tribulus terrestris*, and *Cyperus rotundus*, *etc.* 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 Agri Services, Pakistan)] + [Conquest 24 EC (a.i. Lactofen 168 g l^{-1}, dosage 450 ml acre^{-1}, manufacturer, Kanzo Chemicals, Pakistan)]. All experimental plots received 150-kg N/ha as urea and 60-kg P/ha 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. The crops were harvested in the last week of November.

Procedure for data recording

The parameters studied were plant population, plant height (cm), bolls per plant, boll weight (g), seed cotton yield (kg ha-1) and lint percentage/GOT (%). Six randomly selected plants were tagged in each subplot at maturity for measuring plant height and recorded average plant height (cm), bolls per plant. Total bolls on each plant were counted manually and then averaged. Fifty bolls were randomly collected from each plot and were weighed for recording average boll weight. Seed cotton yields per plot were weighed with an electronic balance and converted into kg ha^{-1} as given.

Lint percentage/ginning out turn was recorded by taking seed cotton samples from each plot. After cleaning and sun drying the samples were then ginned with electric ginning machine. The lint attained was weighed and GOT was calculated by the following formula.

$$\text{Lint percentage} = \frac{\text{Lint yield (kg)}}{\text{Seed cotton yield (kg)}} \times 100$$

Statistical analysis

Statistical analysis of the data was performed as per ANOVA techniques and significant results were subjected to LSD test for mean comparison using MSTATC software (MSTATC, 1991).

Results and Discussion

Plant population ha^{-1}

ANOVA indicated that plant population had significant response to tillage (T), irrigation intervals (I), while tillage × irrigation interactions were not significant (Table 2). Main effect revealed that reduced tillage had higher number of plants (32454 per hectare) than conventional tillage (31375 per hectare). Irrigation at 20 days interval gave more plants than other irrigation intervals (Table 3). Tillage methods were important agronomic factor which distress the proper stand establishment, optimum plant population, water saving percentages and seed cotton yield (Bossange *et al*., 2016). Iirrigation at 20 days interval gave more plants than other irrigation intervals. Uniform plant population was the most important factor to harvest more profitable cotton yield. Adequate plant population was obtained by sowing cotton in optimum irrigation under reduced tillage due to better emergence of seedlings (Coates, 2021).

Plant height (cm)

ANOVA indicated that plant height showed significant response to T and irrigation intervals, while tillage × irrigation was not significant (Table 2). Means showed reduced tillage showed taller plant height (114 cm) than CT (112 cm). Results revealed that irrigation applied with 10 days interval produced highest plant height (120 cm) compared to 15, 20 and 25 days irrigation intervals (Table 4). The higher plant height with frequent irrigations might be due to the growing of more nodes and reduced canopy temperature

Table 2: *Mean square values of plant population, Plant height, boll weight, seed cotton yield and lint percentage as affected by tillage and irrigation intervals.*

Source	D.F	plant population	plant height	bolls per plant	boll weight	seed cotton yield	lint percentage
Replication	2	9985646	0.40000	0.0333	0.00070	1206	0.4690
Tillage (T)	1	8730729**	43.20**	20.83**	0.11**	50466**	53.8680*
Error 1	2	122358	00001.2	0.2333	0.00012	6680	2.4490
Irrigation (I)	4	22690000**	151.8**	67.03**	0.341**	650395**	11.6712**
T×I	4	40977.7^{ns}	1.200	4.33**	0.155**	51984*	0.2655^{ns}
Error 2	16	100183	1.200	1.1333	0.00010	11848	0.6136

Table 3: *Impact of tillage and irrigation on plant population per hectare.*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	29233	28381	28807 d
15	32464	31323	31893 c
20	34602	33360	33981 a
25	33492	32529	33011 b
30	32476	31280	31878 c
Mean	32454 a	31375 b	

LSD0.05 for tillage = 549.57, irrigation = 387.39

Table 4: *Impact of tillage and irrigation on plant height (cm).*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	122	118	120.0 a
15	117	115	116.0 b
20	116	114	115.0 b
25	110	108	109.0 c
30	109	108	108.0 c
Mean	114.80 a	112.40 b	

LSD0.05 for tillage = 1.77, irrigation = 1.3407

Table 5: *Impact of tillage and irrigation on bolls per plant.*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	18 cd	18 cd	18.0 b
15	19 c	19 c	19.0 b
20	25 a	21 b	23.0 a
25	17 de	15 f	16.0 c
30	15 ef	13 g	14.2 d
Mean	18.9 a	17.2 b	

LSD0.05 for tillage = 0.7589, irrigation = 1.3030, tillage × irrigation= 1.8427

under reduced tillage as reported by Idowu *et al* (2019). Siskani *et al.* (2015) communicated similar findings who reported that water stress reduced plant height of cotton. They further reported that irrigation applied as per requirement of the crop resulted in higher plant height.

Bolls plant^{-1}

Bolls plant^{-1} was significantly influenced by tillage (T), I, and T×I (Table 2). Tillage mean revealed that reduced tillage showed higher bolls plant^{-1} than conventional tillage (Table 5). Reduced tillage showed higher bolls plant^{-1} than conventional tillage system, most likely due to more favourable soil micro-climate with regard to soil moisture conservation, nutrients supply, and light transmission. The optimum utilization of resources by crop plants might have caused higher bolls plant^{-1} in reduced tillage compared to conventional tillage system (Blaise, 2011). Irrigation with 20 days interval produced significantly more bolls per plant compared to all other irrigation intervals. Interaction effect indicated that reduced tillage in combination with 20 days irrigation interval had the highest number of bolls per plant. Irrigation with 20 days interval had probably more favorable moisture content than lower or higher irrigation interval under reduced tillage cotton which resulted in the development of more fruiting bodies (Li *et al.*, 2019). Bolls per plant increased with an increase in irrigation intervals from 10 to 20, however, further increase beyond 20 days interval may not be productive for the reduced rate of boll growth. Further, they reported the number of bolls as a genetic parameter that differed. Siskani *et al.* (2015) communicated similar findings who reported that water stress reduced plant height of cotton. They further reported that irrigation applied as per requirement of the crop resulted in higher bolls per plant.

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Table 6: *Impact of tillage and irrigation on boll weight (g).*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	2.12 e	2.32 c	2.22 d
15	2.43 b	2.32 c	2.38 b
20	3.09 a	2.44 b	2.77 a
25	2.32 c	2.22 d	2.27 c
30	2.14 e	2.20 d	2.17 e
Mean	2.42 a	2.30 b	

LSD0.05 for tillage = 0.0174, irrigation = 0.0123, tillage × irrigation= 0.0174

Bolls weight-gms

Bolls weight was affected significantly by T, I and T × I interaction (Table 2). Reduced tillage had heavier boll weight than conventional tillage (Table 6). The better performance of reduced tillage may be attributed toward better establishment of crop stand in comparatively favourable soil environment and more allocation of resources to boll formation compared to conventional tillage for loss of nutrients and moisture. Bossange *et al*. (2016) also observed greater boll weight in conservation or reduced tillage system. The favourable soil physical environment may have contributed to the significant improvements in boll weight under reduced tillage (Blaise, 2011). Irrigation with 20 days interval resulted in heavier bolls compared to 10, 15, 25 and 30 days intervals. Interactions indicated that reduced tillage with 20 days irrigation interval depicted highest boll weight. Boll weight fluctuates between values of 2.2 and 2.8 with irrigation interval from 10 to 20 days. Results indicates that 20 days irrigation interval is optimum for boll weight as a further increase in irrigation interval up to 30 days may result in reduced growth rate. This was probably because of increased translocation of photosynthates from source to sink (boll) due to more favourable soil environment for uptake of nutrients compared to all other irrigation regimes (as more moisture favoured more vegetative growth rather than reproductive growth (Omololu *et al*., 2020). Heavier boll weight with 25 days irrigation interval was perhaps due to more favorable moisture condition for lesser evaporative losses from reduced tillage cotton as reported by Yang *et al*. (2016). Siskani *et al*. (2015) communicated similar findings who reported that water stress reduced plant height of cotton. They further reported that irrigation applied as per requirement of the crop resulted in higher BW.

Table 7: *Impact of tillage and irrigation seed cotton yield (kgha^{-1}).*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	1600 ef	1519 f	1559 c
15	1935 bc	1834 cd	1885 b
20	2256 a	2041 b	2149 a
25	1738 de	1227 g	1482 c
30	1530 f	1141 g	1336 d
Mean	1812 a	1553 b	

LSD0.05 for tillage = 128.41, irrigation = 133.22, tillage × irrigation= 188.40

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

Results revealed that tillage, irrigation intervals, and tillage x irrigation interaction had significant effects on seed cotton yield (Table 2). Main effects revealed that reduced tillage gave highest seed cotton yield (Table 7). The results revealed that all the two tillage systems had identical response to the seed cotton yield indicating that reduced tillage practices may be productive and economical if irrigation is not a limiting factor. Due to the cost-cutting of production, reduced tillage may be more economical and environmentally safe besides conservation of resources. In the long term, reduced tillage in combination with optimum irrigation interval may improve soil properties with significant improvement in the seed cotton yield (Idowu *et al*., 2015; Coates, 2021). Siskani *et al*. (2015) communicated similar findings who reported that water stress reduced plant height of cotton. Seed cotton increased with an increase in irrigation intervals from 10 to 20, however, further increase beyond 20 days interval may not be productive for the reduced rate of boll growth. Further, they reported the number of bolls as a genetic parameter that differed. They further reported that irrigation applied as per requirement of the crop resulted in higher seed cotton. Results revealed that 20 days irrigation interval proved to be more productive regarding seed cotton yield than all other intervals. Irrigation intervals 10 to 15 days had lower seed cotton yield perhaps due to excessive soil moisture that led to more dynamic vegetative growth rather than seed cotton yield. Besides higher seed cotton yield, irrigation with 20 days interval was cost-effective as it saved more water (60%) when compared with 10 and 15 days interval (check treatment for comparison). It can be predicted from results that irrigation interval beyond 20 days may not be productive for the reduced rate of growth as a consequence of low moisture stress. Lower seed cotton yield with shorter irrigation intervals (10 to 15 days) might be due to excess moisture stress that led to flowers and bolls dropping (Siskani *et al*., 2015). Similar findings were conveyed by Sahito *et al*. (2015) who reported that irrigation interval more than 20 days produced higher seed cotton yield. Tan *et al*. (2018) had comparable findings who reported that moderate volume of irrigation would be more economical than excessive use of water. Furthermore, they reported that varieties with different genetic background had different seed cotton yields.

Table 8: *Impact of tillage and irrigation lint %age.*

Irrigation intervals (days)	Tillage		Mean
	Reduced	Conventional	
10	36.17	33.33	34.75 bc
15	37.13	34.23	35.68 b
20	39.07	36.27	37.67 a
25	36.13	33.20	34.67 c
30	35.10	33.17	34.13 c
Mean	36.72 a	34.04 b	

LSD0.05 for tillage = 2.4587, irrigation = 0.9587

Lint percentage

Lint percentage was significantly affected by tillage, irrigation intervals, while their interaction was not significant (Table 2). Mean values for the tillage revealed that reduced tillage produced highest lint %age. Results showed that irrigation with 20 days interval produced highest lint %age among all other irrigation intervals (Table 8). Since bolls plant^{-1} and boll weight are positively correlated with lint yield, reduced tillage might have higher lint/GOT probably due to its higher bolls plant^{-1} and higher boll weight in interaction with optimum irrigation (20 days interval) (Zhang *et al*., 2020). The results of the present investigation are in line with previous findings by Li *et al*. (2020) who reported that GOT was associated with the genetic makeup of a variety. Siskani *et al*. (2015) communicated similar findings who reported that water stress reduced plant height of cotton. They further reported that irrigation applied as per requirement of the crop resulted in higher lint.

Conclusion and Recommendations

Reduced tillage produced 38.9% more bolls per plant, 45.8 % greater boll weight, 41% higher seed cotton yield and 8.1% higher lint %age. Irrigation with 20 days interval can conserve 60% water compared to usual application of irrigation with 10 days interval for the crop life cycle of growth and development.

Novelty Statement

The study depicts that reduced tillage with 20 days irrigation interval is advantageous and adaptable in agro-ecological conditions of Dera Ismail Khan.

Author's Contribution

Niamat Ullah Khan: Conducted the research.
Umbreen Shahzad: Supervised the study and provided technical at every step.
Azhar Abbas Khan, Muhammad Kashan and Shitab Khan: Revised the manuscript.
Sami Ullah: Analysed the lab work
Muhammad Arshad Farooq: Asisted in prepration of final draft.

Conflict of interest

The authors declares that there is no conflict of interests regarding the publication of this article.

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