Research Article

Response of Cotton (*Gossypium Hirsutum* L.) to Phosphorus Levels and Irrigation Intervals

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Abstract | Exploring proper phosphorus level and irrigation interval which enhances cotton production and lint quality was the basis of this research. A field study was conducted in Dera Ismail Khan, Pakistan during 2016 to assess the impact of irrigation interval and phosphorus rates on cotton grown under reduced tillage system (one tiller followed by one rotavator at 7–10 cm depth). Five irrigation intervals (7th, 10th, 13th, 16th and 19th day) and phosphorus levels (0, 50, 100, 150 and 200 kg P_2O_5 ha^{-1}) were kept in main- and subplots, respectively in RCBD with split plots arrangement with three replications. Results revealed that irrigation intervals significantly affected all the parameters such as plant height, sympodial branches, seed cotton yield, and quality-related traits such as fiber length, fiber strength, micronaire, and fiber uniformity. Frequent irrigation interval (7th day) produced taller plants (139 cm) and more sympodial branches (18.3) compared to less frequent irrigations (10-19th day). However, 19th day irrigation interval significantly improved seed cotton yield and fiber quality traits (fiber length, fiber strength, micronaire, and fiber uniformity). Likewise, phosphorus at 150 kg ha^{-1} significantly improved seed cotton yield (3794 kg ha^{-1}) and ginning out turn (39.1%) compared to other phosphorus levels. In conclusion, P at 150 kg ha^{-1} with 19 days irrigation interval optimized yields and quality attributes.

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Introduction

Cotton (*Gossypium hirsutum* L.) is the main fiber crop with high commercial value throughout the world. Several countries in the world such as China, Pakistan, India, USA, Turkey, Uzbekistan, Australia, Egypt, and Brazil etc. have suitable agro-ecological conditions for cotton production. In 2016/17, Pakistan produced 10 percent more cotton than last year (Rehman and Williams, 2017). Pakistan cotton export was 588,578 bales in 2014 (Pakistan Cotton Statistics. 2014). Deep plowing and excessive tillage practices have deteriorated soil properties and affected cotton yield (Yalcin et al., 2005; Mathew et al., 2012). Therefore, reduced tillage was adopted in the present study to cope with the above-mentioned problem.

Irrigation is an important cultural practice that can ensure high and quality cotton production. Although cotton can tolerate drought to some extent, its yield can significantly be improved with proper irrigation interval (Tekinel and Kanber, 1989; Turner, 2018). Excessive irrigation promotes vegetative growth and decreases yield, while inadequate and infrequent irrigation increase shedding ratio (Onder et al., 2009; Davidonis et al., 2004; Balkcom et al., 2006).

Water stress also reduces crop nutrients uptake which affects crop growth adversely (Farooq et al., 2012). The yield of irrigated cotton is declining not only due to misuse of irrigation water but also due to maltreatment of P fertilization (Singh et al., 2000). The farmers either do not use P or use it in too low quantities which do not meet crop P requirement and thus crop remains under nutritional stress. Since soil is not plowed much in reduced tillage, initially there may be a problem of roots proliferation in the hard-compact soil (Głąb, 2011). This can be overcome with phosphorous fertilization which causes vigorous roots development that may have access to feed in a larger forage area. Moreover, irrigation water can be more judiciously and economically used if a cotton rooting system is improved with proper phosphorous fertilization. Phosphorus is the second major nutrient after N restraining cotton production (Pavinato et al., 2010). The soil in the arid and semi-arid region of the world is deficient in phosphorus by almost 80-90% (Arain et al., 2000). It plays an active role in cell division, tissue and floral buds development and bolls formation (Katkar et al., 2002). Phosphorus hastens crop maturity, boll development, and improves lint yield (Ahmad et al., 2009). Research findings revealed that long-term P fertilization in reduced tillage system increased soil organic carbon, reduced soil bulk density, enhanced water use efficiency, improved yield and quality (El-Sodany et al., 2009; El-Maddah et al., 2012; Hai et al., 2010). Reduced runoff and erosion losses were the outcomes of the efficient use of water and P fertilization in reduced tillage system (Busari et al., 2015; Baumhardt and Lascano, 1999; Daniel et al., 1999). Water infiltration in conservation tillage increases with proper P fertilization and irrigation (Sarker et al., 2012). Increased infiltration is due to intact channels of old roots and cracked soil that let water to flow into soil layers Dalmago et al. (2004).

In most parts of Pakistan, rainfall is not enough for growing crops. Moreover, the existing water resources are heavily degraded. Modified rainfall patterns result in water scarcity and droughts which create stress for crops and livestock (Ahmed et al., 2016). This research work addresses crop production at the reduced use of irrigation water coupled with optimum P fertilization. It may help to develop a management program for minimizing yield reduction in case of water shortage. The present research was undertaken with the objective of knowing the response of cotton grown under minimum/reduced tillage system to irrigation intervals and P levels.

Materials and Methods

The research site was Dera Ismail Khan, Pakistan. The area is characterized by warm and heavy textured soil (clay loam, hyper thermic and Typic Torrifluvents according to Soil Survey Staff, 2009) with low rainfall (Figure 1). Cotton was sown on the field previously grown with wheat. After wheat harvesting, the field was given light irrigation. Cotton (cv. MNH-886) was sown hand-planted under reduced tillage system (one tiller/cultivator followed by one rotavator at 7–10 cm depth) with 75 cm row-row and 22.5 cm plant-plant spacing on 3 May 2016. The experiment was designed as RCB with split-plot arrangements replicated thrice. Irrigation intervals (7, 10, 13, 16 and 19 days) and phosphorus levels (0, 50, 100, 150 and 200 kg ha^{-1}) were maintained in the main plot and subplot, respectively. Subplot sized 3 × 10 m (30 m^2). There were four rows in a plot with a row length of ten meter. Twenty days after emergence plants were thinned to single healthy plant hill^{-1}. SOP fertilizer at the rate of 60 kg K_2O ha^{-1} was broadcasted in all the experimental plots uniformly, while P fertilizer (DAP) was broadcasted in the experimental plots according to P treatments detail. Both P and K fertilizers were mixed in the soil with tiller/cultivator and rotavator just before sowing. N (150 kg ha^{-1}) as urea was given in 3 equal doses, at planting, blooming and boll formation stage. First irrigation was given just after sowing. Subsequent four irrigations were given weekly for a month for establishing seedlings in all the experimental plots. Thereafter, irrigation intervals (7th, 10th, 13th, 16th and 19th day) were initiated. The total amount of water supplied to the crop during growing season from irrigation treatments, 7th, 10th, 13th, 16th and 19th day interval was 1750, 1330, 1050, 910 and 850 mm, respectively. The experimental units were treated equally regarding weeds and insect pest control. The Crop was protected by a regular spray of Imidacloprid @ 625 g ha^{-1} against aphid, jassid, thrips, whitefly and mites. Weeds were eradicated manually. Ten plants were randomly selected in each treatment and tagged for recording data on plant height (cm), sympodial branches (plant^{-1}), number of bolls plant^{-1}, boll weight (g), seed cotton yield (kg ha^{-1}), gining out turn (G.O.T %), fiber length (mm), fiber strength (g tex^{-1}), micronaire, and fiber uniformity (%). All the data were recorded at maturity. Field data were recorded at the end of November, while fiber quality traits were analysed using High Volume Instrument at CCRI, Multan.

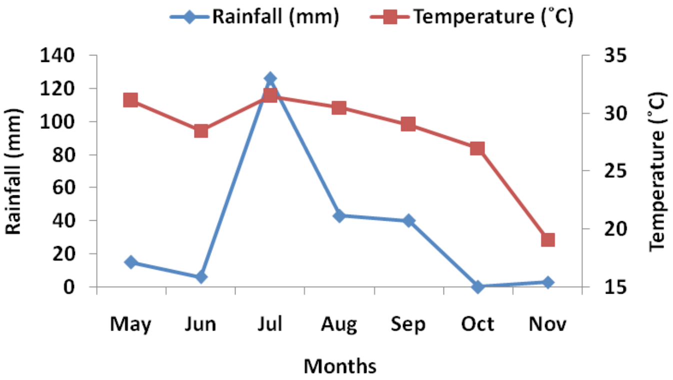

Figure 1: *Monthly total rainfall and average temperature data during 2016.*

Statistical analysis

Data were subjected to statistical analysis via analysis of variance techniques (Steel and Torrie, 1980) and LSD test was applied to significant results through MSTATC software (MSTATC, 1991).

Results and Discussion

Plant height (cm)

Plant height data were not significant when different phosphorus levels and their interaction with irrigation intervals were considered, however, the main effect of irrigation interval was found significant (Table 1). The maximum plant height was obtained from plots irrigated with 7 days interval, whereas the minimum plant height was noted in the plots irrigated with 19 days interval. Results revealed that frequent irrigation interval (I_7) increased plant height (139 cm) more vigorously than less frequent irrigation intervals ranging from I_{10} to I_{19} (10-19 days irrigation interval) (108-132 cm). Taller plants with I_7 might be associated with enough water in the soil which was absorbed along with nutrients through roots and thus caused dynamic vegetative growth. Sahito et al. (2015) and Zonta et al. (2016) also reported that frequent irrigation caused excessive vegetative growth and resulted in taller plants.

Sympodial branches plant^{-1}

Number of sympodial branches is a significant factor that affects final yield. Data given in Table 1 revealed that the main effect of irrigation interval was significant for sympodial branches, conversely, phosphorus levels and interaction of phosphorus with irrigation interval did not differ significantly. The maximum number of sympodial branches was observed in irrigation treatment with 7 days interval, whereas the minimum number of sympodial branches was recorded in irrigation treatment with 19 days interval. Irrigation with 7 days interval (I_7) produced a higher number of sympodial branches compared to irrigation with 10, 13, 16 and 19 days interval. Onder et al. (2009) described that sympodial branches were significantly affected by irrigation intervals. Higher sympodial branches with frequent irrigation might be attributed to more favorable soil moisture that caused vigorous vegetative plant growth. The increased irrigation frequency increased the amount of irrigation water, which increased the plant productive potential via improving the nutrients uptake and photosynthesis. Pettigrew (2004) communicated analogous results who reported that higher amount of irrigation water resulted in more number of sympodial branches.

Table 1: *Plant height (cm), sympodial branches plant^{-1}, no. of bolls plant^{-1}, boll weight (g) and seed cotton yield (kg ha^{-1}) as affected by different phosphorus levels and irrigation intervals.*

Treatments Irrigation intervals (days)	Plant height (cm)	Sympodial branches plant^{-1}	No. of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
7	139 a	18.3 a	20 c	2.0 b	2641 c
10	132 b	15.7 b	21 bc	2.0 b	2691 c
13	128 b	14.4 b	21 bc	2.3 ab	3093 b
16	121 c	12.6 c	23 a	2.4 a	3113 ab
19	108 d	10.1 d	23 a	2.5 a	3346 a
$LSD_{0.05}$	4.75	1.74	1.80	0.25	236.9
Phosphorous levels (kg ha^{-1})					
0	134	15	15 d	1.9 d	2234 d
50	127	14	18 c	2.0 c	2607 cd
100	114	14	21 b	2.3 b	2897 c
150	124	14	25 a	2.7 a	3794 a
200	129	15	22 b	2.4 b	3353 b
$LSD_{0.05}$	NS	NS	1.74	0.17	411.8
Interactions					
P × I	NS	NS	NS	NS	NS

Means followed by same letter within a category in a column are not significant ($p<0.05$) using LSD test.

Bolls plant^{-1}

Main effects of phosphorus levels and different irrigation intervals were significant for the number of bolls plant^{-1} whereas interactive effects of the treatments were found to be non- significant (Table 1). The maximum number of bolls plant^{-1} was obtained from plots irrigated with 19 days interval, whereas the minimum number of bolls plant^{-1} was noted in the plots irrigated with 7 days interval. Likewise, the maximum number of bolls plant^{-1} was observed from plots treated with 150 kg P ha^{-1}, whereas the minimum number of bolls plant^{-1} was noted in control plots where no P was applied. Bolls plant^{-1} data revealed that there was an increasing trend with increasing P level to 150 kg ha^{-1}. However, a further increase in P level beyond 150 kg did not increase bolls plant^{-1}. Irrigation from 7 to 13 days intervals produced the similar number of bolls plant^{-1} whereas thereafter bolls increased with an increase in irrigation from 16-19 days interval; however, the latter two were statistically at par. It is evident from the results that P caused vigorous plant growth and resulted in higher boll setting as also reported by Makhdum et al. (2001) who found that bolls plants^{-1} were increased with application of optimum phosphorus level. Higher bolls per plant may be due to well-nourished plants under optimum moisture condition as reported by Siddiqui et al. (2007) and Ertek and Kanber (2003).

Boll weight (g)

Boll weight was affected significantly by phosphorus and irrigation intervals but their interaction was found to be nonsignificant (Table 1). The maximum boll weight was obtained from 16-19 days irrigation interval whereas minimum boll weight was obtained from 7-10 days irrigation interval. Regarding P levels, maximum boll weight was observed in plots treated with 150 kg P ha^{-1} whereas minimum boll weight was noted in the control plot. Means of phosphorus levels revealed that boll weight increased linearly with the increase in P level and peaked at 150 kg ha^{-1}. However, there was no further increase in boll weight but rather declined with the further increase up to 200 kg P ha^{-1}. Irrigation intervals revealed that boll weight was relatively low with frequent irrigation from 7-10 days interval. However, it increased with less frequent irrigation from 10-19 days interval. Ahmad et al. (2009) reported analogous results that bolls weight increased with normal irrigation interval, however, both extreme of water i.e. high and low moisture stress would definitely affect boll weight adversely.

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

Seed cotton yield responded significantly to different phosphorus levels and irrigation intervals whereas interaction was not significant (Table 1). The maximum seed cotton yield was observed in irrigation treatment with 19 days interval whereas minimum seed cotton yield was obtained from 7 days irrigation interval. Pertaining to the P effect, maximum seed cotton yield was noted in P treatment with 150 kg ha^{-1} whereas minimum seed cotton yield was observed in the control plot. Phosphorus levels increased seed cotton yield up to 150 kg ha^{-1} beyond which there was declining trend when 200 kg P ha^{-1} was applied. Control plot having no P resulted in lowest seed cotton yield. Irrigation in the range of 7-10 days intervals had minimum and similar seed cotton yield whereas irrigation from 16-19 days interval had significantly higher seed cotton yield. These results indicate that seed cotton yield increased with P fertilization applied at the rate of 150-200 kg P ha^{-1}. Cotton is having low rooting density, therefore. nutrients uptake efficiency is low compared to other field crops. Thus, it will require more nutrients for optimum nutrients uptake during the growing season. That is why P deficient plots produced lower seed cotton yield compared to higher P rates (150 to 200 kg ha^{-1}) which resulted in higher seed cotton yield (Singh et al., 2013). Similarly, irrigation with 19 days interval also substantially increased seed cotton yield indicating optimum water requirement. Aslam et al. (2009), Sawan et al. (2011) and Din et al. (2016) had identical results who reported that abiotic stress either in the form of nutrients or water adversely affect yield.

Table 2: *Ginning out turn (%), fiber length (mm), fiber strength (g tex^{-1}), micronaire and fiber uniformity (%) as affected by different phosphorus levels and irrigation intervals.*

Treatments Irrigation intervals (days)	Ginning out turn (%)	Fiber length (mm)	Fiber strength *(g tex^{-1})	Micronaire	Fiber uniformity (%)
7	29.0 c	25.8 e	27.1 c	3.6 e	81.3 e
10	36.8 b	26.2 d	28.0 b	3.8 d	81.8 d
13	36.9 b	26.5 c	28.5 ab	3.9 c	82.2 c
16	37.9 ab	26.7 b	28.8 ab	4.0 b	82.5 b
19	39.1 a	27.0 a	29.0 a	4.1 a	83.0 a
$LSD_{0.05}$	1.61	0.16	0.85	0.10	
Phosphorous levels (kg ha^{-1})					
0	31.9 d	26.5	28.6	3.8	81.8
50	35.3 c	26.5	28.4	3.9	82.2
100	36.4 b	26.3	27.7	3.9	82.2
150	39.1 a	26.6	28.6	3.9	82.6
200	37.0 b	26.2	28.1	3.9	82.1
$LSD_{0.05}$	1.16	NS	NS	NS	NS
Interactions					
P × I	NS	NS	NS	NS	

*Means followed by same letter within a category in a column are not significant ($p<0.05$) using LSD test; *tex means mass in grams per 1000 meters of fibers. The International System of Units uses kilogram per metre for linear densities; in some contexts, the tex unit is used instead.*

Ginning out turn (%)

GOT was significant regarding irrigation and phosphorus effects, however, interactive effects were not significant (Table 2). The maximum GOT was observed in irrigation treatment with 19 days interval whereas minimum GOT was obtained from 7 days irrigation interval. Regarding the P effect, maximum GOT was noted in P treatment with 150 kg ha^{-1} whereas minimum GOT was observed in the control plot. Mean for phosphorus levels revealed that GOT increased with phosphorus application up to 150 kg ha^{-1} and diminished thereafter indicating 150 kg as optimum level. Plots with no P resulted in lowest GOT. Regarding irrigation intervals, 19-days interval had remarkably increased GOT compared to the lower/ shorter interval of irrigation. The variable GOT may be due to genetic as well as environmental factors such as P fertilization and irrigation as communicated by Wang et al. (2004).

Quality parameters

Fiber length (mm), fiber strength (g tex^{-1}), micronaire, and fiber uniformity (%) all responded significantly to irrigation intervals but P levels and irrigation × P interactions were not significant (Table 2). The maximum fiber length, fiber strength, micronaire reading, and fiber uniformity were observed in irrigation treatment with 19 days interval whereas the minimum values for these parameters were recorded when irrigation was given with 7 days interval. The data revealed that quality attributes were adversely affected when the crop was irrigated frequently and vice versa. One possible reason for lower lint quality might be severe sucking type of insects on foliage as well as on newly formed bolls in plots treated with frequent irrigation. The resources were not properly utilized and partitioned to sink and thus resulted in lower lint yield and quality, while the other possible reason was perhaps undesirable excessive vegetative growth which resulted in lower lint yield and quality (Onder et al., 2009). In case of frequent irrigation, there might be more soil moisture content which might have delayed maturity and have more immature bolls at harvest, which resulted in lower fiber quality (Johnson et al., 2002). In this study 19 days irrigation interval was the most suitable irrigation level which had optimum lint yield and lint quality probably due to adequate nutrient and water availability in optimum amount (Booker et al., 2006). That is why irrigation with 19 days interval had a remarkable effect on fiber length, strength, fineness, and uniformity. Shorter intervals reduced lint quality probably due to higher moisture stress that delayed maturity and deteriorated lint quality. Later maturity in a season is subject to so many biotic and abiotic stresses that affect lint quality as reported by Malik et al. (1996) who communicated that lint quality could not be maintained if left for a longer period in the field. Balkcom et al. (2006), Sobrinho et al. (2015), Gutstein (1970), Tewolde and Fernandez (2003) reported that fiber quality was affected by the environmental factor as well as a genetic factor.

Conclusions and Recommendations

The growing of cotton under reduced tillage system required less frequent application of irrigation water (19 days interval) for improving seed quality and seed cotton yield. However, the frequent application of irrigated water (7 days interval) improved plant tallness and sympodial branches plant^{-1}. Phosphorus at the rate of 150 kg ha^{-1} gave higher yield and yield attributes. Nevertheless, it did not influence cotton quality parameters significantly. Phosphorous at 150 kg ha^{-1} and irrigation with 19 days interval can optimize cotton yield under reduced tillage system.

Author's Contribution

Muhammad Tahir Amin conducted the experiment. Khalid Usman prepared the manuscript and made correspondence. Muhammad Waqas Imam Malik helped in data collection and analysis. Nishter Ali assisted in lab analysis of the fiber parameters.

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