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RESEARCH PAPER

Effect of fertilizers and chiseling techniques on optimizing growth of cotton (*Gossypium hirsutum* L.)

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Key Message: This research reveals the significant effect of irrigation intervals and chiseling on plant height and fruiting parts. The interaction of phosphatic fertilizer application techniques also demonstrates positive effects on cotton plants. The findings of this study provide potential avenues to enhance productivity for cotton farmers.

Abstract

Cotton contributes significantly to the production of oilseeds and textile fiber globally, and it is an important component of the socioeconomic and political environment. This study aims to evaluate the effects of commercial sulfuric acid and nitrogen, irrigation intervals, phosphatic fertilizer application, and chiseling on cotton growth and yield. The investigation was carried out using a split-plot setup with three replications at the Central Cotton Research Institute (CCRI), Multan, Pakistan. Nitrogen levels (N1 = 50 kg ha^{-1}, N2 = 100 kg ha^{-1}, N3 =150 kg ha^{-1}) were kept in main plots, while sulphuric acid (S1= 0 kg ha^{-1}, S2= 125 kg ha^{-1}, S3 = 250 kg ha^{-1} and S4 = 375 kg ha^{-1}) was randomized in sub plots respectively. The results showed that watering interval and chiseling had a substantial impact on plant height and the quantity of fruiting parts per plant. Compared to other treatments, interculturing produced higher plant height and more fruiting parts when paired with chiseling and an 8-day irrigation interval. The height and fruiting sections of cotton plants showed a positive link with the long-term effects of phosphatic fertilizer application in wheat crop. The impact of several phosphorus delivery techniques on plant height and fruiting parts varied in bed-furrow planting; hand application without mixing prior to sowing yielded the best results. The application of commercial sulfuric acid, in conjunction with nitrogen, positively affected both plant height and fruiting parts. Increased fruiting parts and plant height were a result of higher sulfuric acid dosages; nitrogen application had no visible impact. These findings can contribute to the development of effective strategies for cotton cultivation, leading to increased productivity and profitability for cotton farmers.

Keywords: Chiseling, Cotton, Growth, Nitrogen, Phosphorus, Sulphuric acid

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Introduction

Cotton holds a significant role in various aspects of daily life, impacting human existence from infancy to the end of life. Its influence is universal reaching into socio-economic and political affairs on a global scale (Kairon et al., 2004). The cultivation, processing, and trade of cotton not only serve as sources of substantial revenue but also form the backbone of livelihoods in numerous countries. As the leading natural textile fiber worldwide, cotton also ranks as the fourth largest oilseeds crop, addressing 40 % of the global textile demand and contributing 3.3 % to the overall production of edible oil (Ali et al., 2012; Zia et al., 2015; Shuli et al., 2018). Pakistan stands prominently as the fourth largest contributor to global cotton production, emphasizing its crucial role in the cotton industry (Zia et al., 2018a, 2018b). Additionally, it holds the third position in consumption and distinguishes itself as a leading exporter of yarn (International Cotton Advisory Committee [ICAC], 2012). This remarkable standing is achieved through a vigorous production of 12.8 million bales cultivated across an expansive area of 2.8 million hectares (Economic Survey of Pakistan, 2014). However, the production of seed cotton in Pakistan encounters challenges such as biological, physical, socio-economic, environmental, and agronomic constraints resulting in a relatively low yield per unit area (Masood et al., 2011; Ali et al., 2015; Arshad et al., 2018; Ashraf et al., 2018).

However, the implementation of appropriate agronomic practices holds the potential to significantly enhance the yield of cotton per unit area. Crucial management decisions including the selection of suitable cotton varieties, identification of optimal planting dates, determination of appropriate plant density, and effective nitrogen management play a pivotal role in shaping the crop's development and ultimate outcome. In Pakistan, the cotton-wheat cropping system covers an extensive 2.8 million hectares representing approximately 33% of the nation's total wheat cultivation area (Economic Survey of Pakistan, 2014). Within this system, the planting of wheat is often delayed due to unavailability of land, a consequence of the late maturity of cotton. This delay subsequently impacts the wheat yield. According to Khan (2003), sowing wheat after the 15^{th} of November may lead to a daily loss of 42 kg ha^{-1} in wheat yield. One of the main goals of cotton breeding programs has been to achieve early crop maturity without sacrificing yield.

To maximize crop profitability, agronomic factors such as row organization and plant spacing must be optimized (Nagender et al., 2017). An established agronomic strategy that regularly shows promise in raising crop production and total profitability is adjusting plant density and crop shape (Hiwale et al., 2013). Reaching the ideal plant stand is essential to increasing yields; too high of a plant density inhibits the growth of individual plants, while too little plant density wastes resources (Munir et al., 2015). Researchers like Heitholt et al. (1992); Killi et al. (2016) have researched the impact of plant density on important parameters like radiation interception, moisture availability, wind movement, and humidity in detail. In turn, canopy height, branching pattern, fruiting behavior, crop maturity, and total yield are influenced by these parameters. According to Nadeem et al. (2010), maintaining a suitable plant density is essential for making effective use of applied nutrients and irrigation resources. Research has indicated that early canopy closure and quick canopy development lead to improved light interception when row width is reduced (Rossi et al., 2004; Wu et al., 2017). Thus, less soil water evaporation may result and weed suppression is aided (Marois et al., 2004). Moreover, plant density's direct effect on yield may not have as much of an economic impact as its ability to achieve early crop maturity (Zaxos et al., 2012). Various studies have explored the relationship between cotton growth, yield, and the response to row spacing. Some researchers have reported that cotton sown in 38 cm rows yields comparable or even higher results than wider rows ranging from 97 to 102 cm (Munir et al., 2015). However, conflicting results have been reported in other studies (Fox, 2007; Reddy et al., 2009).

Enhancing agricultural productivity hinges significantly on the judicious use of fertilizers. Among these, nitrogen (N) emerges as a key factor in cotton production, influencing photosynthesis and overall cotton development by promoting the synthesis of energy-rich compounds. However, careful nitrogen management is imperative as improper practices may compromise final yield and nitrogen use efficiency (Rutto et al., 2013). Nitrogen plays a vital role in shaping both vegetative and reproductive growth. Inadequate nitrogen levels can lead to diminished yields due to accelerated premature leaf senescence (Fageria & Baligar, 2005). Conversely, an excess of nitrogen can delay crop maturity and contribute to issues like boll shedding, diseases, and insect damage (Oosterhuis, 2001). Detecting and rectifying nitrogen deficiency is relatively important, whereas excess nitrogen poses a more challenging problem. This highlights the significance of applying nitrogen in precise doses to attain the maximum economically feasible yield. The crop's success is contingent upon maintaining economically optimal levels of nitrogen fertilizers (Firbank, 2005). Cotton cultivars adapted to diverse agro-climatic regions exhibit distinct responses to mineral fertilizer application (Prasad, 2000).

Hence, a continuous need exists to ascertain the ideal nitrogen levels for indigenous cotton cultivars within the ever-changing environmental dynamics. Accordingly, this research was devised to explore the influence of chiseling in bed-furrow and varying irrigation intervals on both soil moisture content and seed cotton yield. Furthermore, the investigation aimed to establish the phosphatic fertilizer requirements for cotton after a wheat crop. It also attempted to evaluate the effects of various phosphatic fertilizer application techniques on cotton as well as the efficiency of nitrogen and sulfuric acid use in boosting seed cotton yield and improving soil health.

Materials and Methods

Site of experimentation

The Central Cotton Research Institute, Multan is situated at latitude 30o 12' N, longitude 71o 28' E, altitude 123 meters and in the center of the cotton belt of Pakistan. The Institute is in the vicinity of Multan city and is close to the airport, railway station and other agriculture departments. CCRI, Multan, has an agronomic research area where the field experiments were carried out. The purpose of the study was to determine how commercial sulfuric acid, phosphatic, nitrogenous, and chiseling fertilizers affected the growth and yield of cotton in the summer season of 2004.

Soil analysis

Prior to planting, soil samples were taken at a depth of 0 to 30 cm, and their physicochemical properties were examined. Following analysis, the experimental soil was found to be a silty clay loam with the following characteristics: 36% saturation percentage, 15.45 ppm accessible phosphorus, 0.17 dSm^{-1} electrical conductivity (EC), 8.2 pH, and 0.65% organic matter. To record changes in the pH and organic matter content, more soil samples were taken.

Experiment 1: Effects on seed cotton yield by chiseling and irrigation interval in bed-furrow

This study used a split-plot design to assess the effects of irrigation intervals and chiseling in bed-furrows on seed cotton yield. The cotton variety used was CIM-499. Two treatments (T1 = Interculturing followed by chiseling, and T2 = Interculturing with chiseling) were applied to the main plots. With I1 = 8 days and I2 = 12 days between irrigations following chiseling, the subplots were designed to evaluate the effects of irrigation intervals. The experiment was carried out in the study's second year. With graded sticks, the plant-to-plant distance was reliably kept at nine inches. At depths of 1, 2, and 3 feet, samples were taken from the beds and furrows both before and after each irrigation. Six irrigations were administered before chiseling, followed by three irrigations after chiseling with the specified intervals. Additionally, three hoeing operations were executed before chiseling, and four irrigations were applied after chiseling based on the respective treatments. Phosphatic fertilizer (50 kg ha^{-1} P_2O_5) and urea (85 kg ha^{-1}) were applied as per the treatments. Moreover, Confidor was used at a rate of 625 ml ha^{-1} to combat termites. Data on plant height, nodes per plant, and water applied were recorded.

Experiment 2: Assessing the phosphatic fertilizer's residual effect on cotton, applied in wheat crop

In this experiment, cotton variety CIM-506 was dibbled in the soil with a plant-to-plant distance of 1 foot using graded sticks. Eight irrigations and four hoeings were applied throughout the experiment. Nitrogen was applied at a rate of 85 kg/ha, and Confidor was used at 625 ml ha^{-1}. The application of P_2O_5 (phosphatic fertilizer) was determined by treatments in two sets:
In main plots (P_2O_5 application in wheat), T_1 = 100 kg ha^{-1} and T_2 = 50 kg ha^{-1}.
In subplots (P_2O_5 application in cotton), P0 = 0 kg, and P1 = 50 kg.
A split-plot design was employed for this experiment, and the coordination of the Plant Physiology Section for Soil Analysis at CCRI was ensured. The recommended doses of nitrogen for both wheat and cotton were applied in all treatments.

Experiment 3: Impact of phosphorus treatment techniques on cotton grown in bed-furrow planting

For this experiment, soil samples were initially taken from the field for analysis, and then phosphatic fertilizer was applied using different methods based on treatments: T1 = Application of phosphatic fertilizer by broadcast method and by mixing it in the soil before sowing; T_2 = Application of phosphatic fertilizer in bed-furrows manually followed by bed shaping; T_3 = Application of phosphatic fertilizer in bed-furrows manually before sowing without mixing; T_4 = Application of phosphatic fertilizer with a tractor drill before sowing; T_5 = Application of phosphatic fertilizer after 30 days of sowing with interculturing; T_6 = Application of phosphatic fertilizer after 45 days of sowing with interculturing. Cotton variety CIM-506 was dibbled in the soil with a plant-to-plant distance of 1 foot using graded sticks. Seven irrigations and four hoeings were applied during the experiment. Nitrogen was applied at a rate of 28 kg/ha based on the respective treatments, and the remaining dose was applied at the time of flowering. A Randomized Complete Block Design (RCBD) was used for this experiment.

Experiment 4: Impact of nitrogen and commercial sulfuric acid application on the yield of seed cotton

In this experiment, samples were first taken for analysis. The application of sulphuric acid was performed with irrigation according to the following treatments: Nitrogen levels (N_1 = 75 kg/ha, N_2 = 100 kg ha^{-1}, N_3 = 125 kg ha^{-1}) were assigned to the main plots. Sulphuric acid levels (S_1 = 0 kg/ha, S_2 = 10 kg/ha, S_3 = 20 kg ha^{-1}, S_4 = 30 kg ha^{-1}, and S_5 = 40 kg ha^{-1}) were randomized in the subplots. Cotton variety CIM-496 was dibbled in the soil with a plant-to-plant distance of 1 foot using graded sticks. Eight irrigations and four hoeings were applied throughout the experiment. Data on plant height and nodes per plant were recorded.

Statistical analysis

Fisher's analysis of variance technique was used to statistically analyze the yield and yield component data that were collected. Duncan's Multiple Range test at a 5% probability level was used to establish the significance of treatment means (Steel et al., 1997).

Results

Effect of chiseling and irrigation interval on cotton

The study investigated the impact of chiseling and irrigation interval on cotton growth, and the findings are presented in Table 1 that displays data for plant height, nodes per plant, and total fruiting parts (flowers + bolls + buds) per plant across different chiseling treatments and irrigation intervals. Significantly, employing interculturing followed by chiseling with an 8-day irrigation interval yielded a plant height of 74.2 cm, 13.9 nodes per plant, and a total of 44.4 fruiting parts per plant. Similarly, when interculturing was followed by chiseling with a 12-day irrigation interval, the resulting measurements were a plant height of 66.3 cm, 13.9 nodes per plant, and 37.6 fruiting parts per plant. The mean values for interculturing followed by chiseling at a 10-day irrigation interval were 70.25

cm in plant height, 13.9 nodes per plant, and 41 fruiting parts per plant. The results of interculturing with no chiseling and an 8-day irrigation interval showed that each plant had 39.5 fruiting parts, 12.6 nodes, and a height of 70.1 cm. On the other hand, these numbers dropped to 60.5 cm, 11.8 nodes per plant, and 34.3 fruiting parts per plant with a 12-day irrigation interval. The mean values for interculturing with no chiseling at a 10-day irrigation interval were 65.3 cm in plant height, 12.2 nodes per plant, and 36.9 fruiting parts per plant. The study shows that chiseling treatments, particularly with an 8-day irrigation interval, positively influenced plant height and the total number of fruiting parts per cotton plant compared to no chiseling treatments and a 12-day irrigation interval.

Table 1 Effect of chiseling and irrigation interval on plant height, nodes per plant and total number of fruiting parts per plant in cotton

Chiseling treatments	Irrigation interval (days)	Plant height (cm)	Nodes per plant	Total number of fruiting parts/plant (Flowers + bolls + Buds)
Interculturing followed by chiseling	8	74.2	13.9	44.4
	12	66.3	13.9	37.6
Mean	**10**	**70.25**	**13.9**	**41.0**
Interculturing and no chiseling	8	70.1	12.6	39.5
	12	60.5	11.8	34.3
Mean	**10**	**65.3**	**12.2**	**36.9**

Evaluation of residual effect of phosphorous on cotton

Table 2 presents the results of an experiment investigating the effects of different levels of phosphorous (P_2O_5) application on cotton plants specifically plant height (measured in centimeters) and the total number of fruiting parts per plant. The findings clearly demonstrate that when additional phosphatic fertilizer (P_2O_5) was applied on top of the residual P_2O_5, there was a notable increase in both the main stem height and the number of fruits compared to plants with only residual P_2O_5. For instance, the crop that received 50 kg P_2O_5 exhibited a remarkable 23.95 cm increase in main stem height compared to the unfertilized crop (0.00 kg P_2O_5). Similarly, the mean total number of fruiting parts per plant was significantly higher in the crop that received 50 kg P_2O_5 compared to the unfertilized crop. Overall, the results strongly suggest that applying phosphorous fertilizer had a positive residual effect on both plant height and the total number of fruiting parts per cotton plant in this study. The evaluation of the residual effect of phosphorous on cotton indicates that additional phosphatic fertilizer application enhances main stem height and fruit production, thereby benefiting cotton crop productivity.

Table 2 Residual effect of phosphorous on plant height and total fruiting parts per plant in cotton

P_2O_5 (kg ha^{-1})		Plant height (cm)	Total number of fruiting parts per plant (Flowers + bolls + Buds)
Wheat	Cotton		
50	0.00	50.2	30.4
	50.00	61.8	33.4
Mean		**56.0**	**31.9**
	0.00	55.0	34.0
	50.00	68.6	39.9
Mean		**61.8**	**36.9**

Effect of methods of phosphorus application on cotton under bed-furrow planting

In this study, the effect of different methods of phosphorous application on cotton under bed-furrow planting was evaluated. The treatments (T1 to T6) represent various application methods of phosphatic fertilizer (Table 3). The parameters measured were plant height (in centimeters) and total number of fruiting parts per plant (comprising flowers, bolls, and buds). The results showed that all the methods of phosphatic fertilizer application resulted in higher plant height and total number of fruiting parts per plant compared to the broadcasting method. The range of plant height observed across the treatments was from 45.6 cm to 47.3 cm. Similarly, the range of total no. of fruiting parts per plant was from 16.9 to 19.9 (Table 3). Overall, the application of phosphatic fertilizer in the bed-furrow planting method, using any of the six treatments (T1 to T6), led to better growth and increased fruiting parts compared to the traditional broadcasting method.

Table 3 Effect of methods of phosphorous application in bed-furrow planting in cotton

Treatments	Plant height (cm)	Total number of fruiting parts per plant (Flowers + Bolls + Buds)
T_1	45.6	17.2
T_2	47.3	19.2
T_3	47.0	19.9
T_4	46.2	18.8
T_5	46.7	17.7
T_6	46.5	16.9

T_1 = Application of phosphatic fertilizer by broadcast method and mixing in soil before sowing; T_2 = Application of phosphatic fertilizer in bed-furrow manually followed by bed shaping; T_3 = Application of phosphatic fertilizer in bed-furrow before sowing manually without mixing; T_4 = Application of phosphatic fertilizer with tractor drill before sowing; T_5 = Application of phosphatic fertilizer after 30 days of sowing with interculturing; T_5 = Application of phosphatic fertilizer after 45 days of sowing with interculturing

Effect of different doses of commercial sulphuric acid application and nitrogen on cotton

In this study, the effects of commercial sulphuric acid treated seeds of cotton and nitrogen application were evaluated in cotton. Firstly, the constant nitrogen application at a rate of 75 kg ha^{-1} did not result in significant differences in plant height and the total number of nodes per plant, irrespective of the various doses of sulphuric acid applied (Table 4). On the other hand, when the dose of commercial sulphuric acid increased, both plant height and the total number of nodes per plant exhibited an increasing trend. The highest plant height of 808 cm was recorded when 20 L ha^{-1} of sulphuric acid was applied, while the maximum number of nodes (5.2) was observed at a sulphuric acid dose of 30 L ha^{-1}. Furthermore, when comparing the results to the control group with no sulphuric acid application, all the sulphuric acid doses (10 L ha^{-1}, 20 L ha^{-1}, 30 L ha^{-1}, and 40 L ha^{-1}) resulted in higher plant height and total number of nodes per plant (Table 4). Therefore, it can be concluded that the application of different doses of commercial sulphuric acid on seed cotton had a positive effect on the growth parameters of cotton (plant height and nodes per plant) compared to the control group with no sulphuric acid application. However, the constant nitrogen application did not show any significant influence on these growth parameters.

The effect of combined use of different doses of nitrogen, and commercial sulphuric acid treated seed cotton was studied. Plant height and the total number of fruiting parts per plant (including flowers, bolls, and buds) were measured for each combination. The results indicated that as the nitrogen dose increased from 0.00 to 40.0 kg ha^{-1}, and the sulphuric acid dosage ranged from 20.0 to 40.0 L ha^{-1}, both plant height and the total number of fruiting parts per plant increased (Table 5). The highest mean plant height (63.7 cm) and the total number of fruiting parts (24.3) were observed at the highest nitrogen dose (125 kg ha^{-1}) and 40.0 L ha^{-1} sulphuric acid. Overall, the combined application of nitrogen and sulphuric acid positively influenced the plant height and fruiting parts per plant.

Table 4 Effect of different doses of commercial sulphuric acid and nitrogen (75 kg/ha) on seed cotton yield

Commercial sulphuric acid (L ha^{-1})	Nitrogen (kg ha^{-1})	Plant height (cm)	Nodes per plant
0.00	75	707	3.4
10.0	75	802	4.0
20.0	75	808	5.0
30.0	75	808	5.2
40.0	75	9.0	4.4

Sub-effect of commercial sulphuric acid in cotton

Table 6 shows the effects of different levels of commercial sulphuric acid on cotton plants. The research findings are presented in terms of plant height (measured in centimeters) and the overall count of fruiting components per plant, encompassing flowers, bolls, and buds. With a rising application of sulfuric acid, a consistent trend emerges showing heightened plant height and an increased total number of fruiting components per plant. For instance, at 0 kg ha^{-1} of sulfuric acid, the average plant height measured 55.6 cm, and the total number of fruiting components per plant was 20.7. In contrast, with the application of 40 kg ha^{-1} of sulfuric acid, the plant height increased to 67.3 cm, and the total number of fruiting components per plant rose to 26.2. This indicates a positive impact attributed to the application of commercial sulfuric acid on cotton plants, resulting in taller plants with a greater abundance of fruiting components, ultimately contributing to an improved seed cotton yield.

Table 5 Effect of combined use of different doses of nitrogen and commercial sulphuric acid on seed cotton yield

Nitrogen (kg ha^{-1})	Sulphuric acid (L ha^{-1})	Plant height (cm)	Total number of fruiting parts per plant (Flowers + Bolls + Buds)
	0.00	50.6	19.4
	10.0	61.8	20.0
75	20.0	63.4	20.8
	30.0	63.8	24.2
	40.0	67.8	26.4
	Mean	62.0	22.1
	0.00	57.4	21.2
	10.0	61.0	21.4
100	20.0	62.6	22.8
	30.0	66.6	24.6
	40.0	62.6	25.6
	Mean	62.0	23.1
	0.00	55.8	21.4
	10.0	58.8	23.6
125	20.0	62.8	24.0
	30.0	69.8	26.2
	40.0	71.6	26.8
	Mean	63.7	24.3

Table 6 Sub-effect of commercial sulphuric acid on seed cotton yield

Sulphuric acid (kg ha^{-1})	Plant height (cm)	Total number of fruiting parts per plant (Flowers + Bolls + Buds)
0.00	55.6	20.7
10.0	60.5	21.6
20.0	62.9	22.5
30.0	66.7	25.0
40.0	67.3	26.2

Discussion

Appropriate agronomic practices are the crucial factors for enhancing cotton productivity. Farm management practices like variety, sowing date, plant population, fertilizer and insecticide use affect the quantity and quality of cotton crop. Cotton-wheat cropping system is being dominating in Pakistan, planting of wheat is delayed due to un-availability of land due to late maturity which in turn affects the wheat yield. Enhancing earliness in cotton has been focused on most of the cotton breeding programs (Bang et al., 2006). Early maturity enables cotton crop to escape unfavorable environmental conditions, insect injuries, minimize use of chemical pesticides along with other inputs like irrigation water and fertilizer. Plant spacing is a key factor to optimize the crop profitability (Zaxos et al., 2012). Optimal plant population plays a critical role in achieving high yields, as it directly impacts factors such as radiation interception, moisture availability, wind movement, and humidity (Heitholt et al., 1992). These, in turn, influence canopy height, branching pattern, fruiting behavior, crop maturity, and overall yield. Maintaining an appropriate plant density facilitates the efficient utilization of applied fertilizers and irrigation resources (Abbas, 2000). It is worth noting that the influence of plant density on earliness may be of greater economic significance than its impact on yield (Zaxos et al., 2012).

The utilization of a well-balanced fertilizer has proven to be instrumental in enhancing agricultural productivity. Nitrogen (N) plays a central role in the management of cotton production regulating photosynthesis and stimulating the production of energy-rich compounds in dry matter. However, improper management of nitrogen can adversely affect final yield and N use efficiency (Rutto et al., 2013). The influence of nitrogen extends to both vegetative and reproductive growth with its deficiency leading to reduced yield through the acceleration of premature leaf senescence (Fageria & Baligar, 2005). Conversely, an excess of nitrogen can impede crop maturity, promoting issues such as boll shedding, diseases, and insect damages (Oosterhuis, 2001). The success of a crop is contingent upon maintaining economically optimal levels of nitrogen fertilizers (Firbank, 2005). It is noteworthy that tillage practices in various agro-climatic regions exhibit differential responses to the application of mineral fertilizers (Prasad, 2000). Therefore, there persists a continual necessity to ascertain the ideal nitrogen levels for local cotton cultivars especially in the face of an ever-changing environment. Soil aeration increases the vegetative and reproductive growth of different crops. Results of the present studies revealed that inter-culture followed by chiseling, irrigation, phosphatic fertilizer and sulphuric acid application had synergistic effect on vegetative and reproductive growth in cotton. These results are confirmatory to the findings of Firbank (2005).

Cotton is characterized as an indeterminate crop with an extended growing season. The application of nitrogen in a timely manner through split application strategies may have significantly increased the plant-1 dry matter accumulation (DMA), consequently contributing to elevated yields and a higher relative growth rate in cotton. The reliance on the accumulation of dry matter for enhanced performance has been acknowledged in earlier investigations (Giri et al., 2014). The increased number of branches per plant can be attributed to the application of nitrogen fertilization. Nitrogen assumes a critical role in enhancing the leaf area index (LAI), thereby facilitating plants to generate more branches. Numerous studies have confirmed this phenomenon (Saleem et al., 2010; Ali & Hameed, 2011; Main et al., 2014). Additionally, nitrogen's influence on LAI causes the promotion of protein synthesis crucial for cell development, proliferation, and the constitution of the cell wall and cytoskeleton. The observed elevation in LAI with ever-increasing nitrogen concentrations, particularly within the 0 to 225 kg ha^{-1} range, highlights the affirmative impact of nitrogen on cotton growth, development, and vegetative constituents (Gundlur et al., 2013). However, it is remarkable that increased nitrogen uptake resulted in a major emphasis on vegetative growth at the expense of reproductive growth. Conversely, reduced nitrogen levels led to low LAI due to the insufficient fulfillment of assimilate requirements in the growing segments (Norton & Silvertooth, 2007; Munir et al., 2015). The beneficial influence of nitrogen on cotton growth and development can be explained by the simultaneous augmentation in dry matter accumulation with increased nitrogen concentrations (Gundlur et al., 2013). Previous research confirms the idea that an optimal and satisfactory nitrogen supply encourages cell elongation, thereby fostering greater vegetative growth and more cotton dry matter (Sunitha et al., 2010). In contrast to circumstances with higher nitrogen levels, insufficient nitrogen, especially in nitrogen-depleted soil, may hamper cell elongation, reducing plant vegetative growth and leading to lower dry matter accumulation (Reddy et al., 2004; Munir et al., 2015).

Conclusion

The findings of this research study provided important new information about how phosphatic fertilizer use, irrigation intervals, chiseling, and commercial sulfuric acid and nitrogen use affect cotton plant growth. These findings demonstrated that plant height and the quantity of fruiting parts per plant were significantly influenced by both chiseling and irrigation intervals. When compared to other treatment combinations, the combination of chiseling and interculturing, along with an 8-day irrigation interval, produced the best results in terms of plant height and total fruiting parts per plant. The study also revealed the beneficial long-term effects of phosphatic fertilizer application in past wheat crop on cotton plant height and fruiting parts. Different phosphorus delivery techniques in bed-furrow planting showed varying impacts on plant height and fruiting parts; the best technique was to manually apply the fertilizer before sowing without mixing. In conclusion, this study's findings show potential for developing practical cotton-growing practices that would maintain Pakistani cotton farmers' profitability and productivity. To maximize cotton production and support the socioeconomic growth of the area, more research on farm management techniques must be carried out, and the agricultural community must be informed of these developments.

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