RESEARCH ARTICLE

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Effects of Shoot Apex Removal on Growth and Yield Attributes of Cotton

Z.A. Awan, M. Saleem, L.A. Khan, A.U. Imran

ABSTRACT

The current study was designed to investigate the effect of shoot apex removal on the growth and yield attributes of the cotton crop. A field experiment was conducted in the cotton-growing season (2020-2021) at Muzaffargarh, district of South Punjab. The field trial was comprised of two acres of land where one acre of land was considered as treatment (cotton plants with shoot apex removal) and the other acre of land served as a control plot (cotton plants without shoot apex removal). The data were collected fortnightly (1st, 2nd, 3rd, 4th and 5th times) from the randomly selected cotton plants (n=50) from the treated and control plot after fifteen days of treatment (shoot apex removal). The data were comprised of vegetative parameters (i.e., plant height, no. of nodes and leaves), reproductive parameters (i.e., no. of squares, flowers, immature/mature bolls, the opening of bolls and boll weight) and cotton fiber quality parameters [i.e., fiber length, strength, finesse and GOT (ginning outturn)]. Descriptive analysis was employed on all data recorded through an independent two-sample *t-test* to evaluate the positive effect of shoot apex removal in cotton production. Our results indicated that after removing the top shoot of the cotton plants, greater effects had started to occur in the treated plants such as vegetative growth had become significantly (at $p \leq 0.001$) slow down and reproductive growth considerably (at $p \leq 0.01$) enhanced. Besides, removal of the shoot apex in cotton plants has developed resistance against the sucking pest i.e., pink bollworm infestation significantly reduced by 50% and whitefly population has lessened by 11%. The results also indicated that this treatment significantly augmented (at $p \leq 0.01$) the boll weight by 12%, as well as improved the cotton fiber length, strength and fineness by 7% as compared to the normal cotton plant. It was concluded that shoot apex removal caused cotton plants to produce numerous lateral shoots to develop more branches to carry more cotton bolls on them eventually significantly enhancing the cotton yield by 13% (18 monds acre^{-1}) as compared to the control plot. It can be suggested that the practical implementation of removing the shoot apex of the cotton plant would act as a promising technique to enhance the cotton yield.

Keywords: *Gossypium hirsutum*, Muzaffargarh, shoot apex, quality, yield.

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I. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is one of the most widely cultivated cash crops in tropical and subtropical regions of the world (Zhang *et al*., 2020). It is not only an excellent source of natural fiber but also an edible oilseed crop, in addition to this, the cotton plant can be used for livestock feed and medicinal products (Ullah *et al*., 2017; Egbuta *et al*., 2017). Pakistan is ranked fifth in cotton production around the globe where it accounts for 4.5% in agriculture value addition, serves as the raw material for the textile industry (the country's largest agro-industrial sector) employs 17%, earns 60% of foreign exchange and shares 0.8% in GDP (Rehman *et al*., 2019; Rana *et al*., 2020). In Pakistan, the conventional cotton production system based on the integrated use of synthetic chemicals (fertilizers, pesticides and herbicides) led to over-exploitation of natural resources (Lampridi *et al*., 2019). Knowing the limitations of conventional cotton cultivation, there is a need to employ precise input resources with an alternative technique in cotton production. Because of the high economic importance of this "white gold" crop, considerable attention has been taken into account by conventional plant breeding methods to improve its growth, quality and yield (Razzaq *et al*., 2021).

Shoot apex removal is the practice of removing a plant's growing point (commonly termed pinching) that has been opted to affect the plant growth and productivity (Wien, 2016). Mostly this practice is used to reduce plant height and encourage the growth of secondary shoots, it almost stunted the stem and also affects the reproductive habit of plants. Removal of shoot apex breaks apical dominance due to reduction in auxin levels and allows the lateral shoots to develop and grow like compact flourishing plants with a better flowering and fruiting yield (Müller & Leyser, 2011). Furthermore, due to shoot apex removal the content of cytokinins also improve which act as long-distance signals in regulating the development of secondary growth in stems (Ali *et al*., 2021). Previously it was reported that the yield attributes depend upon the number of branches that bear flowers which can be manipulated by inhibiting the vertical growth and encouraging lateral shoots of plants with the help of pinching (Baskaran & Abirami, 2017). Improved cotton productivity is a key index for evaluating the quality of cotton fiber, and is closely correlated with the effective growth of cotton plants. Research related effect of shoot apex removal on growth, shape and yield attributes of cotton crop has been limited and not documented. Due to scanty literature, cotton growers are unaware of this shoot apex removal technique for the maximization of yield attributes. The overall goal of this research was to evaluate the effect of shoot apex removal on plant growth, shape and yield attributes of cotton production in Muzaffargarh, Punjab. Therefore, the objective of this study was to clarify and summarize the effects of shoot apex removal on vegetative, reproductive and quality parameters of cotton yield.

II. Experiment Methodology

A. *Study Site*

Core cotton zone Muzaffargarh, district of southern Punjab was selected to conduct the field experiment for cotton cultivation. Where, Punjab is the leading producer of cotton and accounts for about 80% share of Pakistan's total cotton production (Khan *et al.*, 2021). A field trial was carried out for cotton cultivation in Muzaffargarh (30° 4' 27.7572" N, 71° 11' 4.7544" E) in the cotton cropping years 2020-2021 (Fig. 1). Muzaffargarh is one of the major contributing districts of Punjab with the production of 430.63 thousand bales during 2019-20 which makes 6.31% of Punjab. It was piloted by WWF-Pakistan's Better Cotton projects under the Sustainable Agriculture and Food Programme (SAFP).

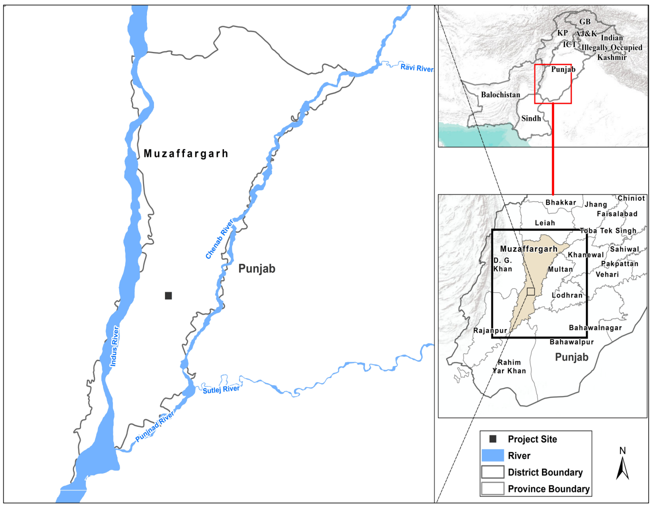

Fig. 1. GIS Map of the experimental site at Muzaffargarh Southern Punjab, Pakistan.

B. *Field Trial*

The total experimental area for the field trial was about two acres (8093.71 m^2). To keep the homogeneity, the field was separated by a water channel into two main plots, an acre plot was considered as a treated/project plot and the other acre was considered as a control plot. The land was plowed with chisel plough (3-times) and rotavator (1-time), leveled with simple land leveler and ridges were formed. The same variety of cottonseeds named IUB-13 was sown in both plots with a rate of 6 kg $acre^{-1}$ by maintaining plant to plant (0.228 m) and row to row (0.762 m) distance. To fulfill the nutrient requirement, field soil was supplemented with a uniform rate of plant fertilizers viz., diammonium phosphate (DAP): 50 kg $acre^{-1}$ and urea: 100 kg $acre^{-1}$. For pest management, cotton crop was sprayed 6-times with different pesticides (i.e., names) against common pests (whitefly and pink bollworm) based on fortnightly pest scouting. Furthermore, the land was uniformly irrigated 11-times. Basic trial information was mentioned in Table I.

TABLE I: FIELD TRIAL LAYOUT AND MANAGEMENT PRACTICES

Plot Size	1 acre	1 acre
Land preparation		
Chisel plough	3-times	3-times
Rotavator	1-times	1-time
Land leveling	simple leveler	simple leveler
ridges formation	ridger	ridger
Variety	IUB-13	IUB-13
Sowing date	03 May 2020	03 May 2020
Seed rate	6 kg $acre^{-1}$	6 kg $acre^{-1}$
Cultivation practices		
Plant to plant distance	0.228 m	0.228 m
Row to row distance	0.762 m	0.762 m
Thinning	Yes	Yes
Gap filling	No	No
No. of irrigation	11	11
Fertilizer application		
DAP	50 kg $acre^{-1}$	50 kg $acre^{-1}$
Urea	100 kg $acre^{-1}$	100 kg $acre^{-1}$
Pesticide application	6 different	6 different
Tagged plants	N=50	N=50

After 80-days of plant vegetative growth, the cutout stage was identified to remove the shoot apex of cotton plants because it changes plant behavior from vegetative to reproductive phase (flowering to fruiting). The cut-out stage is the specific stage of the cotton crop in which the crop focuses on reproductive growth by supplying more food to the fruit (cotton bolls). At this stage, removal of shoot apex was done to access its impact on growth and productivity of cotton crop by improving shape and weight of cotton boll as well as fiber traits. Removal of shoot apex was done after the plant completes its optimal growth at approximately a height of 5 ft (1.524 m).

An eye was kept on the crop growth to observe and count the appearance of flowers and emerging squares. As the average no. of squares reached the maximum level and the whitefly reached by 4-5 per leaf the plant showed a cut-out stage. From each main plot, about 50 plants were randomly selected and tagged (with yellow cards). From the treatment plot, tagged cotton plants were used to remove the shoot apex with suitable equipment such as a sickle reaping hook.

C. *Studied Parameters and Data Collection*

Data regarding vegetative parameters per plant such as plant height (m), no. of nodes and no. of leaves; and reproductive parameters per plant such as no. of squares, no. of flowers, no. of immature & mature bolls and weight of cotton bolls (g) was recorded fortnightly (5-times) after 10 days of shoot apex removal. The studied attribute viz., plant height was measured from the base of plant soil up to plant tip through a measuring tape. Besides, the magnifying lens was also used to observe the pest attack for pest scouting i.e., whitefly infestation at vegetative stage and pink bollworm at reproductive stage. For this, randomly selected cotton bolls (n=100) from each treatment were collected and dissected to check the infestation of pink bollworm. Moreover, about 100 cotton bolls from the tagged plants were randomly collected from each plot to calculate the average boll weight (g). Hence, the maximum average cotton yield of the tagged cotton plants from both plots was used to computed the maximum cotton yield per acre (mond). For qualitative parameters of cotton fiber such as fiber length (mm), fiber strength (g tex^{-1}) and fiber finesse (µg $inch^{-1}$) were assessed by Central Cotton Research Institute (CCRI), Multan. Besides, ginning outturn (GOT: %) was computed by Romi Cotton Factory, Muzaffargarh and findings are presented in tables.

D. Data Analysis

The recorded data were summarized, tabulated and analyzed via descriptive analysis using computer software Statistical Package of Social Science (SPSS) version 25. All the mentioned parameters (vegetative, reproductive and qualitative) of the tagged plants in both plots (treated: with shoot apex removed cotton plant & control: normal cotton plant) were estimated by an independent two-sample *t-test* assuming equal variances for comparing the mean values.

III. Results & Discussion

A. Assessment of Vegetative Parameters

Our results revealed that there is a non-significant difference was found in vegetative parameters (plant height, number of nodes & leaves) at 1st data collection date (4th Sep 2020) between the control and treatment plot (Table II). It was noticed that the plant height of normal plants in the control plot was high as compared to the detopped plant (treated: shoot apex removed) in the treatment plot. Results showed that after fifteen days of shoot apex removal the average plant height on the first data collection date (4th Sep 2020) was 71.62 inches (1.82 m) in the treatment plot was not significantly different from the plant height in the control plot. Subsequently, plant height was gradually increased to 75.02 inches (1.91 m) in the normal cotton plant of control plot but stopped to 66.10 inches (1.68 m) in the treated (shoot apex removed) cotton plant till the last date of data collection (05th Nov 2020). Hence, it showed a significant reduction of plant height by 12% at $p \le 0.001$ in the treatment plot as compared to the normal cotton plant.

In previous studies, it was noticed that removal of shoot apex stimulates growth hormone i.e., cytokinins to trigger the lateral shoots to start growth and ultimately it suppresses apical dominance that controls plant height and removes a metabolic sink in plants (Sunitha *et al*., 2007; Ferguson *et al*., 2009; Müller, and Leyser, 2011). Resulting in decreased auxin production and increased nutrient distribution into and growth of the lateral shoots (Ohta & Ikeda, 2016). Likewise, various studies reported the reduction in plant height with shoot apex removal in different species of plants (Bazargani *et al*., 2011; Baskaran & Abirami, 2017). The average number of nodes was significantly reduced by 16% in a pinched cotton plant as compared to a normal plant till the last date of data collection. In contrast, the average number of leaves was significantly high by 20-30% from the 2nd date to the last date of data collection showed that vegetative growth was improved laterally in detopped plants and the process of food preparation enhanced (Table II). Bazargani *et al*. (2011) reported that the formation of multiple shoots will be promoted by a balance of auxin and cytokinin. Since hormone balance is presumably important to the overall effect on growth and morphological changes. By removing the shoot apex auxins concentration reduces that hampers upward plant growth and the lateral shoots trigger to grow as a result the number of branches as well as the number of leaves increased (Habiba *et al*., 2012). The current finding is also in line with those of Ali *et al*. (2021), Ona *et al*. (2015) and Sharaf-Eldien *et al*. (2017), who documented that removal of the shoot apex in several ornamental plants increased the number of leaves $plant^{-1}$.

Table II: EFFECT OF SHOOT APEX REMOVAL ON VEGETATIVE ATTRIBUTES OF COTTON PLANT FORTNIGHTLY

Data collection		Plant Height	No. of Nodes	No. of leaves
	Field plot	Studied parameters $plant^{-1}$		
1st Data	Control	71.62	52.88	143.96
	Treatment	73.06^{ns}	52.96^{ns}	153.28^{ns}
2nd Data	Control	73.42^{***}	56.04^{***}	147.72
	Treatment	66.10	48.92	178.80^{***}
3rd Data	Control	74.76^{***}	58.04^{***}	118.8
	Treatment	66.10	48.92	141.00^{***}
4th Data	Control	75.04^{***}	57.96^{***}	42.44
	Treatment	66.10	48.92	55.20^{***}
5th Data	Control	75.00^{***}	57.92^{***}	11.56
	Treatment	66.10	48.92	15.12^{***}

Note: The significance values * at $p \le 0.05$; ** at $p \le 0.01$; *** at $p \le 0.001$; ns at the non-significant level for two-group mean comparison t-test assuming equal variances.

B. Assessment of Reproductive Parameters

Results showed that after shoot apex removal reproductive stage of the cotton plant progressed (Table III). Initially, the average number of squares in the control plant is non-significantly higher among cotton plants (treated and control). After shoot apex removal, the number of squares (n=17) gradually increased by 31% at 2nd data collection, 22% (n=7) at 3rd data collection and eventually no square has found till the last data collection date. This would be due to the increase of nutrient uptake since the distribution of some mineral nutrients was changed by the removal of the shoot apex (Xi *et al*., 2005; Pandet *et al*., 2021). Hence, the availability of nutrients exerted a significant influence on several squares at the flowering stage in the cotton crop (Vani *et al*., 2020).

Likewise, the average number of flowers has been significantly high by 30% (at $p \le 0.001$) in treatment plants right after removal of the shoot apex as compared to the normal plant from the control plot. It was noticed that number of flowers per plant was increased during the 1st-4th times of data collection (29%, 33%, 27% and 25%) and eventually flowering stage stopped till the 5th data collection. The number of flowers is directly related to the number of lateral branches. Shoot apex removal suppressed apical dominance and ultimately enhanced several lateral shoots that consequently increases the number of flowers (Swapna *et al*., 2008). Ohta and Ikeda (2016) and Ohta (2017) also reported that after the shoot the apex removal the number of flowers was notably increased due to the relatively greater availability of photosynthetic products and mineral nutrient uptake by increasing the leaf areas of lateral shoots. Our results are in line with Pandey *et al*. (2021), who reported the maximum number of flowers plant^{-1} (237.49 g) was obtained after shoot apex removal as compared to the non-shoot apex removal plant (213.35 g). Likewise, Mohanty *et al*. (2015) and Sarkar *et al*. (2018) recorded the maximum yield per ha at pinching in the ornamental plant (African marigold varieties).

Moreover, the average number of immature and mature cotton bolls were significantly high 6-8% in detopped plant as compared to the normal plant. It was observed that during the 2nd-4th times of data collection the number of immature bolls was significantly high by 17% and 12% in a treated plant as compared to the control plant. While the average number of mature cotton bolls at the 4th time of data collection was the maximum by 24% in detopped plant as compared to the normal plant.

The study also focused on the opening of mature bolls, detopped plants were showed significantly higher numbers of opening cotton bolls under the effect of shoot apex removal as compared to the normal plant. The maximum number of opening bolls were counted in a treated plant which was significantly high by 16%, 32% and 56% on the 2nd, 3rd and 4th date of data collection, respectively (Table III). Likewise, Vani *et al*. (2020) documented that switching of vegetative growth towards the reproductive stage with the removal of shoot apex and availability of nutrients eventually enhanced the number of cotton bolls.

TABLE III: EFFECT OF SHOOT APEX REMOVAL ON REPRODUCTIVE ATTRIBUTES OF COTTON PLANT FORTNIGHTLY

Data Collection		No. of squares	No. of flower	No. of immature bolls	No. of mature bolls	No. of open bolls
	Field plot	Studied parameters plant^{-1}				
1st Data	Control	12.12	1.92	7.04^{ns}	5.44^{ns}	0.12^{ns}
	Treatment	11.08^{ns}	2.48**	6.32	5.08	0.08
2nd Data	Control	12.96	2.04	8.48	4.2	6.2
	Treatment	17.00***	2.72***	9.96**	4.84**	7.2*
3rd Data	Control	6.04	2.48	8.08	7.56	0.76
	Treatment	7.36*	3.16***	9.04*	7.84*	1.00**
4th Data	Control	0.56	0.48	2.40	2.32	2.00
	Treatment	2.52***	0.60^{ns}	2.68^{ns}	2.88^{ns}	3.12***
5th Data	Control	0.00	0.00	0.00	0.00	0.00
	Treatment	0.00	0.00	0.00	0.00	0.00

Note: The significance values * at p≤0.05; ** at p≤0.01; *** at p≤0.001; ns at non-significant level for two-group mean comparison t-test assuming equal variances.

Besides, our results showed that the average boll weight from tagged plants (n=50) in the treatment plot was significantly high by 12% at p≤0.01 as compared to the control plot. Average boll weight was measured as 2.60 g boll^{-1} and 53.66 g plant^{-1} from a treated plant, while 2.39 g boll^{-1} and 47.88 g plant^{-1} from a normal cotton plant in the control plot. Hence, cotton yield (mond) per acre of each plot has been computed by multiplying the weight of yield per plant with the total number of plants per acre. Results revealed that the maximum yield of about 18 monds is expected from the cotton cultivation under the effect of shoot apex removal is notably high by 13% as compared to the normal cotton cultivation (16 monds).

C. Assessment of Pest Infestation

For pest scouting, whitefly infestation was assessed during 5-times of data collection and the overall data revealed that the whitefly population was lessened by 11% in detopped plants as compared to normal cotton plants in the control plot. Moreover, a significant reduction (at p≤0.01) of whitefly infestation was found at 3rd time of data collection that was 21% followed by a 13% reduction in whitefly count at 4th-time of data collection in detopped plants as compared to untreated plants (Fig. 2). While the infestation of pink bollworms was considerably reduced by 53% from the cotton bolls of the treated plant as compared to the untreated plant.

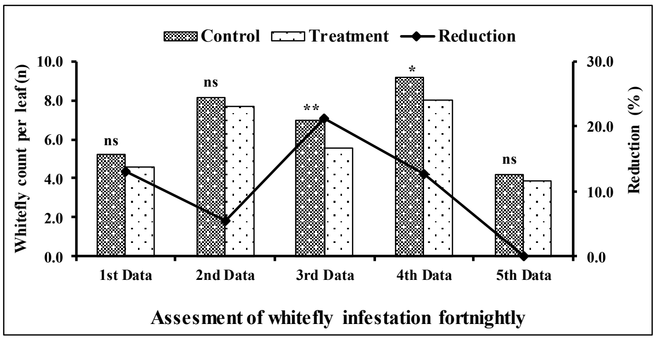

Fig. 2. Effect of shoot apex removal on whitefly infestation in cotton plant fortnightly.

Note: The significance values * at p≤0.05; ** at p≤0.01; ns at non-significant level for two-group mean comparison t-test assuming equal variances.

D. Assessment of Qualitative Parameters of Cotton Lint

The findings of qualitative testing of cotton lint showed that cotton fiber length, strength and finesse were considerably high by 7% collected from the treated plant as compared to the cotton fiber of the normal plant. Likewise, the results of ginning outturn (GOT: %) displayed that GOT of cotton fiber from detopped plant was 36% while GOT cotton fiber from the normal cotton plant was 34% that is 6% reduced.

IV. Conclusion

Based on the findings of this experiment, it was concluded that after the uniform distribution of input resources (seed rate, fertilizers, pesticides, irrigated water) in both plots (control & treated) for cotton cultivation, the plants with shoot apex removal (in treatment plot) showed considerable positive effects on vegetative growth, lower the level of pest infestation, improved reproductive growth with enriched yield attributes. It is estimated that yield attributes were considerably enhanced with the increase in bolls maturity after shoot apex removal which can significantly enhance the cotton yield per plant and yield per acre.

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Conflict of Interest

Authors declare that they do not have any conflict of interest.

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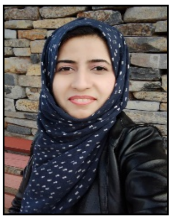

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