The Pharma Innovation Journal 2023; 12(6): 4569-4575

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 4569-4575

www.thepharmajournal.com
Received: 15-03-2023
Accepted: 18-04-2023

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Effect of fertigation levels and canopy management practices on growth, yield and economics of Bt cotton (*Gossypium hirsutum* L.)

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Abstract
A field experiment was conducted during the year 2021-22 at Cotton Research Unit Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the effect of fertigation levels and canopy management practices on growth and yield of Bt cotton. The experiment was laid out in Split Plot Design with three replications and sixteen treatment combinations. The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 120 cm with 50 cm dripper spacing. The results of present investigation revealed that, PDKV-JKAL-116 (BG-II) Bt hybrid had better crop growth, yield attributes, and seed cotton yield than PKV-Hy-2 Bt genotype under drip irrigation. The seed cotton yield was significantly highest in genotype PDKV-JKAL 116 Bt (BG-II) (3844 kg ha^{-1}). Among the nutrient management, application of 125% N and K ha^{-1} applied through drip fertigation produced significantly higher seed cotton yield of 3734 Kg ha^{-1} as against the seed cotton yield of 3416 $Kgha^{-1}$ in lower dose of 100% N and K in four splits. Canopy management data of this study indicates that, canopy management practices like monopodia removal at 60 DAS and de-topping at 75-80 DAS had advantage to produce higher seed cotton yield than no canopy management. Significantly highest seed cotton yield of 3963 $kgha^{-1}$ was recorded in the treatment of monopodia removal at 60 DAS and de-topping at 75-80 DAS) followed by SCY of 3610 $kgha^{-1}$ in the treatment of monopodia cutting at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS. Monopodia removal at 60 DAS and de-topping at 75-80 DAS registered 18.60% yield increase over no canopy management (Control). Genotype PDKV-JKAL-116 (BG-II), 125% fertigation level and canopy modifications practice (monopodia removal and detopping) reflected in increasing the GMR, net monetary returns and B: C ratio compared to farmers practice (control).

Keywords: Bt cotton, drip, fertigation, canopy management, nutrient management**,** detopping, monopodia removal, PGR, economics

1. Introduction
Cotton (*Gossypium hirsutum* L.) is the most important fibre crop of world with significant role in Indian agriculture, industrial development, employment generation and contribution to the national income. Productivity of cotton largely depends upon the availability of high yielding varieties and hybrids along with improved agronomic production technologies. Though release of Bt cotton in the country increased the productivity of the crop, several other production factors may help further upgrade the productivity. Some situations such as high soil fertility, addition of chemical fertilizers and irrigation water management practices lead to more of vegetative growth and resultant competition for natural resources. Under optimum growing conditions, cotton crop produces excess vegetative biomass that is often associated with reduced yield (Heitholt 1994) [8]. A dense and lavish growth causes abnormal shedding of young fruiting bodies like buds, flowers and bolls, delayed maturity, boll rot (due to shading), and reduced yield (Zhao and Oosterhuis 2000) [27]. Growth modification practices therefore become important by converting its phase of vegetative to reproductive growth to ensure a proper nutrient source-sink relationship.
Managing the equilibrium between vegetative and reproductive growth is an important part in cotton production. This can be achieved by detopping and pruning/removal of monopodial branches. Detopping is the removal of top terminal portion after prominent vegetative growth stage. This may encourage growth of already formed sympodial as well as formation and development of fruiting bodies. Detopping may also help to reduce sucking pests and bollworm infestation, as it avoids fresh growth out let which is unwanted at particular stage.

Hence detopping of cotton after required growth may result in blooming of cotton production. Monopodial branches are always formed at the base of cotton plant. Induction of high number of sympodial branches and thereby increase in number of square and bolls are essential for yield maximization of seed cotton (Dhillion *et al.*, 2006) [3]. Therefore, there is need to manipulate the growth of cotton to get good architecture by monopodia removal, so that the plant can get required sunlight with minimal mutual shading (Shwetha *et al.*, 2009) [22].

As like detopping and pruning of vegetative branches, plant growth can also be modified by the use of plant growth regulators (PGRs) which may help in improving the cotton productivity. PGRs include a broad category of organic compounds that promote, inhibit or modify physiological and/or morphological behaviour of the plant. They have the potential to promote crop earliness, improve square, flower and boll retention, increase nutrient uptake and keep harmony between vegetative and reproductive growth, thus improve lint yield and quality. Growth retardants like mepiquat chloride (MC) is known to reduce internodal length, thereby, reducing plant height and stimulating the translocation of photosynthates towards reproductive sinks (bolls), all of which result in higher yields (Kumar *et al.*, 2005) [114]. The most used growth regulator in cotton is mepiquat chloride, which is an inhibitor of gibberellic acid. This curtails excessive vegetative growth and increases cotton yield and quality (Ren *et al.*, 2013) [18]. Sadhana Kumari (2021) [19] also highlighted the increase in seed cotton yield with use of mepiquat chloride. It is necessary to focus on crop monitoring, nutrient management and plant canopy management with an objective to increase the harvest index. In view of this hypothesis, the experiment was conducted with an objective to characterize the growth and development of *Bt* cotton hybrids by detopping, pruning of vegetative branches and use of plant growth retardants for improving cotton productivity with split application of nitrogen under drip irrigation.

2. Materials and Methods

The field experiment entitled "Response of Bt cotton to split application of nutrients and canopy management under drip irrigation" was conducted during the year 2021-22 at Cotton Research Unit Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with an objective to study the growth and development of Bt cotton hybrids by de-topping, pruning of vegetative (monopodial) branches and use of plant growth retardants for improving cotton productivity with split application of nutrients (N and K) under drip irrigation. The experiment was laid out in Split Plot Design with three replications and sixteen treatment combinations of Bt genotypes (PKV-Hy-2 BG-II and PDKV-JKAL-116-BG-II), nutrients levels i.e. 100 per cent and 125% recommended N and K fertilizers through fertigation and canopy management practices i.e.C1- Control,C2-Monopodia cutting at 60 DAS and detopping at 75-80 DAS, C3- Monopodia cutting at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS and C4- Spraying of mepiquat chloride 5% w/w at 75 DAS.

The topography of the field was fairly uniform and level. The soil of the experimental field was black and clayey in texture belonging to vertosols and slightly alkaline in reaction (8.2), Low in available nitrogen (170.0 kg ha^{-1}), medium in phosphorus (19.18 kg ha^{-1}), organic carbon (0.52%), and fairly rich in available potassium (308 kg ha^{-1}). The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 120 cm with 50 cm dripper spacing. The cotton crop was sown on 10th June, 2021 at the spacing of 120x45 cm with RDF of 120:60:60 Kg NPK ha^{-1}. Irrigation water was applied through drip irrigation system on every alternate day based on cumulative pan evaporation. The drip irrigation water to be applied plant-1 was determined by the formula given by Michael (2008) [16]. The sources of nutrients were urea (46% N), single super phosphate (16% P_2O_5), and murate of potash (60% K_2O) for nitrogen, phosphorus and potash, respectively. The fertilizer was applied as per the treatments. The total dose of phosphorus was applied as basal dose in all the treatments and N and K was applied at sowing and at 30 days interval in unequal splits as per the crop growth stages of cotton as below. The N and K fertilizers was applied in four unequal splits as 20% at sowing, 30% each at 30 & 60 DAS, and 20% at 90 DAS growth stages of cotton (Table 1). The fertilizer was given through fertigation by ventury.

Table 1: Splits of nitrogen and potassium fertilizers

N & K fertilizer dose	Quantity of N& K	No. of splits	Stage of Crop
100% N and K	120 Kg N& 60Kg K	4 splits	--
		20% N & K	Sowing
		30% N& K	30 DAS
		30% N& K	60 DAS
		20% N& K	90 DAS
125% N and K	150 Kg N& 75 Kg K	4 splits	--
		20% N& K	Sowing
		30% N& K	30 DAS
		30% N& K	60 DAS
		20% N& K	90 AS

3. Results and Discussion

The results of the present study as well as relevant discussion have been summarized under following heads:

3.1 Growth parameters, Yield attributes and seed cotton yield

3.1.1 Performance of Bt cotton genotypes

The data presented in Table 2 indicated that among the genotypes, significantly highest values of plant height, sympodial branches and sympodial length was recorded in PDKV-JKAL 116 Bt (BG-II) genotype. The maximum dry matter partitioning of leaves, stem and fruiting bodies in PDKV-JKAL 116 Bt (BG-II) reflected in significantly highest total dry matter at harvest (409.46 g) in PDKV-JKAL-116 Bt hybrid than PKV Hy-2 (BG-II) Bt (382.05 g). The optimum accumulation of dry matter followed by adequate partitioning

of assimilates to the developing sinks enables the crop to attain its true yield potential. Similarly, all the yield attributing characters *viz*, number of bolls picked per plant (57.86), seed cotton yield per plant (228.27) and boll weight (5.27 g) were found significantly superior in PDKV-JKAL 116 Bt (BG-II) genotype than PKV Hy-2 (BG-II) Bt cotton. The extent of number of bolls picked per plant with JKAL-116 was 27.11 per cent than PKV-Hy 2 genotype.

All the significant yield attributes of cotton resulted in higher seed cotton yield in PDKV-JKAL 116 Bt (BG-II) genotype than PKV-HY-2 (Table-2). The seed cotton yield was significantly highest in genotype PDKV-JKAL 116 Bt (3844 kg ha^{-1}) which was found significantly superior over genotype PKV-Hy 2 Bt (3306 kg ha^{-1}). There was 13.99 per cent yield increase in PDKV-JKAL-116 than the PKV-Hy 2 genotype. The results obtained by Srinivasulu *et.al*. (2006) [24] also emphasize the same point and they observed the significant difference in different cotton hybrids in respect of growth and yield attributes. Similar and significant results regards to stalk yield and biological yield was registered in. PDKV-JKAL-116.All the significant increase in growth and yield attributes and maximum seed cotton yield resulted in maximum harvest index of 41% in case of genotype PDKV-JKAL-116 Bt followed by harvest index of 39% in PKV Hy-2 (BG-II) genotype.

3.1.2 Effect of split application of nutrients through drip fertigation on cotton

Among the nutrient levels 125 per cent N and K in four splits (150 Kg N& 75 Kg K) at sowing, 30, 60 and at 90 DAS reported significantly highest values of plant height, sympodial branches and sympodial length, which might be due to enhanced availability and uptake of nutrients leading to enhanced photosynthesis, expansion of leaves and translocation of nutrients to the reproductive parts as compared to lower levels of fertigation method. These results are in conformity with findings of Jena and Aladakatti (2017) [10], Kakade *et al.* (2017) [11], The maximum dry matter per plant (404.72 g) was recorded in higher nutrient dose of 125% N and K than 100% N and K in four splits than PKV N1i.e.100% N and K (386.79 g) as shown in Table 2.Similarly, all the yield attributing characters *viz*, number of bolls picked per plant (53.45) and seed cotton yield per plant (224.03) was found significantly superior in higher dose of fertilizer application through drip irrigation than lower dose of 100% dose of N and K given through fertigation. The increase in more number of bolls per plant under higher level of fertigation might be due to enhanced availability and uptake of nutrients to enhance photosynthesis, expansion of leaves and translocation of nutrients to reproductive parts as compared to lower rate of N and K given through fertigation. Similar advantage of higher level of fertigation of nutrients in improving the number of picked bolls per plant and weight of seed cotton per plant were reported earlier by Sahadeva Reddy and Aruna (2010) [21], Bhalerao *et al.* (2011) [1] and Gokila (2012) [5].

The increase in seed cotton yield per plant attributed to increased number of picked bolls per plant and numerically higher boll weight with higher level of N and K fertigation. The boll weight was found non-significant, however numerically maximum boll weight of 5.08 g was recorded in V2(125% N and K).Among the nutrient levels, application of 125% N and K ha^{-1} applied through drip fertigation produced significantly higher seed cotton yield of 3734 Kg ha^{-1} as indicated in Table 3 as against the seed cotton yield of 3416 $Kgha^{-1}$ in lower dose of 100% N and K in four splits (V1). The extent of seed cotton yield in 125% dose was 8.5% than 100% N and K in four splits. This higher yield in N2 (125% N and K) was mainly due to favourable yield attributes like number of bolls picked per plant, seed cotton yield per plant and overall improved growth due to more fertilizer application in this treatment. There was a significant response to fertigation of 125 per cent recommended dose of N and K ha^{-1} through drip in four splits than other lower level of fertigation (100 per cent). The data regarding stalk yield, seed index and ginning percentage (Table 3) was found non-significant, however total biological yield (9287 $Kgha^{-1}$) was found significantly superior in N2(125% N and K) than N1(100% N and K) with maximum harvest index of 40%. Increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by 125% N and K fertigation and consequent better formation and translocation of assimilates from source to sink might have increased seed cotton yield and harvest index under higher level of fertigation. The results are in conformity with the findings Hadole *et al.* (2012) [6] and Nalayani *et al.* (2012) [17], Thakare *et al.* (2017) [25] and Lavanya *et al.* (2021) [15].

3.1.3 Response of Canopy Management in Bt cotton

Different canopy management practices (Monopodia removal, detopping and spraying of PGR) showed significant differences in all the growth and yield attributes and seed cotton yield. All the growth parameters showed significant response to different canopy management practices. Significantly highest plant height (161.88 cm) was recorded in control treatment where no any canopy management practice was adopted. Lower plant height in other canopy treatments (C2, C3 and C4) was noticed because of detopping and spraying of Mepiquate chloride spray as a growth retardant. However significantly highest number of sympodia (36.81) and sympodial length (49.93 cm) was noticed in the treatment of canopy management where monopodia removal was done at 60 DAS and detopping at 75-80 DAS. The next best treatment in regards to these parameters was C3 i.e. removal of monopodia at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS was done.

Canopy management practice of monopodia removal at 60 DAS with detopping at 75-80 DAS also reflected in significantly highest dry matter accumulation per plant. Significantly maximum total dry matter (410.69) was also recorded in this treatment (C2) followed by 393.44 g total dry weight in C3 (Monopodia removal at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS). Lowest total dry matter was observed in control treatment (C1). Removal of monopodia and suppressing plant height by detopping, helps in initiation of more lateral branches and improving the mobilization of assimilates to reproductive parts thus increasing sympodial branches $plant^{-1}$. These results are in accordance with those reported by Hallikeri *et al.* (2010) [7], Kataria and Valu (2018) [12], Dodiya *et al.* (2018) [4], Chaudhari *et al.* (2021) [2].

Similarly, canopy management practices in cotton reflected superior in all the yield attributing characters (Table 2) *viz*, number of bolls picked per plant (58.30), seed cotton yield per plant (239.43) were found significantly superior in C2

(Monopodia removal at 60 DAS and detopping at 75-80 DAS) except boll weight which was found at par with other canopy treatments, but numerically maximum boll weight of 5.23 g was registered in canopy management practice of Monopodia removal at 60 DAS and detopping at 75-80 DAS. The extent of number of bolls picked per plant with JKAL-116 was 27.44 per cent than control treatment.

All the favourable growth and yield attributes in canopy management practices also resulted in increasing the seed cotton yield in all the canopy management practices (C2, C3 and C4) than control (C1) as indicated in Table 2.Canopy modification by removal of monopodia at 60 DAS and detopping at 75-80 DAS had influence on seed cotton yield as compared to no modification in the canopy. Significantly highest seed cotton yield of 3963 kgha^{-1} was recorded in C2 (Monopodia removal at 60 DAS and detopping at 75-80 DAS) followed by SCY of 3610 kgha^{-1} in C3 (Monopodia cutting at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS). However C3 and C4 (Spraying of mepiquat chloride 5% w/w at 75 DAS) were found significantly at par with each other in respect of seed cotton yield. Kaul *et al.*(2016) also reported the positive impact of spraying of Mepiquat Chloride on growth and seed cotton yield in cotton. The best canopy management treatment C2 i.e. Monopodia removal at 60 DAS and detopping at 75-80 DAS registered 18.64% yield increase over control treatment (no canopy modifications).As cotton is indeterminate in growth habit detopping of the cotton plant after suitable vegetative growth (75-80 DAS) encourages the better growth of already developed sympodial branches and also increased the sympodial length resulting in maximum boll weight and number of bolls per plant. The results of monopodia removal and detopping are more prominent in this experiment as a result of higher dose of fertilizers given through fertigation and availability of soil moisture throught the growing season of crop. There were non-significant differences among the canopy management practices (C2, C3, C4) in cotton in respect of stalk yield of cotton, however all these treatments were found significantly superior over control treatment. Highest harvest index of 41% was registered in C2 i.e. Monopodia removal at 60 DAS and detopping at 75-80 DAS. Kataria and Valu (2018) [12], Singh *et al.* (2014) [23], Veeraputhiran *et al.* (2018) [26], Jadhav *et al.* (2019) [9] and Chaudhari *et al.* (2021) [2] also earlier reported the importance and significant response of detopping and spraying of mepiquat chloride on growth and yield attributes and seed cotton yield. Sadhana Kumari (2021) [19] also highlighted the practical importance of nitrogen levels and spraying of mepiquat chloride on growth and yield of Bt cotton.

Interaction

Interaction effect of Bt cotton hybrids, nutrient management and canopy management practices in cotton was found non-significant in case of growth parameters *viz*. Plant height, number of monopodia, number of sympodia and sympodial length, number of bolls per plant and all other yield attributes and seed cotton yield.

3.1.4 Economics (GMR, NMR and B:C ratio)

Among the genotypes PDKV-JKAL 116 Bt recorded significantly higher gross monetary returns (Rs. 231582 ha^{-1}), net returns (Rs.147704 ha^{-1}) and B:C ratio of 2.76 as compared to PKV-Hy 2 Bt genotype (Table 3). The extent of increase in net return with PDKV-JKAL 116 Bt was to the tune of 19.73% over PKV-Hy 2 Bt. Among the nutrient management treatment 125% recommended N and K applied through fertigation was found significantly superior in increasing GMR(Rs. 224958 ha^{-1}), NMR (Rs. 141318 ha^{-1}) and B:C ratio (2.68). Among the canopy modification practices in cotton C2 i.e. Monopodia removal at 60 DAS and detopping at 75-80 DAS significantly increased the GMR (Rs.238771 ha^{-1}), NMR (Rs.152122 ha^{-1}) and maximum B: C ratio of 2.75 which was found superior over other canopy management practices in cotton. Canopy management practice of C3 (Monopodia removal at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS) and C4 (Spraying of mepiquat chloride 5% w/w at 75 DAS) was found statistically at par with each other in respect of GMR and NMR. Lowest GMR (Rs.194228 ha^{-1}), NMR (Rs. 77153 ha^{-1}) and B;C ratio of 2.51was registered in control treatment (No canopy management).Canopy management with Monopodia removal at 60 DAS and detopping at 75-80 DAS registered 23.03% of increase in net monetary return over control indicating the importance of canopy management in bt cotton hybrids under irrigated conditions. Similar results in respect of GMR.NMR and B:C ratio was also reported earlier by Shwetha *et al.* (2009) [22].

Table 2: Growth characters and yield attributes of Bt cotton genotypes as influenced by split application of nutrients and canopy management under drip irrigation

Treatments	Plant Height (cm)	No of Sympodia plant^{-1}	Sympodial length plant^{-1} (cm)	Total Dry Matter per Plant (g)	No. of Bolls Picked per plant	Seed Cotton yield per plant (g)	Boll Wt. (g)
I) Main plot treatments							
A) Bt cotton Hybrids							
V_1: PKV Hy-2 (BG-II)	149.26	28.62	40.00	382.05	42.17	209.84	4.19
V_2: PDKV-JKAL-116(BG-II)	157.31	35.63	42.89	409.46	57.86	228.27	5.27
S.E. m ±	1.54	0.68	0.37	1.94	0.93	2.70	0.08
CD at 5%	5.33	2.34	1.29	6.70	3.21	9.35	0.28
B) Nutrient management							
N_1- 100% RDF (N& K in four splits)	150.42	29.83	38.99	386.79	46.58	214.08	4.94
N_2- 125% RDF (N& K in four splits)	156.15	34.42	43.90	404.72	53.45	224.03	5.08
S.E. m ±	1.54	0.68	0.37	1.94	0.93	2.70	0.08
CD at 5%	5.33	2.34	1.29	6.70	3.21	9.35	NS
II) Sub plot treatments							
C) Canopy Management							
C_1- Control	161.88	28.08	36.36	388.30	42.30	202.47	4.92

C_2-Monopodia removal at 60 DAS and detopping at 75-80 DAS	142.94	36.81	49.93	410.69	58.30	239.43	5.23
C_3-Monopodia removal at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS	155.35	33.28	41.68	393.44	51.43	220.09	5.04
C_4-Spraying of mepiquat chloride 5% w/w at 75 DAS	152.98	30.32	37.82	390.58	48.03	214.23	4.95
S.E. m ±	1.70	0.96	1.02	5.66	1.38	3.98	0.11
CD at 5%	4.95	2.81	2.97	16.52	4.03	11.63	NS
Interaction (VxNXC)							
S.E. m ±	3.39	1.92	2.04	11.32	2.76	7.97	0.23
CD at 5%	NS	NS	NS	NS	NS	NS	NS

Table 3: Seed cotton yield (Kgha^{-1}), stalk yield, harvest index and economics of Bt cotton as influenced by split application of nutrients and canopy management under drip irrigation

Treatments	Seed Cotton Yield (Kgha^{-1})	Stalk Yield (Kgha^{-1})	Biological yield (Kgha^{-1})	Harvest Index %	Gross Monetary Return (Rsha-1)	Net Monetary returns (Rsha-1)	B:C Ratio
I) Main plot treatments							
A) Bt cotton Hybrids							
V_1: PKV Hy-2 (BG-II)	3306	5301	8607	39	199208	118554	2.47
V_2: PDKV-JKAL-116(BG-II)	3844	5601	9444	41	231582	147704	2.76
S.E. m ±	72	68	89	--	4368	4368	--
CD at 5%	251	234	308	--	15114	15114	--
B) Nutrient management							
N_1- 100% RDF (N& K in four splits)	3416	5348	8764	39	205832	124941	2.54
N_2- 125% RDF (N& K in four splits)	3734	5554	9287	40	224958	141318	2.68
S.E. m ±	72	68	89	--	4368	4368	--
CD at 5%	251	NS	308	--	15114	15114	--
II) Sub plot treatments							
C) Canopy Management							
C_1- Control	3224	5184	8408	38	194228	117075	2.51
C_2-Monopodia removal at 60 DAS and detopping at 75-80 DAS	3963	5618	9581	41	238771	152122	2.75
C_3-Monopodia removal at 60 DAS and spraying of mepiquat chloride 5% w/w at 75 DAS	3610	5550	9160	39	217515	132583	2.56
C_4-Spraying of mepiquat chloride 5% w/w at 75 DAS	3503	5450	8954	39	211066	130736	2.62
S.E. m ±	88	99	187	--	5278	5278	--
CD at 5%	256	289	547	--	15407	15407	--
Interaction (VxNXC)							
S.E. m ±	175	198	375	--	10557	10557	--
CD at 5%	NS	NS	NS	--	NS	NS	--

4. Conclusions

The results of present investigation revealed thatPDKV-JKAL-116(BG-II) Bt hybrid had better crop growth, yield attributes, seed cotton yield, harvest index than PKV-Hy-2 Bt genotype under drip irrigation. Among the nutrient management, higher dose of recommended N and K i.e.125% given through drip irrigation was found beneficial in increasing the yield attributes and seed cotton yield, harvest index, GMR, NMR and B:C ratio than the 100% split doses of N and K at sowing, 30, 60 and at 90 DAS.

Canopy management data of this study indicates that, canopy management practices like monopodia removal, detopping had advantage to produce higher seed cotton yield than no canopy management. Canopy management with use of mepiquat chloride spray was also found beneficial in increasing the seed cotton yield compared to control. Canopy modifications practices reflected in increasing the GMR, net monetary returns and B:C ratio compared to farmers practice (control).

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