Standardizing Use of Mepiquat Chloride for Higher Productivity of Densely Planted *Bt* Cotton Variety

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Abstract

Standardizing use of mepiquat chloride for higher productivity of densely planted *Bt* cotton variety" was carried out at the Regional Research Station, Abohar and Regional Research Station, Faridkot during the *kharif* season of 2021 on *Bt* cotton variety PAU *Bt* 3. The soil of experimental field was silty loam at Abohar and sandy loam at Faridkot. The experiment was laid out in a split plot design with four plant spacings (67.5×15 cm, 67.5×30 cm, 67.5×45 cm and 67.5×60 cm) as main plots and five Mepiquat chloride levels (MC (5%) @ 375 ml ha^{-1} at squaring, MC (5%) @ 375 ml ha^{-1} at flowering, MC (5%) @ 750 ml ha^{-1} at squaring, MC (5%) @ 750 ml ha^{-1} at flowering and after 15 days and Control (No MC)) as sub plots with three replications. Lowest plant density (67.5×60 cm) and MC (5%) @ 750 ml ha^{-1} at squaring resulted in significant reduction of plant height, LAI (Leaf Area Index) and dry matter as compared to control at both the locations. Higher boll retention and opened bolls were observed in 67.5×60 cm and MC (5%) @ 750 ml ha^{-1} at flowering. There was no significant effect of both the treatments factors on node count, monopods and sympods. Highest seed cotton yield was obtained with 67.5 ×30 cm (at Abohar) and 67.5×15 cm (at Faridkot) although these two spacing levels were at par with each other. MC (5%) @ 750 ml ha^{-1} at flowering resulted in 22.9% and 21.3% increase in seed cotton yield over control at Abohar and Faridkot, respectively. Different plant spacings and mepiquat chloride applications showed a non-significant effect on different fibre quality parameters except halo length at Faridkot. At both the locations, highest B:C ratio was observed in 67.5×30 cm and MC @ 750 ml ha^{-1} at flowering.

Introduction

Cotton belongs to the *Malvaceae* family within the genus *Gossypium* and is considered as an important commercial fibre crop of the world. It is an important cash crop often known as 'white gold'. It plays a significant role in the agricultural, economic and social sector of the nation. Cotton is placed in the top fifteen important widely grown crops of the world even though; it is not used as a staple food (Wendel *et al* 2010). Cotton serves as a multipurpose plant, providing fundamental resources such as fibre, oil, oil cake, hulls and lint. The abundant fibre and energy in the form of fat and protein is present in whole cotton seeds, which are widely recognized as a popular feed for dairy cattle. The seeds are about 15% value of the crop which contain protein (20%), oil (20%) and starch (3.55%), after pressing to make oil and its cake used as animal feed [1]. The oil obtained from the kernels of the seeds, once refined, becomes a valuable edible and nutritious resource. It is suitable for use as both cooking oil and in the preparation of salad dressings. Fibers emerge from the seed's outer covering, contributing in the development of a lint boll of cotton. This boll serves as a protective fruit; in commercial cultivation, it is removed from the seed through a process called ginning, and the lint is subsequently processed into cotton fibre.

India is a major producer of cotton in the world followed by China, USA, Brazil and Pakistan. India accounts about 21% of cotton production in the world [2], however, the lint productivity is 445 kg ha^{-1}, which is very less than the world average of 765 kg ha^{-1}. Cultivated cotton comprises of four species i.e *G. herbaceum* (Asian cotton), *G. hirsutum* (American Upland cotton), *G. barbadense* (Egyptian cotton) and *Gossypium arboreum* grown in India under diversified ecosystems. In India, *Gossypium hirsutum* constitutes 88% of the total cotton production, and all the existing *Bt* cotton hybrids are from *G. hirsutum*. Major cotton growing states in India are Maharashtra, Gujarat, Punjab, Madhya Pradesh, Haryana, Rajasthan, and Tamil Nadu.

Punjab is among one of the ten major cotton growing states in India. In *kharif* season, cotton is considered as second main crop in Punjab after paddy and a major cash crop of the south-western districts of the state. During 2020-21, American cotton occupied 2.48 lakh ha in Punjab with production of 10.14 lakh bales and average yield was 694 kg lint ha^{-1} [3]. The *Malwa* belt of the state is also known as 'cotton belt' with more than 95 % area of cotton crop in state under *Bt* cotton hybrids [4]. Although Punjab has highest lint productivity in India, it is still lesser than highly productive nations like China and Brazil with lint productivity around 1700-1800 kg ha^{-1}. Most developed nations with highest lint productivity plant cotton in HDPS (High Density Planting System) with planting density of 10 plants m^{-2}. However, in Punjab, farmers have been recommended to plant cotton with 2 plants m^{-2} due to high cost of seed of *Bt* hybrids which is achieved by keeping plant to plant spacing at 75 cm. Recently, Punjab Agricultural University has developed and released three *Bt* cotton varieties, which will reduce the seed cost. With the availability of *Bt* cotton varieties, HDPS can be tested for these varieties for increasing the productivity. An optimum plant density may vary according to location, cultural practices, and environmental conditions (Silvertooth *et al* 1999). Cotton is a perennial plant that exhibits indeterminate growth, persisting in its vegetative growth even as fruiting has begun (Oosterhuis 2001) which may lead to competition for photosynthates. This suggests that vegetative growth of cotton is almost at the expense of cotton yield. Moreover, in dense planted cotton, excessive vegetative growth may occur, which may increase the shade in the plant canopy, reduces the supply of assimilates to reproductive structures, thereby causing fruit abscission and reduced yield (Mauney 1986 and York 1983).

In high density cotton production system, Plant Growth Regulators (PGR) are common tactics used to manipulate the growth of the plant canopy to promote early maturity and prevent yield reduction caused by auto shading and to decrease plant height (Hodges *et al* 1991 and Krieg and Kerby 1985). One such PGR, mepiquat chloride has been recommended by Punjab Agricultural University to check the rank growth in cotton commonly observed in highly fertile soils. Mepiquat chloride (MC) (1,1 dimethyl piperidinium) is an organic compound soluble in water, serving as a gibberellin suppressant.

It hinders the synthesis of gibberellic acid, resulting in decrease in the rate of cell expansion and cell division (Srivastava 2002). The reduction in cell elongation after MC treatment leads to reduced plant height and lower cotton leaf area (Kerby 1985). Applying MC restricts the endogenous production of gibberellic acid, causing plants to exhibit a more compact and shortened structure. This is achieved by inhibiting cell elongation, ultimately resulting in decreased length of internodes (Rademacher 2000). MC is considered beneficial for managing plant architecture in conditions that encourage vegetative growth, which can negatively impact the quality and yield of fibres (Oosterhuis and Egilla 1996 and Constable 1991). Cotton plants treated with MC typically are compact, with lesser nodes (Reddy *et al* 1990), reduced internode length and lesser reproductive branches (Bogiani and Rosolem 2009). The application of MC leads to a decrease in leaf expansion, stem and petiole length, node count, as well as an advancement in the maturation of the cotton crop. This treatment yields varying outcomes in terms of yield (Bogiani and Rosolem 2009; Cook and Kennedy 2000; Mao *et al* 2015). The use of MC results in a reduction of leaf area per plant that surpasses the effect on boll load, consequently increasing the number of bolls per unit of leaf area. Mepiquat chloride application encourages boll formation on lower sympodia, thereby enhancing the synchronization of boll maturation and the demand for photosynthates (Gwathmey and Clement 2010). MC is commonly employed to maintain a balance between vegetative and reproductive growth, subsequently adjusting cotton yield (Zhao and Oosterhuis 2000; Yang *et al* 2014).

Boll density and boll weight are the two main factors used to determine cotton yield. These yield components can be managed by optimum Plant density and Mepiquat chloride (MC) application (Stewart 2005). Most researchers have studied the optimum plant density for high quality and yield in cotton. Some have depicted non-significant relation between plant density and yield (Jones and Wells 1998 and Bednarz and Robertz 2000), whereas others noted reduced yields at very low or high density (Bridge *et al* 1973 and Smith *et al* 1979). Optimum plant population in cotton depends on various factors such as rainfall, temperature, crop management and soil health. Also, variable yield responses have been reported with MC application, with some studies showed a negative response (Zhao and Oosterhuis 2000) while other showed no response (Nichols *et al* 2003 and Pettigrew and Johnson 2005). Favourable response to MC application has been reported, under situations that favour excessive vegetative growth *viz.*, excessive nitrogen, warm and humid conditions (Gwathmey and Clement 2010) and with high plant density (York 1983).

Thus, the rational approach would be to curtail extravagant vegetative growth by applying plant growth regulators to enhance translocation of metabolites towards reproductive sinks. The plant spacing and the application of mepiquat chloride (MC) are thought to influence the dynamics of different factors related to growth and yield. Increasing plant density may increase the yield through higher plant population However, excess vegetative growth may affect the retention of fruiting bodies resulting in adverse effect of HDPS. Hence, MC application may help in limiting the vegetative growth thereby increasing the retention of bolls ultimately leading to higher yields. It is therefore hypothesized that higher plant density, when supplemented with Mepiquat chloride, will lead to improvement in reproductive bodies, resulting in higher seed cotton yield and enhanced overall productivity of the Bt cotton variety under consideration. This Research was undertaken with the two objectives i.e., to optimize the Mepiquat chloride application rate for dense planted *Bt* cotton variety and to study the effect of increased plant density and Mepiquat chloride (MC) application on the cotton growth and productivity.

Materials and methods

Study site details and general management practice

The field experiment related to the study entitled were conducted at Punjab Agricultural University, Research Station, Abohar and Faridkot during *kharif* season of 2021-22. The agroclimatic and meteorological conditions of the experimental sites are discussed below:

Abohar

Abohar is located at 30° 9′ N latitude, 74° 12′ E longitude and 185 m above sea level in the Trans-Gangetic agro-climatic zone. The Abohar region experiences a semi-arid climate characterized by intensely hot and dry summers from April to June. This is succeeded by a period of hot and humid conditions from July to September, and the winters in December-January are cold. The region is situated in the southwestern portion (Agro Climatic-IV zone) of Punjab. The average annual rainfall of Abohar is 284 mm. The temperatures (mean maximum and minimum) show considerable fluctuations throughout the year. Warming of the temperature starts from March with temperature rising above 40° C during the month of June. Monsoon rains start from early July and remains until mid-September which is responsible for over 200 mm rainfall during this period. Winter season extends from the November to February with average temperature ranging from 12°C to 20°C during this period. The summer temperature often exceeds 35°C and sometimes touches 45.6°C with dry spells in May.

Faridkot

Faridkot is located at 30° 40′ N latitude, 74° 44′ E longitude and 200 m above sea level in the Trans-Gangetic agro-climatic zone. Faridkot is situated in the south-western segment (Agro Climatic-IV zone) of Punjab and is characterized by a semi-arid and subtropical climate. The average annual rainfall of this zone is 419 mm. The climate is extremely hot and dry in the summer with frequent dust storms but during monsoon season from July to September the moist air penetrates district and causes high humidity, cloudiness and monsoon rainfall. Foggy nights are very common during the winter months.

Meteorological conditions during crop season

Abohar

The meteorological data of 2021 was recorded from Agrometeorology observatory of PAU Regional Research Station, Abohar is presented graphically in Fig. 3.1. The maximum weekly mean temperature ranged between 22.3°C to 41.4°C and mean minimum temperature ranged between 5.7°C to 26.0°C. The weekly mean maximum and minimum temperatures of 41.4°C and 5.7°C were recorded during standard meteorological week of 21st and 52nd respectively. The mean maximum relative humidity was 85.3% during 52nd standard meteorological week. The area had received the total rainfall of 169.8 mm during the entire crop season and there were 13 rainy days during crop season.

Faridkot

Mean weekly meteorological data, recorded at agrometeorology observatory of PAU Regional Research Station, Faridkot has been graphically depicted in Fig. 3.2. During the *kharif* growing season (2021), weekly mean maximum and weekly mean minimum temperature ranged from 18.4 -40.3 and 3.3-28.1°C, respectively. The maximum weekly mean temperature of 40.3°C was recorded during the 23rd and weekly mean minimum temperature of 3.3°C was recorded during the 51st standard meteorological week of the year 2021. Maximum weekly mean relative humidity (95.8 %) was

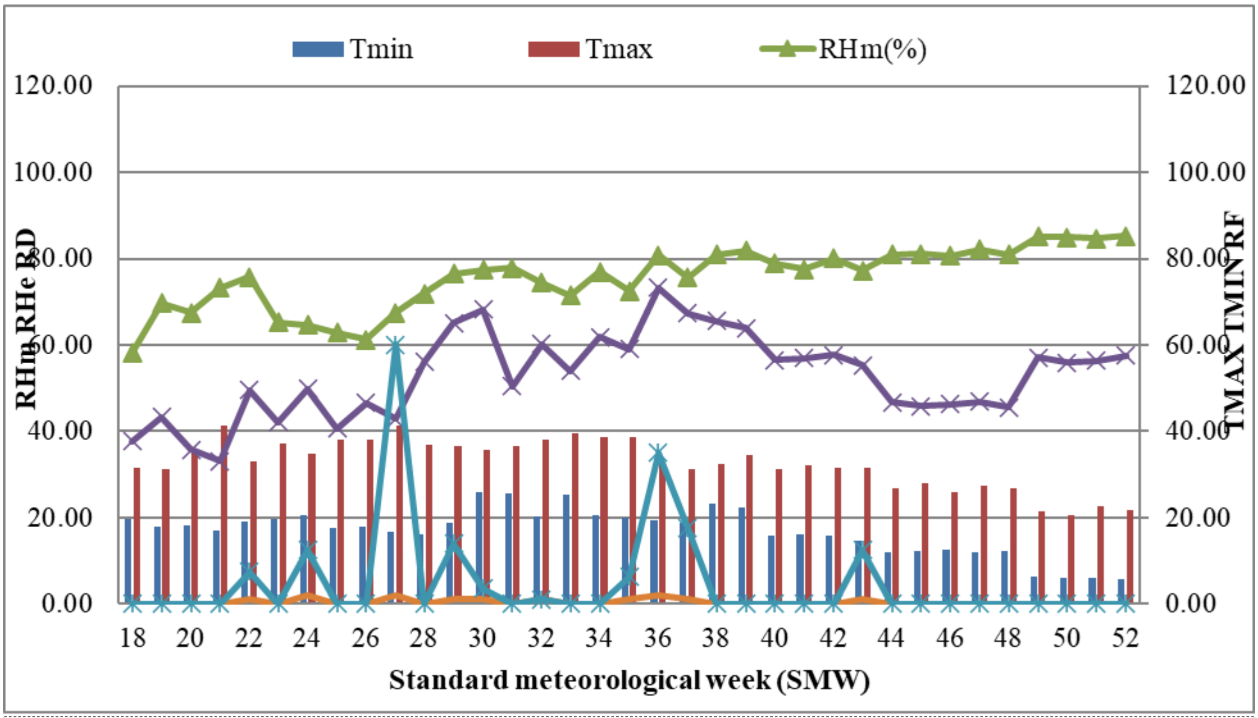

Figure 1. Weather condition at Abohar during kharif season 2021-22

recorded in the 52^{nd} standard meteorological week of the year 2021. The area had received the total rainfall of 491 mm during the entire crop season and there were 29 rainy days during the crop season.

Soil of experimental site

The experimental site in Faridkot had a sandy loam soil, while in Abohar, it was silty loam.

Experiment details and layout

Main plots: Plant density (4)

S_1: 67.5×15 cm

S_2: 67.5 ×30 cm

S_3: 67.5 × 45 cm (recommended for *Bt* cotton varieties)

S_4: 67.5×60 cm (recommended for non-*Bt* cotton varieties)

Subplots: Mepiquat chloride levels (5)

T_1: MC (5%) @ 375 ml ha^{-1} at squaring

T_2: MC (5%) @ 375 ml ha^{-1} at flowering

T_3: MC (5%) @ 750 ml ha^{-1}at squaring

T_4: MC (5%) @ 750 ml ha^{-1}at flowering and after 15 days

T_5: Control (No MC)

In-season measurement

Biometric observations like plant height, node count, dry matter partitioning, leaf area index (LAI) have been recorded at 30, 60, 90, 120 and 150 DAS. The data pertaining to various growth and yield attributes viz. monopods per plant, sympods per plant, boll retention, opened bolls per plant, unopened bolls $plant^{-1}$ and boll weight and total weight was recorded just before start of first picking.

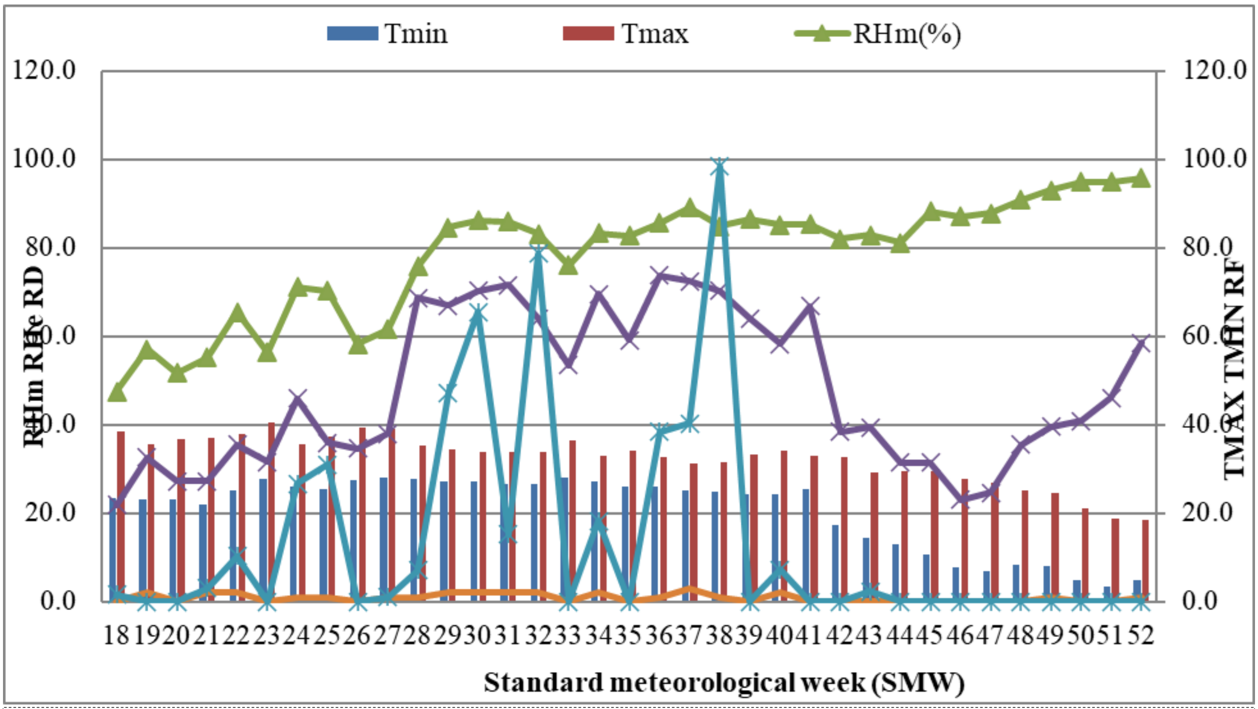

Figure 2. Weather conditions at Faridkot during kharif season 2021-22

Phenological observations like days to square initiation, days to flower initiation, days to boll formation, days to boll opening, and Earliness Index were recorded. Harvesting of mature open cotton bolls was done by two manual picking separately for each plot. The produce of both pickings was accumulated to determine seed cotton yield and other parameters like ginning outturn, lint yield, seed yield and halo length etc.

Statistical analysis

The data collected on various aspects of present investigation were statistically analyses as per split plot design (Cheema and Singh 1991), using CPCS-1 software developed by the Department of Mathematics and Statistics, PAU, Ludhiana (Punjab). The data was compared at 5% level of significance.

Results

Monopods per plant, sympods per plant, boll retention, boll weight, opened bolls plant^{-1}, unopened bolls plant^{-1} and total weight was influenced by spacings with wider spacing (67.5×60 cm) resulting in higher monopods, more boll retention, more opened bolls, lesser unopened bolls, more total bolls plant^{-1} and higher boll weight. However, in densely planted crop, an increase in proportion of total seed cotton yield i.e., 2326 and 2190 kg ha^{-1} was witnessed by Bt cotton sown at 67.5×30 cm and 67.5×15 cm at Abohar and Faridkot, respectively. Lesser days to square initiation, flower initiation, and boll formation were observed in widely sown crop, which brought earliness in the crop, thereby, Earliness index was significantly higher in cotton sown at 67.5 ×60 cm at both locations. Although highest gross returns and net returns were observed with 67.5×30 cm and 67.5×15 cm at Abohar and Faridkot, respectively, B:C ratio was highest in 67.5×15 cm at both the locations. This clearly established dense planting to be more remunerative over other spacings. Quality parameters like GOT, Micronaire value were not affected except halo length at Faridkot.

Table 1. Effect of plant spacing and mepiquat chloride application on plant height (cm) of *Bt* cotton

Treat-ment	**30 DAS**			**60 DAS**			**90 DAS**			**120 DAS**			**150 DAS**		
	ABR	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**
Plant spacing															
67.5 × 15 cm	28.9	30.1	29.5	72.5	71.0	71.8	94.7	95.5	95.1	109.4	108.8	109.1	138.4	120.5	129.5
67.5 × 30 cm	27.5	27.8	27.7	72.4	72.5	72.5	93.8	94.2	94.0	106.7	105.5	106.1	136.5	119.7	128.1
67.5 × 45 cm	27.3	27.1	27.2	71.9	72.2.	72.0	90.1	91.5	90.8	103.4	105.2	104.3	131.3	117.1	124.2
67.5 × 60 cm	26.9	26.9	26.9	71.9	73.7	72.8	88.0	89.3	88.6	100.7	105.6	103.1	129.9	116.7	123.3
CD (p=0.05)	1.2	1.8	0.9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mepiquat chloride (MC) applications															
MC@ 375 ml ha^{-1} at squaring	28.0	27.8	27.9	71.5	71.4	71.5	86.7	88.2	87.4	99.7	100.8	100.3	129.8	114.2	122.0
MC@375 ml ha^{-1} at flowering	28.3	27.5	27.9	72.9	71.8	72.4	97.1	98.3	97.7	111.6	112.3	112.0	138.5	121.1	129.8
MC@ 750 ml ha^{-1} at squaring	27.0	27.6	27.3	70.3	70.3	70.3	82.4	81.7	82.0	92.4	93.3	92.8	122.1	111.2	116.7
MC@750 ml ha^{-1} at flowering	27.8	28.0	27.9	72.5	71.5	72.0	92.3	92.4	92.4	104.1	107.7	105.9	134.5	117.8	126.2
Control (No MC)	27.1	28.9	28.0	73.7	76.7	75.2	99.7	102.6	101.1	117.5	117.2	117.4	145.2	128.2	136.7
CD (p=0.05)	NS	NS	NS	1.7	1.9	1.2	10.5	9.3	6.9	11.2	13.4	8.6	10.1	6.9	6.0
Interaction (B ×C)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Plant Height

The data presented in Table 4.1 revealed that during initial crop growth (at 30 DAS), the plant height was significantly influenced by different levels of plant densities at both locations. Lowest plant density (67.5×60 cm) resulted in least plant height which was statistically at par with plant height observed in 67.5×45 cm and 67.5×30 cm but lesser when compared with 67.5×15 cm. At all other growth stages, there were no differences in plant height under different spacings. These findings are in accordance with results obtained by Moola Ram and Giri (2006) that higher plant density resulted in significantly greater plant height compared to lower plant densities.

Fruiting bodies dry matter

The1data presented in the Table 4.5 revealed that different plant spacings exerted a non-significant effect on fruiting bodies dry matter except at Abohar (120 DAS), where 67.5×60 cm spacing resulted in highest production of fruiting bodies as evident from the dry matter. Different mepiquat treatments significantly influenced fruiting bodies dry matter. Highest dry matter partitioning to fruiting bodies at 90 DAS was recorded with MC @ 750 ml ha^{-1} at flowering followed by MC@375 ml ha^{-1} at flowering and MC @ 750 ml ha^{-1} at squaring and was significantly higher than control at both the locations, as shown in Table 4.5. However, MC@375 ml ha^{-1} at squaring didn't result in any improvement in dry matter towards fruiting bodies over control. At 120 days, all MC treatments exhibited better dry matter partitioning towards fruiting bodies as compared to control, with the same trend as noticed at 90 DAS.

Table 2. Effect of plant spacing and mepiquat chloride application on periodic dry mattepartitioning of fruiting bodies (g plant-1) of Bt cotton

Treatments	**90 DAS**			**120 DAS**			**150 DAS**		
	ABR	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**	**ABR**	**FDK**	**Pooled data**
Plant spacing									
67.5 × 15 cm	34.7	33.9	34.3	48.2	48.9	48.5	100.9	103.1	102.0
67.5 × 30 cm	35.4	35.7	35.5	50.0	49.9	49.9	104.2	105.4	104.8
67.5 × 45 cm	37.9	37.5	37.7	50.8	50.7	50.7	107.3	107.0	107.2
67.5 × 60 cm	37.0	38.9	37.9	52.1	52.0	52.0	113.0	109.5	111.3
CD (p=0.05)	NS	NS	NS	1.8	NS	NS	NS	NS	NS
Mepiquat chloride (MC) applications									
MC @ 375 ml ha^{-1} at squaring	33.5	33.1	33.3	49.0	48.2	48.6	102.1	100.4	101.3
MC@ 375ml ha^{-1} at flowering	38.3	38.2	38.2	53.0	52.9	53.0	110.9	110.7	110.8
MC @ 750 ml ha^{-1} at squaring	35.9	36.4	36.2	51.3	51.6	51.5	106.4	106.9	106.7
MC@750 ml ha^{-1} at flowering	43.0	45.6	44.3	54.0	57.2	55.6	112.8	118.3	115.5
Control (No MC)	30.6	29.1	29.9	44.0	41.9	43.0	99.6	95.0	97.3
CD (p=0.05)	4.5	5.7	5.1	4.7	6.2	5.2	6.3	8.6	7.8
Interaction (B ×C)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of plant spacing and mepiquat chloride application on periodic dry mattepartitioning of fruiting bodies (g plant-1) of Bt cotton

Treatment	Opened bolls			Unopened bolls			Total bolls			Boll weight(g) plant^{-1}		
	ABR	FDK	Pooled data	ABR	FDK	Pooled data	ABR	FDK	Pooled data	ABR	FDK	Pooled data
Plant spacing												
67.5 × 15 cm	11.0	11.4	11.2	6.69	5.47	6.08	17.7	16.8	17.3	2.29	2.27	2.28
67.5 × 30 cm	18.7	18.5	18.6	3.89	4.67	4.28	22.6	23.1	22.9	2.40	2.48	2.44
67.5 × 45 cm	23.6	20.9	22.2	3.09	3.47	3.28	26.7	24.3	25.5	2.81	2.87	2.84
67.5 × 60 cm	29.9	24.9	27.4	2.44	2.40	2.42	32.4	27.3	29.8	2.90	3.18	3.04
CD (p=0.05)	1.9	2.5	1.4	0.44	0.50	0.29	1.4	2.2	1.2	0.20	0.10	0.10
Mepiquat chloride (MC) applications												
MC @ 375 ml ha^{-1} at squaring	20.2	18.4	19.3	4.05	4.58	4.32	24.2	23.0	23.6	2.62	2.73	2.67
MC @ 375 ml ha^{-1} at flowering	22.2	19.6	20.9	3.80	3.33	3.56	25.9	23.0	24.5	2.58	2.67	2.62
MC @ 750 ml ha^{-1} at squaring	20.9	19.3	20.1	3.06	2.83	2.95	24.0	22.2	23.1	2.61	2.67	2.64
MC @ 750 ml ha^{-1} at flowering	22.8	21.3	22.1	2.74	2.00	2.37	25.6	23.3	24.4	2.57	2.60	2.58
Control (No MC)	18.0	15.8	16.9	6.50	7.25	6.87	24.5	23.0	23.8	2.62	2.84	2.73
CD (p=0.05)	1.7	1.3	1.1	0.26	0.57	0.31	1.4	NS	1.0	NS	0.10	0.08
Interaction (B ×C)	NS	NS	2.1	NS	NS	0.62	NS	NS	2.0	NS	NS	NS

Dry matter accumulation by fruiting bodies at 150 DAS showed similar response to MC applications as observed at 90 DAS, where MC@ 750 ml ha^{-1} at flowering recorded highest fruiting body dry matter (115.5 g plant^{-1}) and MC @375 ml ha^{-1} at flowering (110.8 g plant^{-1}) and MC @750 ml ha^{-1} at squaring (106.7 g plant^{-1}) showing more partitioning towards fruiting bodies as compared to control (97.3 g plant^{-1}).

Total bolls

Total number of bolls plant^{-1} is an important parameter related to yield. Data presented in Table 4.8 revealed that different plant densities significantly affected total bolls plant^{-1} at Abohar and Faridkot. Among different plant densities, 67.5×60 cm resulted in higher number of bolls per plant (32.4 and

27.3) followed by 67.5×45 cm (26.7 and 24.3 at Abohar and Faridkot, respectively). This was due to the fact that at wider spacing, there is better utilization of sunlight and other resources on cotton plants which helps in better boll retention leads to highest number of bolls per plant. The pooled analysis also showed significant effect of various plant spacings on total bolls.

Variation among different treatments of mepiquat chloride for total bolls per plant was also significant at Abohar but non-significant at Faridkot

Open bolls plant^{-1}

Open bolls plant^{-1} at a particular harvesting time is most important character and in the present study it has directly contributed towards seed cotton yield. Data pertaining to open bolls (Table 4.8) revealed that decreasing plant density resulted in significant increase in open bolls plant^{-1}. Among different plant densities, 67.5×60 cm revealed maximum number of open bolls plant^{-1} (29.9 and 24.9) followed by 67.5×45 cm (23.6 and 20.9 for Abohar and Faridkot, respectively). Due to better utilization of sunlight and other resources, higher boll retention and total number of bolls, number of open bolls was higher in widely planted cotton as compared to densely planted cotton. The pooled analysis also showed significant effect of various plant spacings on opened bolls in cotton with similar trend.

Plant growth retardant treatments also exerted a significant impact on open bolls plant^{-1} over control. Application of mepiquat chloride @ 750 ml ha^{-1} at flowering recorded highest open bolls plant^{-1} at Abohar (22.8) as well as at Faridkot (21.3), though it was statistically at par with mepiquat chloride @ 375 ml ha^{-1} at flowering (22.2) at Abohar only. Control treatment resulted in statistically least values for open bolls at Abohar (18.0) and Faridkot (15.8), which clearly indicated that mepiquat chloride was effective in improving the number of open bolls plant^{-1}. The increase in open bolls plant^{-1} with MC application was due to improved source-sink relationship and better dry matter partitioning towards fruiting bodies. Wankhade *et al* (2002) reported similar results. For both the locations, interaction effect was found to be non-significant for open bolls plant^{-1}. However, pooled analysis showed significant interaction between plant spacings and MC treatments for open bolls plant^{-1}.

Unopened bolls plant^{-1}

These are physiologically mature bolls which were yet to open at the time of picking but they can contribute to the final yield in picking. Data pertaining to unopened bolls per plant (Table 4.8) revealed that increased plant densities resulted in more number of unopened Bolls plant^{-1}. Among different plant densities, 67.5×60 cm revealed minimum number of unopened bolls plant^{-1} (2.44 and 2.40) followed by 67.5×45 cm (3.09 and 3.47 for Abohar and Faridkot, respectively) in comparison to 67.5×15 cm (6.69 and 5.47) which exhibited significantly highest values at both locations. Different MC levels also varied significantly for unopened bolls plant^{-1}. Application of mepiquat chloride @ 750 ml ha^{-1} at flowering resulted in lowest unopened bolls plant^{-1} (i.e., 2.74 and 2.00 for Abohar and Faridkot, respectively) among all treatments, at both locations. All MC treatments had lesser number of unopened bolls as compared to control. Higher vegetative growth (leaves per plant and dry matter accumulation) in control plots was the prime reason of more number of unopened bolls at Abohar (6.50) as well as at Faridkot (7.25). The pooled data also showed significant effect of mepiquat application on unopened bolls with same trend. Interaction between both the factors (plant spacings and MC treatments) was non-significant at both locations, however, pooled analysis showed significant1 interaction between plant spacings and mepiquat chloride applications.

Conclusions

The study emphasized the substantial impact of plant spacing and Mepiquat chloride on cotton growth, yield, and economics. Wider plant spacing enhances dry matter partitioning towards leaves and fruiting bodies, while densely planted crops show increased proportion of total seed cotton yield. Mepiquat chloride, particularly at 750 ml ha^{-1} during flowering, balances vegetative and reproductive growth, improving yield attributes. Economic analysis highlights the economic viability of dense planting, with higher benefit-cost ratios. Likewise, Mepiquat chloride at 750 ml ha^{-1} during flowering yields improved net returns. This study provides valuable insights for cotton growers, emphasizing the importance of strategic plant spacing and growth regulator application for enhanced productivity and profitability.

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