Original Research Article

Impact of growth retardant and defoliant on morpho-physiological traits and yield improvement in cotton

ABSTRACT

In cotton, mechanized harvesting has gained popularity in recent years due to labor-intensive process and shortage of labor. However, the efficiency of mechanical harvesting of cotton depending on the morphological characters of plants such as plant height, internode length and synchronized boll maturity and opening, *etc*. To increase the efficiency of mechanical harvesting in cotton is achieved by the use of some chemicals moreover to good lint yield and fibre quality. With this background, the field experiment was conducted to study the impact of growth retardant and defoliant on morpho-physiological traits and yield improvement in cotton (CO 17) during 2021-2022 by following randomized block design with four treatments and five replications. The current study revealed that spraying of 0.015 % mepiquat chloride (MC) at square formation and boll development stage significantly reduced the plant height, leaf area, total dry matter production and number of bolls when compared to control. However, chlorophyll content and normalized difference vegetation index (NDVI) were recorded higher in 0.015 % mepiquat chloride (MC) applied treatments than control. Moreover, spraying of mepiquat chloride (0.015%) at square formation and boll development stage followed by spraying of 0.9% sodium chlorate (SC) at 60% boll bursting stage significantly increased the seed cotton yield compared to other treatments and recorded maximum seed cotton yield of 25.22 % compared to control. Hence, it is clearly indicated that application of MC followed by SC could be a better practice for canopy management in cotton, resulted in improving the efficiency of mechanical harvesting and good lint yield and fibre quality.

Key words: Cotton, growth retardant, mepiquat chloride, defoliant, sodium chlorate, yield

1. INTRODUCTION

Cotton (Gossypium *spp* L.) is one of the most important fibre crops commercially cultivated in India to maximize profits by selling high quality fibre, with a significant impact on agriculture, industrial development, job creation, and the economy. It is an indeterminate and perennial tropical plant. India have the largest area of 123.50 lakh hectares, estimated production of 340.62 lakh bales and 469 kg/ha of yield under cotton cultivation [1]. Generally, cotton harvesting is a labor-intensive process in almost all the developing countries where it is done by hand picking. Therefore, mechanized harvesting has gained popularity in recent years due to a severe labor shortage. Several chemicals are used to increase the efficiency of mechanical harvesting of cotton to achieve good lint yield and fibre quality. When these chemicals are applied correctly and according to the label guidelines, the time between boll maturity and crop harvest can be decreased. Their primary aim is to target physiological processes within the cotton plant, which can be used to control plant growth, cause defoliation or desiccation, and stimulate the synchronized opening of cotton bolls. Harvest aid chemicals speed up the harvest of a mature crop and reduce the risk of yield or fibre quality loss before harvest.

Excessive vegetative growth can result in unwanted shade within the plant canopy, fruit abscission and yield losses. Mepiquat chloride is a growth inhibitor widely used in cotton canopy management to prevent excessive growth and yield loss. It is used to shorten plant height and internodal distance. Additionally, sodium chlorate ($NaClO_3$) used as a defoliant and desiccant in cotton production. Defoliant application prior to cotton harvest has several advantages, including reduced leaf trash content in collected lint, faster dew drying and early boll opening due to full sun exposure [2]. However, the effect of growth inhibitor and defoliant on cotton canopy management and leaf defoliation are not well documented and need to study. Therefore, this present study was conducted with an objective to evaluate the effects of mepiquat chloride (MC) and sodium chlorate (SC) on morpho-physiological traits and yield parameters in cotton.

2. MATERIALS AND METHODS

The field experiment took place in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore (111N; 771E; 426.7m MSL) from September 2021 to February 2022. The experiment was laid out by following randomized block design (RBD) with five replications and four treatments. Cotton variety CO 17 is a short duration and having zero monopodia with short sympodial length was used as a test crop. The cotton seeds were bought from the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore.

2.1. Treatment details

The experiment had four treatments *viz.,* T1 - Control, T2 - Spraying of Mepiquat Chloride (0.015%) at square formation stage followed by Sodium Chlorate (0.9%) at 60% boll bursting stage, T3 - Spraying of Mepiquat Chloride (0.015%) at boll development stage followed by Sodium Chlorate (0.9%) at 60% boll bursting stage, T4 - Spraying of Mepiquat Chloride (0.015%) at square formation and boll development stage followed by Sodium Chlorate (0.9%) at 60% boll bursting stage. In this present study, effects of mepiquat chloride and sodium chlorate on morpho-physiological parameters, leaf defoliation percentage, boll opening percentage and antioxidant enzyme activities of cotton (CO 17) were recorded.

2.2. Plant height

Plant height of randomly selected and tagged plants from each replication of four treatments was measured from the base of the stem to the tip of the plant and expressed in cm.

2.3. Leaf area

Cotton leaves were collected from all the treatments with replication and used for measuring the leaf area by using leaf area meter (LICOR, Model LI 3000) and leaf area was denoted as cm^2 $plant^{-1}$.

2.4. Dry Matter Production

Above-ground portion of plants were harvested from each replication of four treatments and oven dried at 50°C for one weeks to achieve a consistent weight. Then, using an analytical balance, dry matter production (DMP) was calculated and reported as g $plant^{-1}$.

2.5. NDVI

Green Seeker, a handheld crop sensor which was was utilized to detect the Normalized Difference Vegetation Index (NDVI, Trimble).

2.6. Chlorophyll content

The photosynthetic pigments were determined using Dimethyl sulfoxide (DMSO) [3] method followed by spectrophotometer readings at 645 and 663 nm, the following formula was used to estimate total chlorophyll and the values provided in mg g^{-1} of fresh weight.

$$\text{Total chlorophyll} = (8.02 \times \text{OD at } 663) - (20.2 \times \text{OD at } 645) \times \frac{V}{1000 \times W}$$

Where,
OD - Optical Density
V - Final volume of supernatant
W - Weight of the leaf sample taken in gram

2.7. Number of bolls per plant

After application of sodium chlorate, five plants from each treatment were tagged. Then bolls per plant was recorded and expressed as number. One week after application of sodium chlorate, the seed cotton yield was calculated as gram plant^{-1}.

2.8. Statistical analysis

The data collected on different parameters from field experiments were statistically evaluated in Randomized Block Design using AGRES software. The critical difference (CD) was calculated with 5% probability.

3. RESULT AND DISCUSSION

3.1. Plant height

Increased vegetative growth causes shadowing inside the canopy, resulting in fruit abscission and a decrease in yield [4]. Cotton canopy management by mepiquat chloride is the one of the agricultural practices to enhance the cotton yield. MC increased the cotton yield by increasing air flow through the plant canopy as it alter plant canopy [5]. Because of the limited boll setting %, high plant density reduced lint yield, boll weight, and boll number per plant. The adequate plant density increased the lint yield by increasing the number of bolls per area [6] [7] [8]. Our results showed that plant height was reduced by spraying of 0.015% MC at square formation and boll development stage and 0.9% SC at boll bursting stages of cotton, compared to control (Fig. 1.). However, spraying of 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage (T4) recorded significantly lesser of 59.60, 80.40 and 98.96 cm plant height at 66, 86 and 126 DAS, respectively, compared to other treatments, followed by 0.015% MC at square formation stage and 0.9% SC at 60% Boll bursting stage treatment (T2). Plant height was higher in control among all other treatments at 66, 86 and 126 DAS and it recorded maximum of 77.90, 135.40 and 155.72 cm respectively. Overall, spraying of MC reduced the plant height when compared to control. Similarly, Foliar application of MC 250 ppm at 80 DAS or MC 125 ppm at 60 and 80 DAS reduced plant height by 11.2 and 8.1 percent, respectively, over control [9]. Zhao and Oosterhuis. [10] also observed that MC application reduced plant height, improved leaf CO_2 -exchange rate, and increased leaf starch content. Magnitskiy et al. [11] found that plant growth inhibitors can diminish internodal length and vegetative development by delaying cell division and elongation of plant aerial parts, as well as restricting gibberellin production.

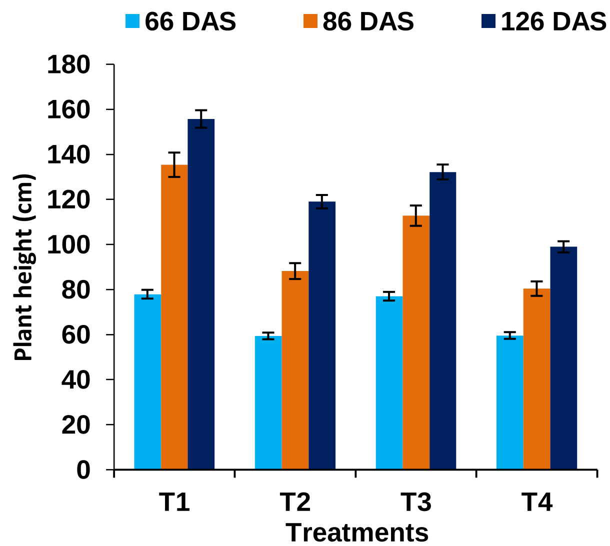

Fig. 1. Effect of mepiquat chloride on plant height (cm) of cotton variety (CO 17)

T1 - Control
T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage
T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage
T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

3.2. Leaf area

Excessive shadowing inside the plant canopy resulted in abscission of fruit and yield loss. Plants treated with MC are shorter and more compact and have a reduced leaf area index due to smaller leaf size and mature faster [8]. Shortened stem, reduced leaf expansion, petiole length, node number and faster maturity of cotton crop are all visible consequences of MC, according to Bogiani and Rosolem. [12] In hybrid Bt cotton 'DDH-11,' application of MC 50 ppm sprayed at 90 DAS was most effective in reducing plant height and leaf area, resulting in higher boll weight and significantly higher seed cotton production than control [13]. In our study, Fig. 2. showed that leaf area was significantly decreased due to the application of 0.015% MC and 0.9% SC. During 66 DAS, the minimum leaf area was observed in T4 (5109.19 cm^2 $plant^{-1}$) and statistically on par with T2 and highest leaf area was recorded in T3 with the value of 9082.23 cm^2 $plant^{-1}$ and on par with T1 (Control) (9006.19 cm^2 $plant^{-1}$). Similarly, the leaf area was significantly reduced in T4 (5329.69 cm^2 $plant^{-1}$) followed by T2 (4997.60 cm^2 $plant^{-1}$) and T3 (5962.78 cm^2 $plant^{-1}$) over control (9975.43 cm^2 $plant^{-1}$) during 86 DAS. MC treatment reduced plant height, leaf area and number of leaves are connected with stunted vegetative growth [14] [15]. Similar to MC, foliar application of SC also reduced leaf area at 126 DAS in T4 (4458.97 cm^2 $plant^{-1}$) next to T2 (4972.05 cm^2 $plant^{-1}$) and T3 (5223.73 cm^2 $plant^{-1}$) compared to T1 (11146.59 cm^2 $plant^{-1}$).

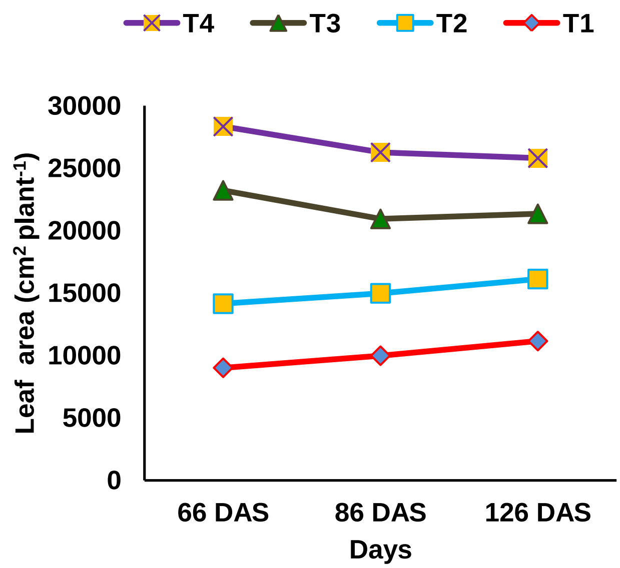

Fig. 2. Effect of mepiquat chloride and sodium chlorate on leaf area (cm^2 $plant^{-1}$) of cotton variety (CO 17)

T1 - Control T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

3.3. Total dry weight

Nagashima et al. [16] found that MC application to cotton seeds reduced plant height that synergistically reduced shoot and root growth. Because of the decreased leaf area and compact structure, the plants with MC application showed reduced competition for nutrients and light intensity [8]. This findings were in close agreement with Rosolem et al. [17] who reported that when applying MC, the dry matter production was reduced due to the change in the source-sink ratio. The experimental results indicated that total dry matter production or total biomass production was statistically reduced by application of MC and SC (Fig. 3.). At 66 days after sowing, total dry weight of T2 (41.91g $plant^{-1}$) and T4 (42.33 g $plant^{-1}$) were reduced significantly over T1 (52.67 g $plant^{-1}$) and T3 (54.60 g $plant^{-1}$).

During 86 DAS, spraying of MC (0.015%) reduced the total dry weight of plants subjected to the foliar application of 0.015% MC at square formation stage and boll development stage + 0.9% SC at 60% Boll bursting stage (T4) (64.93g $plant^{-1}$) followed by T2 (69.34 g $plant^{-1}$) and T3 (76.06 g $plant^{-1}$) over T1 (94.65 g $plant^{-1}$). When MC was applied as a seed treatment or as a foliar application, there was a reduction in dry matter production or no influence on DMP has been recorded [18] [19]. Similarly, Raut et al. [20] reported that spraying of MC reduced shoot dry weight compared to control. Ashraf et al. [21] observed significant loss in biomass due to the application of defoliants. Experimental results obtained showed that total dry weight was effectively reduced due to the application of SC in T4 next to T3 and T2 compared to control at 126 DAS (Fig. 3.). Dry matter production had a significant reduction on defoliant treated soybean [22].

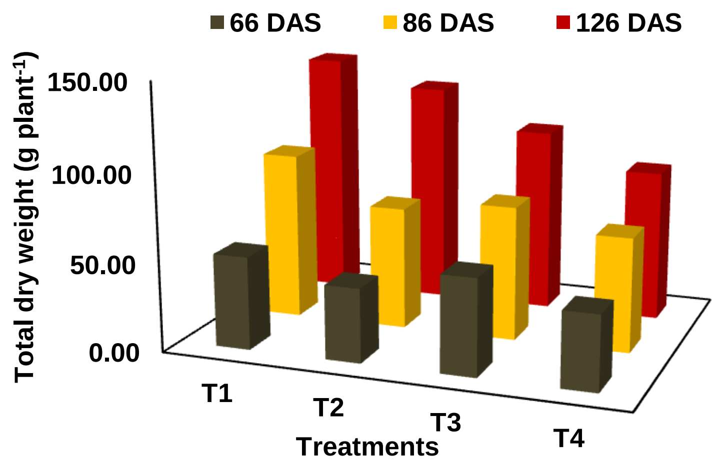

Fig. 3. Effect of mepiquat chloride and sodium chlorate on total dry weight (g plant^{-1}) of cotton variety (CO 17)

T1 - Control T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

3.4. Normalized Difference Vegetation Index (NDVI)

In cotton, the NDVI has been used to determine crop maturity, leaf area, biomass, plant height, height-to-node ratio, nodes above cracked boll, nodes above white flower, water stress, plant N status, and lint production [23]. According to Vellidis et al. [24] NDVI could be favorably used to apply growth regulator to cotton and used to form the basis for decentralisation of defoliant application zones for the cotton crop. In this current study, application of MC showed a positive effect on NDVI at 66 and 86 DAS over control (Figure 4). However, Spraying of SC at 60% boll bursting stage reduced the NDVI value (Figure 4). Spraying of 0.015% MC at square formation stage and boll development stage + 0.9% SC at 60% Boll bursting stage (T4) had highest NDVI of 0.91 and 0.83 during 66 and 86 DAS respectively next to 0.015% MC at square formation stage + 0.9% SC at 60% Boll bursting stage (T2) (0.90 and 0.82 at 66 and 86 DAS respectively). The control plant showed declined NDVI of 0.83 and 0.83 at 66 and 86 DAS respectively. At three days after spraying of SC, NDVI of T2 (0.53), T3 (0.51) and T4 (0.51) was reduced compared to control (0.77). Benedetti and Rossini [25] discovered that NDVI corresponds with photosynthetic efficiency and can be used to predict wheat output in a various agricultural locations. In winter wheat, NDVI has been used to determine photosynthetic efficiency, nitrogen uptake and grain production [26] [27].

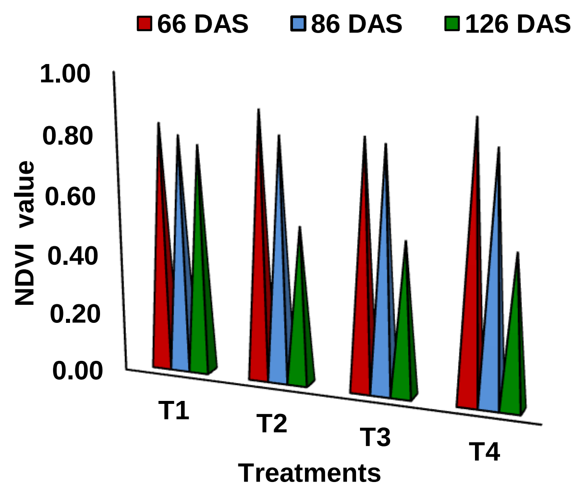

Fig. 4. Effect of mepiquat chloride and sodium chlorate on NDVI value of cotton variety (CO 17)

T1 - Control
T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage
T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage
T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

3.5. Chlorophyll content

Chlorophyll plays an important role in photosynthesis. MC increased the amount of chlorophyll content in cotton leaves that were dark green in color. Cotton that has been treated with MC usually has thicker, "leathery" leaves with more chlorophyll [28]. Increase in chlorophyll a and chlorophyll b was observed in MC treated plants at 66 and 86 DAS, a same trend was observed in total chlorophyll. According to Pal et al. [29] growth retardants have a significant impact on leaf chlorophyll content. In onion, they observed that, application of MC (125 g a.i.ha-1) at 35 DAT produced the highest total chlorophyll (2.37 mg/g), followed by 125 g a.i.ha-1 of MC at 50 DAT (2.33 mg/g) over control (1.92 mg/g). In our study, we found that application of mepiquat chloride significantly increased total chlorophyll content of cotton (CO 17) (Fig. 5.). At 66 DAS, T4 and T2 had the maximum amount of chlorophyll a, chlorophyll b and total chlorophyll compared to T1 and T3. T4 had highest total chlorophyll content of 2.06 mg g^{-1} FW over control (1.81 mg g^{-1} FW) at 86 DAS. At 86 DAS had no significant difference on chlorophyll b. Spraying of SC reduced the chlorophyll content (Fig. 5.). The chlorophyll a, chlorophyll b content of SC treated plant significantly reduced compared to control. Therefore, total chlorophyll content of T2 (0.99 mg g^{-1} FW), T3 (0.93 mg g^{-1} FW) and T4 (0.90 mg g^{-1} FW) was decreased over control (1.33 mg g^{-1} FW) due to the application of SC. Rigon et al. [30] found that applying MC to seed before sowing reduced plant height, seedling vigour, leaf area, sugar, starch, and chlorophyll content, and root-shoot dry weight. Similarly, increased chlorophyll content due to MC treatment was observed by Zhao and Oosterhuis. [10]. They also suggested that the increase could be connected to a higher specific leaf weight. MC treatment has a positive effect on chlorophyll content of cotton leaves. chlorophyll a, chlorophyll b and total chlorophyll content of cotton var Suraj has been increased in MC treated plant over control [20]. Jin et al. [30] observed the negative effect on chlorophyll a and chlorophyll b at 24 hr due to the application of defoliants. The total chlorophyll content had a significant reduction due to the application of various defoliants [31].

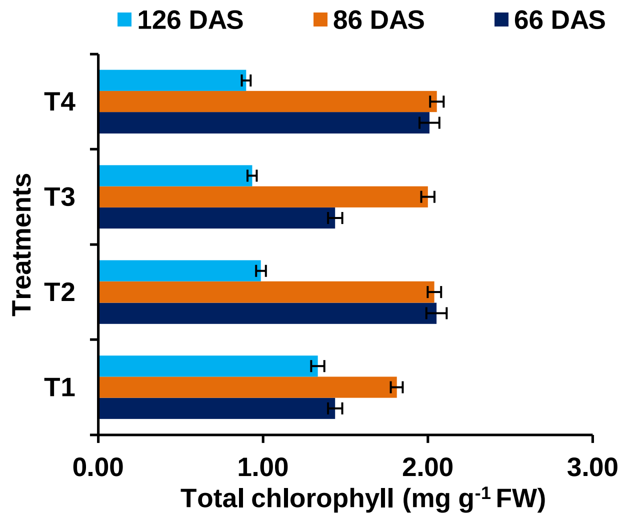

Fig. 5. Effect of mepiquat chloride and sodium chlorate on total chlorophyll (mg g^{-1} FW) of cotton variety (CO 17)

T1 - Control T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

3.6. No of Bolls per plant

Lu et al. [32] found that no difference was observed from number of bolls per plant, boll weight and lint yield with respect to Xinsaili (defoliant) treatment. In this present study, figure 6 shows that highest boll number was observed in T1 (control) with the value of 35 compared to T3 (0.015% MC at boll development stage + 0.9% SC at 60% Boll bursting stage) (26) and on par with T4 (0.015% MC at square formation stage and boll development stage + 0.9% SC at 60% Boll bursting stage) (26). Cotton plants treated with 0.015% MC at square formation stage + 0.9% SC at 60% Boll bursting stage had lowest number of bolls (T3)(23) compared with other treatments. Similarly, Kerby et al. [33] reported that MC was used to reduce vegetative growth, nutrient resources will be move to developing bolls and a higher proportion of boll production is shifted to lower nodal positions than in untreated cotton.

3.7. Seed cotton yield

Application of MC increased the seed cotton yield and also improves the fibre quality [5]. In comparison to MC application at 50 DAS, MC application at 70 DAS improved seed cotton yield plant^{-1} (23%) and ultimate cotton yield (23%) [34]. In our study, Seed cotton yield was observed at 126 DAS which had a significant difference between control and other treatments (Fig. 6.). T4 plants (0.015% MC at square formation stage and boll development stage + 0.9% SC at 60% Boll bursting stage) had the higher seed cotton yield of 140.12 g plant^{-1}which was on par with T2 (0.015% MC at square formation stage + 0.9% SC at 60% Boll bursting stag) (127.83 g plant^{-1}) and T3 (0.015% MC at boll development stage + 0.9% SC at 60% Boll bursting stage) (127.80 g plant^{-1}) over T1 (control) (111.90 g plant^{-1}). Plant growth inhibitors such as MC and cycocel (CCC) are known to reduce internodal length, resulting in lower plant height and increased photosynthates transfer to reproductive sinks (bolls), which lead to higher yields [35]. According to Gormus. [36] application of MC at first flowering and two weeks after first flowering stage produced considerably higher seed cotton production than untreated control.

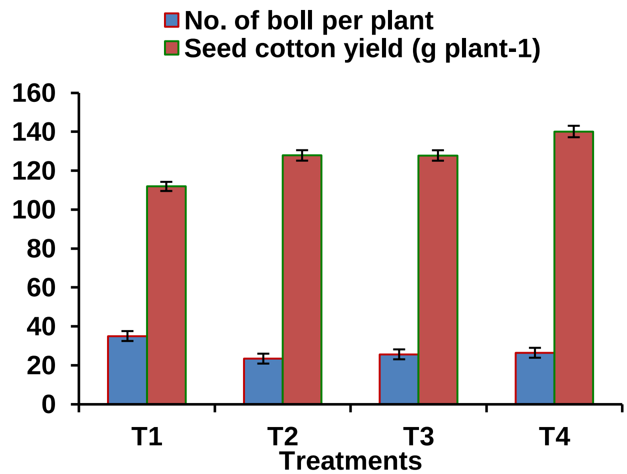

Fig. 6. Effect of mepiquat chloride and sodium chlorate on number of bolls per plant and seed cotton yield (g plant^{-1}) of cotton variety (CO 17)

T1 - Control T2 - 0.015% MC at square formation stage followed by 0.9% SC at 60% Boll bursting stage T3 - 0.015% MC at boll development stage followed by 0.9% SC at 60% Boll bursting stage T4 - 0.015% MC at square formation stage and boll development stage followed by 0.9% SC at 60% Boll bursting stage

4. CONCLUSION

Mechanical harvesting of cotton is depending on the plant canopy, which could be influenced by application of growth retardant chemicals followed by defoliants to increase the efficiency of mechanical harvesting and good lint yield and fibre quality. Hence, our field experiment was concluded that application of 0.015 % mepiquat chloride (MC) at square formation and boll development stage significantly reduced the plant height, leaf area, total dry matter production and number of bolls when compared to control, however chlorophyll content and normalized difference vegetation index (NDVI) were increased significantly than control. Moreover, spraying of mepiquat chloride (0.015%) at square formation and boll development stage followed by spraying of 0.9% sodium chlorate (SC) at 60% boll bursting stage significantly increased the seed cotton yield compared to other treatments and recorded maximum seed cotton yield of 25.22 % compared to control. Therefore, it is clearly indicated that application of MC followed by SC could be a better practice for canopy management in cotton, resulted in improving the efficiency of mechanical harvesting and good lint yield and fibre quality.

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