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Sai Durga C
Research Scholar, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Babu S
Associate Professor, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Karthikeyan A
Assistant Professor, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Dhanasekaran K
Professor, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Corresponding Author:
Sai Durga C
Research Scholar, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Effect of cyclanilide + Mepiquat chloride on growth characteristics in varietal cotton

Sai Durga C, Babu S, Karthikeyan A and Dhanasekaran K

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Abstract
The field experiment was conducted at field no.1 of G block of the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Cuddalore district of Tamil Nadu during the summer season (January to June, 2024) to evaluate the impact of plant growth regulators on cotton plant architect (*Gossypium hirsutum* L.). The experiment was laid out in a randomized block design with three replications. The experiment comprised of seven treatments of PGR application at 60 and 80 DAS and few at 50 and 70 DAS based on the plant monitoring approach *viz.*, T_1 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC @ 0.6 ml L^{-1} of water, T_2 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.9 ml L^{-1} of water, T_3 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water, T_4 - Application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS, T_5 - Application of mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS, T_6 - Nipping at 80 DAS, T_7 - Untreated check. The entire treatment was replicated three times. In the treatments including plant monitoring approach the chemical is sprayed at 50 and 70 DAS upon satisfying the criteria for the application. registered the beneficial results of growth characters, yield characters, yield and fibre quality characters of varietal cotton. Among the different PGR practices tested, application of the plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water (T_3) significantly exerted a beneficial result in growth characters *viz*., plant height, plant dry matter production, number of main stem nodes, length between top fourth and fifth internodes, Height-to-node ratio with monopodial branches showing a non- significant effect, growth analysis *viz*., LAI and chlorophyll content in leaf.

Keywords: Plant architect, PGRs, cyclanilide + mepiquat chloride

Introduction

Cotton is the most ubiquitous and profitable fiber with diverse industrial and domestic applications. Grown in more than 100 countries, it employs over 350 million people in fields and textile mills, accounting for around 7 per cent of all labor force recruitment in developing nations. Its global market worth is estimated to be around 40 billion dollars (Adeleke, 2023) [1]. It is an important agricultural commodity for the world market that provides raw materials for a wide range of industrial applications as well as numerous domestic uses (Zhang *et al*., 2020) [22]. Cotton is the second most important food source in the world, it also contributes significantly to India's net foreign exchange earnings through exports of raw cotton, intermediate products like yarn and fabrics, and final finished goods like knitwear, clothes, and makeup. The term "White-Gold" is also employed to describe it because of its economic significance in India. India's production of cotton is of paramount significance since it has an enormous effect on the nation's economy, agriculture, and society (Gyan *et al*., 2023) [9]. India got 1st place in the world in cotton acreage with 124.69 lakh hectares area under cotton cultivation i.e. around 39 per cent of world area of 318.8 lakh hectares. Approximately 67 per cent of Indian's cotton is produced on rain-fed areas and 33 per cent on irrigated lands. In terms of productivity, India is on 33rd rank with yield of 441 kg ha^{-1}.

The area under cotton cultivation has observed a significant increase at a rate of 0.72 per cent annually. Despite the increasing area under cotton cultivation, India still lags behind by 32 ranks in terms of productivity. Out of various challenges faced by the cotton farmers, few of the most concerning factors are fruit abortion, flower and boll shedding, delayed maturation, boll rot and harvesting challenges. One amongst the various reasons for these are the excessive vegetative growth which diverts the photo assimilates to the vegetative parts rather than the ecomonic reproductive parts. The balance between a plant's vegetative and fruiting stages is crucial since cotton plants continue to develop vegetatively even after fruiting has commenced. The environment and management may have an impact on this equilibrium (Wei *et al*., 2021) [20]. Vegetative overgrowth diminishes productivity, promotes fruit abscission, and shades the plant canopy (Reema *et al*., 2017) [16]. Overgrowth caused by an abundance of fertilizer and water can postpone maturity and exacerbate pest and boll rot issues (Oosterhuis, 2001) [14]. It also increases the growth of vegetative branches will reduce the light and ventilation interception within the plant population, resulting in competition for light and inorganic nutrients between the fruiting branches (FB) and main stem, thereby increasing the number of rotten bolls and reducing lint yield (Dong *et al*., 2003) [8]. It also makes the plant susceptible to the pests and diseases adding on to the cost of cultivation reducing the profit margin to the farmers.

To increase the distribution rate of assimilates to reproductive organs and increase the flower or boll ratio and lint yield in cotton, it is important and necessary to break the apical dominance (Dai *et al*., 2017) [6]. Topping in cotton is utmost important to increase the productivity. Timely topping ensures transportation of nutrients from vegetative branches to reproductive branches, that helps in reduction of abscission and rotting of cotton bolls and also promote cracking of bolls, in order to help reach the goals of early maturity, high and stable yield of cotton (Huan Song, 2017) [10]. Manual topping is very laborious and time consuming and due to the shortage of manual labor and the decline in quality and efficiency due to various reasons, manual topping has been unable to meet production demands on time (Wu *et al*., 2023) [21].

One of the easy and economical way of controlling this problem is, application of PGRs. PGRs are categorized as a broad category of compounds that promote, inhibit or otherwise modify plant physiological or morphological processes. It is well established that plant growth regulators alter the source-to-sink connection, boost translocation, and improve photosynthetic efficiency, all of which increase square and boll retention as well as boll set percentage which exactly addresses the problem in hand. Mepiquat chloride is a plant growth regulator used to manage the rampant vegetative growth of cotton (Murtza *et al*., 2022) [13]. Cyclanilide another PGR seems to enhance the effect of the compound it is mixed with (Burton *et al*., 2008) [2] and produce a uniform stand (Burton *et al*., 2009) [3]. The combination of these two chemicals offers a new method of controlling vegetative growth in cotton (Soares *et al*., 2016) [18] and may offer a quicker response in cotton (Kumari *et al*., 2013) [12]. Because conditions vary from field to field, farmers can use certain measures and visual indicators to schedule PGR applications. This is called Plant monitoring based approach of PGR application.

Materials and Methods

The experiment was conducted in the field no.1, G block of the Experimental farm, at the Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Cuddalore district of Tamil Nadu. The crop was raised during summer season of 2024 and the experimental area comes under the North Eastern Agro-Climatic Zone of Tamil Nadu which was geographically located at 11°24'N latitude and 79°44'E longitude with an altitude of ± 5.79 m above MSL. Experimental soil was clay loam with pH 8.2 and EC 0.61 dSm^{-1}, containing 227.60 kg ha^{-1} available nitrogen (low), 21.40 kg ha^{-1} available phosphorus (medium) and 278 kg ha^{-1} available potassium (high). The experimental field area comes under the North Eastern Agro Climatic Zone of Tamil Nadu with a prevailed mean maximum and minimum temperature of 34.2 °C and 20.4 °C with a relative humidity of 70.3 per cent, respectively and the rainfall was 56.4 mm in 6 rainy days during the experimental period.

The varietal cotton CO 17, with a duration of 125 to 135 days was raised at spacing of 90 x 60 cm with three replications in a randomized block design (RBD). The treatments included: T_1 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC @ 0.6 ml L^{-1} of water, T_2 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.9 ml L^{-1} of water, T_3 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water, T_4 - Application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS, T_5 - Application of mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS, T_6 - Nipping at 80 DAS, T_7 - Untreated check. Plant growth regulator based on standard applications were initiated at 60 DAS with the second application made at 80 DAS. An additional treatment consisting of nipping at 80 DAS was included. Whereas, in the treatments T_1 to T_3 the chemical is applied based on the plant monitoring approach which takes into consideration the growth and development of the cotton crop. The parameters used in determining the appropriate time for the spraying of the chemical is:

- **Height to Node Ratio:** Height of the plant from cotyledon to terminal branch measured to number of nodes present. If the value exceeds 2 (HNR > 2) then it is assumed to be the right time of PGR application.
- **Length between 4th and 5th internode:** It is the most common factor where the length between 4th and 5th internode exceeds 2.5 in., PGR is applied.

Based on these parameters, the chemical was applied at 50 and 70 DAS.

Biometric observation of growth, growth oriented analysis and physiological characters *viz*., plant height, dry matter production, number of monopodial branches $plant^{-1}$, number of main stem nodes $plant^{-1}$, length of top fourth and fifth internodes $plant^{-1}$, height-to-node ratio, leaf area index and chlorophyll content in leaves (SPAD- readings). Plant height data from five plants per plot was collected prior to the first and second applications at (30 DAS), flowering stage (60 DAS), boll development stage (90 DAS) and at harvest stage. The collected plant samples at 60, 90 DAS and at harvest for estimating DMP were chopped, initially sun-dried and then oven dried at 80°C ± 5°C for 72 hours till concordant values of weight were obtained. The weight was measured using an electronic balance and expressed in kg ha^{-1}. The length and breadth of the third leaf were measured from the top of the plant and multiplied with number of leaves and the adjustment factor 0.78 to arrive at total leaf area $plant^{-1}$ on 30, 60, 90 DAS. The number of monopodial branches $plant^{-1}$ was counted from the randomly tagged five plants in each plot at first picking and mean worked out and expressed as number $plant^{-1}$.

In addition, total number of main stem nodes plant-1 was counted from the first true leaf node above the cotyledons until reaching the uppermost unfurled leaf at 30, 60 and 90 DAS. The length of the top fourth and fifth internodes from the terminal point of plant was measured by using measuring tape at 30, 60 and 90 DAS. Height-to-Node Ratio (HNR) = Plant height (in.) / number of main stem nodes plant^{-1} was recorded at 40 and 75 DAS. Chlorophyll content of leaves at 40, 75 and 100 DAS was recorded as described using the chlorophyll meter (SPAD- 502, Soil Plant analysis Development Section, Minolta Camera Co. Ltd., Japan). The readings were recorded on the upper most fully expanded leaf in between the leaf margin and the midrib of five SPAD readings from five randomly chosen plants at different growth stages. The average values were worked out and taken as the final value and expressed as SPAD readings. The estimated data were analyzed as per the procedure outlined by Gomez and Gomez (1991) and critical difference was worked out at 5 per cent probability level for significant results.

Results and Discussion

Effect on plant height

The height of the cotton plant is drastically reduced by the application of cyclanilide 2.10% w/w + Mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} of water at 50 and 70 DAS (T_3). The height of the plant was observed to be more in control plot (T_7).

Plant growth regulation effects of cyclanilide and mepiquat chloride are thought to occur due to disrupted auxin movement (Burton *et al*., 2008) [2] as well as inhibition of gibberellin synthesis. When cyclanilide is combined with mepiquat chloride, it is used for early season growth management, to prevent excessive vegetative growth and produce a uniform stand. The inhibition of gibberellin biosynthesis by mepiquat chloride is mediated by auxin, which induces enzymes to metabolize the inactive form GA20 to the active GA1 and cyclanilide probably inhibited the auxin transport and increase the efficiency of gibberellin biosynthesis inhibitor. It is observed that higher the concentration of the applied PGR, lower is the height observed. This phenomenon was also observed in the experiment conducted by Kaur *et al*. (2021) [11].

Effect on Dry Matter Production

DMP was found to be higher in cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 0.6 ml L^{-1} of water at 50 and 70 DAS (T_1). The least amount of DMP was found in Control (T_7).

It is observed that the application of high dosage of PGRs have reduced the dry matter production. This might be due to the reduction of plant height and reduced number of main stem branches. But it was slightly compensated with its tendency to increase the weight of the leaf and boll weight due to increased photosynthetic rate and better partitioning of the photo assimilates to the reproductive parts. The optimum dosage of the chemical had higher DMP which was due to increased number of sympodial branches and bolls which compensated the loss of vegetative weight. This was in line with Riar (2011) [17].

Effect on main stem nodes and length of 4th and 5th internode

The number of nodes in the main stem is important for cotton yield for fruiting branches are formed from these structures. The PGRs have significantly decreased number of main stem nodes. Application of cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} of water at 50 and 70 DAS (T_3) reported lowest number of main stem nodes. The highest number was observed in untreated plot (T_7).

The internode lengths of the uppermost five nodes on the cotton plant should also be monitored. Any internode located below this region has ceased expanding. The uppermost 5 nodes are the region of the plant actively growing which can be managed by applications of mepiquat chloride. Measurements of these nodes are also incorporated into the decision for "Plant Monitoring Approach Based Rate Recommendations". The PGRs have observed to decrease the length of top fourth and fifth internode. This might be due to restricted cell division due to inhibition of gibberilic acid and reduced height of the plant which eventually reduced the length between the respective nodes. This is in conformity with Celsia (2024) [5].

Effect on Height to node ratio

The height to node ratio (HNR) should be monitored to evaluate vegetative growth. A cotton plant is considered to be vegetative when the average internode length is greater than a specific value at a specific developmental stage. Application of cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} of water at 50 and 70 DAS (T_3) has reduced the height node ratio to the lowest. This due to the reduced plant height due to reduced intermodal length. The results are in line. Higher the concentration of the chemical, lower is the HNR. The highest HNR is observed to be the untreated control (T_7). This is in line with Raut *et al*. (2019) [15].

Effect of PGRs on Physiological characters of cotton

Effect on LAI

Leaf area index (LAI) is the ratio of leaf area per plant to the ground area occupied by the plant canopy. It determines the total assimilating area available to cotton plants and the amount of source that will eventually be accessible for translocation to sink. Lowest LAI was noted in cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} of water at 50 and 70 DAS (T_3). Highest LAI was reported in the untreated check (T_7).

PGRs significantly reduce LAI. MC has said to control the canopy structure through reduction of leaf area. Since mepiquat chloride does not stop the growth of the cotton plant, the reduction in leaf size is also generally correlated with an increase in leaf thickness. In cotton, MC increased the number of photoassimilates produced by the leaves, altered the source–sink relationship, decreased ribulose 1,5-bisphosphate carboxylase/oxygenase (RuBisCO) activity, and increased stomatal conductivity (Zhao and Oosterhuis, 2000) [23].

Effect on Chlorophyll content

Application of cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} of water at 50 and 70 DAS (T_3) has significantly increased the chlorophyll content of the leaves. Least chlorophyll content was observed in the control plot (T_7). MC application has a significant impact on chlorophyll contents in cotton leaves and the authors suggested that this increment might be associated with higher specific leaf weight due to the fact that MC application up-regulated the chlorophyll contents. MC is said to improve photosynthetic rate and relative chlorophyll content (SPAD value) and further improves photosynthesis in cotton leaves, CO_2 exchange rate and starch concentration, improves cotton's secondary metabolites by raising phenolic acids like lignin, total phenols, and tannins (Cai *et al*., 2002) [4], increases membrane stability by regulating ionic salts like Sodium (Na^+), Potassium (K^+), and Chlorine (Cl^-) (Wang *et al*., 2020) [19] and improves cotton's ability to withstand osmotic pressure by raising its proline and protein content (Deng *et al*., 2013) [7].

Table 1: Effect of plant growth regulators on Plant height (cm), dry matter production (kg ha^{-1}) at harvest stage of variety cotton

Treatments	Plant height (cm)	Dry matter production (kg ha^{-1})
T_1 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water	103.66	5121
T_2 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.9 ml L^{-1} of water	90.03	4984
T_3 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water	83.60	4454
T_4 - Application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS	97.80	4838
T_5 - Application of mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80DAS	96.23	4774
T6 - Nipping at 80 DAS	98	4645
T7 - Untreated check	117.56	4397
S.Ed±	1.96	45.69
CD (p=0.05)	3.97	91.27

Table 2: Effect of plant growth regulators on main stem nodes plant^{-1}, Length between top fourth and fifth internode (cm) and Height to Node Ratio (HNR) at various stages of variety cotton

Treatments	Number of main stem nodes plant^{-1}		Length between top fourth and fifth internode (cm)		Height to Node Ratio (HNR)	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
T_1 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water	14.98	18.93	3.98	3.15	1.69	1.87
T_2 -Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.9 ml L^{-1} of water	13.86	16.53	3.89	2.57	1.67	1.61
T_3 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water	13.28	15.06	3.73	2.31	1.64	1.57
T_4 - Application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS	15.87	17.84	4.23	2.84	1.91	1.88
T_5 - Application of mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80DAS	15.63	17.83	4.85	2.95	1.96	1.91
T_6 - Nipping at 80 DAS	15.21	17.87	5.01	2.89	2	1.89
T_7 - Untreated check	15.34	19.97	4.89	5.53	2.02	2.19
S.Ed±	0.54	0.45	0.07	0.12	0.017	0.03
CD (p=0.05)	1.08	0.99	0.16	0.24	0.04	0.07

Table 3: Effect of plant growth regulators on Leaf Area Index (LAI) and Chlorophyll content (SPAD readings) at various stages of variety cotton

Treatments	Leaf Area Index		Chlorophyll content (SPAD readings)	
	60 DAS	90 DAS	60 DAS	90 DAS
T1 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water	3.12	2.87	43.14	40.65
T2 -Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.9 ml L^{-1} of water	2.96	1.83	44.91	41.17
T3 - Plant monitoring approach application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 1.2 ml L^{-1} of water	2.81	1.29	45.63	42.73
T4 - Application of cyclanilide 2.10% + mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80 DAS	3.45	2.21	41.72	39.83
T5 - Application of mepiquat chloride 8.40% w/w SC@ 0.6 ml L^{-1} of water at 60 and 80DAS	3.57	2.41	42.07	39.51
T6 - Nipping at 80 DAS	3.66	2.63	42.17	38.22
T7 - Untreated check	3.86	3.15	41.96	35.97
S.Ed±	0.07	0.09	0.16	0.35
CD (p=0.05)	0.15	0.19	0.32	0.71

Conclusion

The results of the field experiment on cotton crop variety revealed that the growth characters such as plant height, number of main stem nodes, length between top fourth and fifth internodes, Height-to-node ratio and growth analysis *viz.*, LAI were significantly influenced by the application of different plant growth regulators at various growth stages of cotton. Among all treatments, significant reduction was found with the application of cyclanilide 2.10% w/w + mepiquat chloride 8.40% w/w SC @ 1.2 ml L^{-1} on 50 and 70 DAS (T_3) and shows a decrease in DMP and increase in chlorophyll content in leaf and number of monopodial branches plant^{-1} was found non-significant under this treatment (T_3). The increase in growth characters and growth analysis were recorded under untreated check (T_7).

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