



Effect of Different Defoliant and Time of Application on Defoliation Percentage and Boll Opening Percentage in High Density Cotton (*Gossypium hirsutum* L.)

P. Chandrasekaran^{1*}, V. Ravichandran¹, A. Senthil¹, L. Mahalingam²
and N. Sakhivel³

¹Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

²Department of Cotton, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

³Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. This study was designed by all authors.

The work was done by author PC under the guidance of author VR who reviewed, edited and administered the writing evidence. Data and statistical analysis were performed and first draft of the manuscript composed by the author PC. Authors AS, LM and NS assisted in the writing of the paper. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the time and type of chemical defoliant to improve the mechanical and manual picking of high density cotton CO 17 in terms of higher defoliation and increase boll opening percentage.

Study Design: The study was performed in split plot design with seven treatments and four replications.

Place and Duration of Study: This field study was carried out in Department of Crop Physiology TNAU, Coimbatore during September 2019 to January 2020.

*Corresponding author: E-mail: chandrumano11@gmail.com;

Methodology: Three time of defoliants application (120 Days After Sowing (DAS), 127 DAS and 134 DAS) for main plot and seven treatment levels of Control, 2, 4 D (0.5%), Ethephon (0.5%), Ethephon (0.5%) + TIBA (450 ppm), Sodium chlorate (0.9%), 6-BAP (0.1%), Thidiazuron + Diuron (0.03%) for sub plot.

Results: Defoliation percentage was significantly enhanced from 4 days after defoliants spray. Boll opening percentage also increased with defoliants spray when compared to control plants. Although a significant effect was observed on SPAD value, NDVI value and seed cotton yield.

Conclusion: From this study, application of Thidiazuron + Diuron (0.03%) and Sodium chlorate (0.9%) had significantly positive effect in per cent defoliation and boll opening percentage and it will work better in young cotton plants compare to mature one.

Keywords: Cotton; defoliation; NDVI; SPAD meter; seed cotton yield.

1. INTRODUCTION

Cotton is a perennial plant with indeterminate growth character which provides employment and sustenance to a population of nearly 42 Million people in India. It grows in tropical and subtropical regions around the world, including the India, Americas, Africa and Egypt. There are four commercially grown species of cotton available and *Gossipium hirsutum* occupied 90% of world production. Cotton is an important cash crop for Indian farmers. It is third in total acreage planted among all crops in India after rice and wheat. India is projected to produce 28.7 million bales of cotton in 2018-19 and India recorded first in cotton cultivated area of 12,235 in thousand hectares and productivity of 519 kilogram per hectare and second place in production after China during 2017- 2018 [1]. In Tamil Nadu most of the cotton cultivars produce huge foliage even at the time of crop maturity which delay in opening of bolls and resulted in asynchronized boll opening. The multiple pickings require more expenditure and is also time consuming because of dependence of labors. The availability of labors and picking cost is also a serious problem of current situation. Most of the farmers uproot the cotton after one or two pickings and in this situation the unopened bolls cannot contribute to final seed cotton yield. These problems can be solved by introduction of mechanical picking in cotton cropping system. For mechanical picking, it is necessary to shed the leaves artificially through application of defoliants which will also synchronize boll opening [2]. It will help in timely vacation of the field for next crop and also which contain ethylene help in leaf drop, synchronous and early boll opening due to full exposure to sunlight. It makes cotton ready for single picking by machine [3].

Defoliation is the detachment or drop of leaves from plant. Physiologically matured leaves detached naturally but in case of chemical defoliants induce abscission layer in the petiole which helps to early and uniform dropping of leaves. Defoliants applied before harvesting in response to enhance the harvesting efficiency in terms of reduce trash in the lint, pest and diseases, lodging of plants. The defoliating too late or early can negatively affect the yield due to presence of higher number of late season immature bolls. However, the seed cotton yield was greater in the plots where defoliant was applied at the time of 60 per cent boll maturity [4]. They use several techniques to determine crop maturity, including 60 percent open bolls, 3 Nodes above cracked boll and visual inspection of cut bolls (hard to cut and brown seed coats). Proper defoliation has numerous benefits including reducing the amount of leaf and other plant material in harvested seed cotton [5], reducing damage to fiber in the ginning process by lessening the amount of cleaning required for lint quality, reducing losses to boll rot, and allowing for earlier harvest to avoid weathering [6]. Defoliants function optimally when applied to mature, healthy leaves at appropriate rates [7]. Application of ethephon (90 ml) resulted in the optimal defoliation effect and ripening of the cotton on 5 and 15 days respectively after the chemical application. It was found that the Ethephon application had a larger effect on the cotton defoliation than the boll opening rate [8]. [9] observed that earlier application at 140 DAS lead to severe yield loss but later application of defoliants at 150 DAS significantly and adversely recorded higher defoliation and yield. At present there is no recommendation for defoliants in Tamil Nadu, hence the present study was conducted with the aim to identify the type of defoliant, their physiological mechanisms and suitable time of application.

2. MATERIALS AND METHODS

Field experiment was conducted at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during 2019 to 2020. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH. 8.38), low in organic carbon (0.52%), low in available nitrogen (202 kg/ha), medium phosphorus (14.0 kg/ha) and high in available potassium (878 kg/ha). The maximum and minimum temperature was 30.4°C and 20.8°C from sowing to final harvest. CO 17 cotton variety was used as experimental material and it is medium duration variety had 140 to 150 days. This variety was developed for mechanized harvest of with high density planting (100 X 10 cm spacing). The experiment was laid out in a split-plot design with four replications. The main plot consist of three stage of defoliant spray viz., Spray at 120 DAS, Spray at 127 DAS and Spray at 134 DAS (Days After Sowing) and the sub-plots were seven foliar treatments (Control, 2, 4 D (0.5%), Ethephon (0.5%), Ethylene (0.5%)+ Triiodbenzoic acid-TIBA (450 ppm), Sodium chlorate (0.9%), 6 benzylaminopurine (BAP) @ 0.1%, Thidiazuron + Diuron (0.03%). Control treatment was sprayed with water. Each plot had 6 X 5 m area were arranged accordingly so that each plot could be mechanically harvested without affecting other plots. Recommended cultural practices and plant protection measures were followed throughout the crop growing season.

2.1 Defoliation Percentage and Boll Opening Percentage

Defoliation Percentage and boll opening percentage was calculated by using the formula given by [10],

$$\text{Defoliation Percentage} = \frac{L_a - L_b}{L_a} \times 100\%$$

Where,

L_a = Number of leaves before treatment,
 L_b = Number of leaves after treatment.

Boll opening percentage was determined on the tagged plants. Bolls on each plant were examined and recorded as either opened or closed and the boll opening percentage was calculated by following equation,

$$\text{Boll Opening Percentage} = \frac{OB}{TB} \times 100\%$$

Where,

OB = Number of opened bolls,
 TB= Number of Total bolls.

2.2 Soil Plant Analytical Development (SPAD)

SPAD readings were recorded by using Chlorophyll Meter (SPAD 502) designed by the Soil Plant Analytical Development (SPAD) section, Minolta, Japan. The Minolta SPAD-502 measures chlorophyll content as ratio of transmittance of light at wavelength of 650 nm and 940 nm. Five readings were taken from each replication and the average value computed using method described [11].

2.3 Normalized Difference Vegetation Index (NDVI)

The NDVI value was recorded by using green seeker (handheld crop sensor). It is calculated from near infra red (NIR) and red wavelength regions. Instead, it was higher in green leaves, lower in yellow and orange leaves, but intermediate in red leaves, which may due to a low sensitivity of the bands used for NDVI for the color change from green to yellow color [12].

2.4 Seed Cotton Yield and Statistical Analysis

One week after application of the last defoliation treatments, seed cotton yield was determined in plots by manual harvesting of the center two rows of each plot and calculated $g \text{ plant}^{-1}$. Number of bolls harvested from each plant with replication was counted and total number of bolls per plant was calculated. Bolls weight was calculated by adding the weight of five bolls from each plant and divided it by total number of fruits and expressed in $g \text{ boll}^{-1}$.

The data collected were subjected to statistical analysis in split-plot design using Least square design (LSD) [13].

3. RESULTS AND DISCUSSION

3.1 Effect of Defoliant on Defoliation Percentage

Significant differences between the treatments, time of applications and interaction effects used for study were observed for various parameters.

The leaf SPAD value, NDVI value and defoliation percentage were significantly difference between treatments and time of application and these parameters observed in 4 and 15 days after defoliant spray. As per observation, immediately after application of the defoliant the green leaves showed shedding symptoms on 4 days after defoliant spray to 15 days after spray. The leaves shedding were observed significantly higher in (63.6, 64.9 and 63.4%) Thidiazuron + Diuron (0.03%) treatment followed by Sodium chlorate (0.9%) treatments at three different times of defoliant spray. Defoliant spray at 120 DAS showed significantly higher defoliation rate from 4 days after defoliant spray. These two defoliant work better in 120 DAS of defoliant application. At 15 days after defoliant spray Thidiazuron + Diuron (0.03%) recorded higher defoliation (98.6, 98.1 and 97%) in all three time of application which is on par with Sodium chlorate (0.9%). Similar results were observed in [14] and [15] found the highest defoliation rate in Drop Thidiazuron + diuron treated plants. It might be due to the change of the ethylene to auxin ratio, leaf abscission prematurely occurred after application of defoliant like Thidiazuron [16]. Although, some defoliant were used to enhance the boll maturity [17]. Defoliation indicated that chemical induced abscission results in reduced chlorophyll, photosynthesis, alterations in carbohydrate transport, and hormone crosstalk. The increase of ROS-scavenging enzymes in plants will increased the abscission of leaves, and boll opening due to stress [18].

3.2 Effect of Defoliant on Physiological Parameters

As plants aging, chlorophyll content of leaves decreases. 4 days after defoliant spray, Sodium chlorate (0.9%) showed significantly less SPAD value which is on par with 2, 4 D (0.5%). 120 and 127 DAS recorded lowest SPAD value compare to 134 DAS. In interaction effect, Sodium chlorate (0.9%) at 120 DAS registered significantly lowest value when compare to other treatments. Finally at 15 days after defoliant spray, 134 DAS recorded significantly lowest value. Sodium chlorate (0.9%) at 127 DAS and 2, 4 D (0.5%) at 134 DAS registered lowest SPAD values. Sodium chlorate (0.9%) showed lowest value (21.8 units) followed by Thidiazuron + Diuron (0.03%) treatment (23.9 units). Lower SPAD value indicates that degradation of chlorophyll in response to defoliant application which enhances the defoliation process. In this, we conclude sodium chlorate works better in later maturity stages and Thidiazuron and Diuron works better in early maturity stages of cotton. Similar result showed by [19] that the chlorophyll content decreased more in thidiazuron defoliant treated plants when compare to control plants. It may be due to the degradation of chlorophyll and formation of anthocyanin and xanthophylls.

At 4 days after defoliant spray foliar spray at 120 DAS showed significantly lowest NDVI in Sodium chlorate (0.9%) (0.437 units) treatment followed by (0.507 units)

Table 1. Effect of defoliant on defoliation percentage of CO 17 cotton variety

Treatments	Defoliation %				Defoliation %			
	(4 days after defoliant spray)				(15 days after defoliant spray)			
	120 DAS	127 DAS	134 DAS	Mean	120 DAS	127 DAS	134 DAS	Mean
Control	5.2	6.2	7.6	6.3	37.9	27.7	26.1	30.6
2, 4 D (0.5%)	42.4	35.8	32.7	37.0	73.8	74.7	73.5	74.0
Ethephon (0.5%)	33.9	35.9	33.3	34.4	60.9	65.3	66	64.1
Ethephon (0.5%)+ TIBA (450 ppm)	36.6	23.4	33.6	31.2	70.2	69.7	69.3	69.7
Sodium chlorate (0.9%)	45.7	49.9	45.4	47.0	97.5	97.3	96.4	97.1
6-BAP (0.1%)	22.9	23.1	23.2	23.1	62.1	61.3	63	62.1
Thidiazuron + Diuron (0.03%)	63.6	64.9	63.4	64.0	98.6	98.1	97	97.9
Mean	35.8	34.2	34.2		71.6	70.6	70.2	
Factors	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.13**	0.48**	0.78**	0.83**	0.41	1.00**	1.65**	1.72**
CD (0.05)	0.035	0.97	1.60	1.68	NS	2.02	3.42	3.50

* Denotes significant at the 0.05 level of probability ** Denotes significant at the 0.05 level of probability

Table 2. Effect of defoliant on chlorophyll index (SPAD unit) of CO 17 cotton variety

Treatments	(4 days after defoliant spray)				(15 days after defoliant spray)			
	120 DAS	127 DAS	134 DAS	Mean	120 DAS	127 DAS	134 DAS	Mean
Control	40.7	42.2	42.4	41.8	31.3	34.9	31.1	32.4
2, 4 D (0.5%)	37.6	37.6	36.6	37.3	28	31.8	22.3	27.4
Ethephon (0.5%)	39.5	38.8	41.4	39.9	28.1	29.9	29.2	29.1
Ethephon (0.5%)+ TIBA (450 ppm)	39.3	34.9	41.7	38.6	30.9	25.8	31	29.2
Sodium chlorate (0.9%)	32.9	37.1	40.9	37.0	23.8	21.8	23.4	23.0
6-BAP (0.1%)	42.3	42.3	38.6	41.1	30.4	30.5	28.7	29.9
Thidiazuron + Diuron (0.03%)	40.03	40.6	41.4	40.8	23.9	24	27	25.0
Mean	38.9	39.1	40.4		28.1	28.4	27.5	
Factors	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.20**	0.46**	0.77**	0.81**	0.15**	0.039**	0.65**	0.68**
CD (0.05)	0.57	0.94	1.61	1.63	0.43	0.80	1.35	1.38

* Denotes significant at the 0.05 level of probability ** denotes significant at the 0.05 level of probability

Thidiazuron + Diuron (0.03%). De greening occurred towards leaf drop up to 15 days after defoliant spray. In that 15 days after defoliant spray 2, 4 D (0.5%) spray at 120 and 127 DAS and Sodium chlorate (0.9%) had lower NDVI values. This explored that Sodium chlorate (0.9%) at 120 DAS and 2, 4 D (0.5%) at 127 DAS reduce the foliage which recorded the lower NDVI values in the field. Similar report was given [20] while the photosynthetic apparatus is being dismantled and the chloroplasts turn into gerontoplasts, a simultaneous increase of anthocyanin accumulation is observed. The NDVI, which is calculated from near infra red (NIR) and red wavelength regions, it was high in green leaves, low in yellow and orange leaves,

but intermediate in red leaves, which might be due to a low sensitivity of the bands used for NDVI for the color change from green to yellow [12]. This non continuous response to senescence does not represent chlorophyll content, higher NDVI in red leaves might be a consequence of the presence of anthocyanins, which have been shown to contribute to increased NDVI values [21]. As senescence is progressing, a swelling of thylakoid membranes, a slight increase in the number of plastoglobuli, and a decrease of pigment contents is observed; eventually leading to the degradation of the thylakoid membranes, the significant increase in the number and size of plastoglobuli, and to the further decrease of chlorophyll contents [22].

Table 3. Effect of defoliant on NDVI (NDVI unit) of CO 17 cotton variety

Treatments	(4 days after defoliant spray)				(15 days after defoliant spray)			
	120 DAS	127 DAS	134 DAS	Mean	120 DAS	127 DAS	134 DAS	Mean
Control	0.727	0.727	0.730	0.728	0.645	0.615	0.660	0.640
2, 4 D (0.5%)	0.547	0.653	0.703	0.634	0.220	0.210	0.0335	0.255
Ethephon (0.5%)	0.613	0.713	0.740	0.689	0.0375	0.0315	0.415	0.0368
Ethephon (0.5%)+ TIBA (450 ppm)	0.590	0.690	0.707	0.662	0.530	0.470	0.560	0.520
Sodium chlorate (0.9%)	0.437	0.717	0.700	0.618	0.195	0.0355	0.265	0.272
6-BAP (0.1%)	0.677	0.757	0.700	0.711	0.550	0.540	0.580	0.557
Thidiazuron + Diuron (0.03%)	0.507	0.727	0.760	0.664	0.0395	0.265	0.0330	0.0330
Mean	0.585	0.712	0.720		0.416	0.0396	0.449	0.420
Factors	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.005**	0.009**	0.015**	0.015**	0.003**	0.006**	0.010**	0.01**
CD (0.05)	0.015	0.018	0.037	0.0316	0.008	0.012	0.021	0.021

* Denotes significant at the 0.05 level of probability ** Denotes significant at the 0.05 level of probability

Table 4. Yield parameters of CO 17 cotton variety as influenced by different defoliant and time of application

Treatments	Number of bolls				Single boll weight (g)				Seed cotton yield (g /plant)			
	120 DAS	127 DAS	134 DAS	Mean	120 DAS	127 DAS	134 DAS	Mean	120 DAS	127 DAS	134 DAS	Mean
Control	15	16	20	17.0	6.1	5.1	5.8	5.7	61.8	60	56.8	59.5
2, 4 D (0.5%)	17	15	12	14.7	5.9	5.7	4.4	5.3	56.4	51.1	57.2	54.9
Ethephon (0.5%)	14	18.3	12	14.8	5.2	5.3	5.5	5.3	63.7	59.9	60.4	61.3
Ethephon (0.5%)+ TIBA (450 ppm)	14.3	15.7	16	15.3	6.4	6.5	4.2	5.7	67.4	52.3	51.9	57.2
Sodium chlorate (0.9%)	15	19	11.7	15.2	5.6	6.3	4.7	5.5	51.1	59.5	51.4	54.0
6-BAP (0.1%)	16	14.3	15.7	15.3	5.2	6	4.8	5.3	56.7	55.2	50.6	54.2
Thidiazuron + Diuron (0.03%)	17	13	15.3	15.1	4.5	4.7	5.6	4.9	59.9	61.5	62.1	61.2
Mean	15.4	15.9	14.6		5.6	5.7	5.0		59.6	57.1	55.8	
Factors	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.11**	0.22**	0.036**	0.038**	0.05**	0.06**	0.10**	0.10**	0.25**	0.69**	1.13**	1.19**
CD (0.05)	0.030	0.44	0.76	0.76	0.13	0.12	0.23	0.21	0.70	1.40	2.34	2.42

*Denotes significant at the 0.05 level of probability ** Denotes significant at the 0.05 level of probability

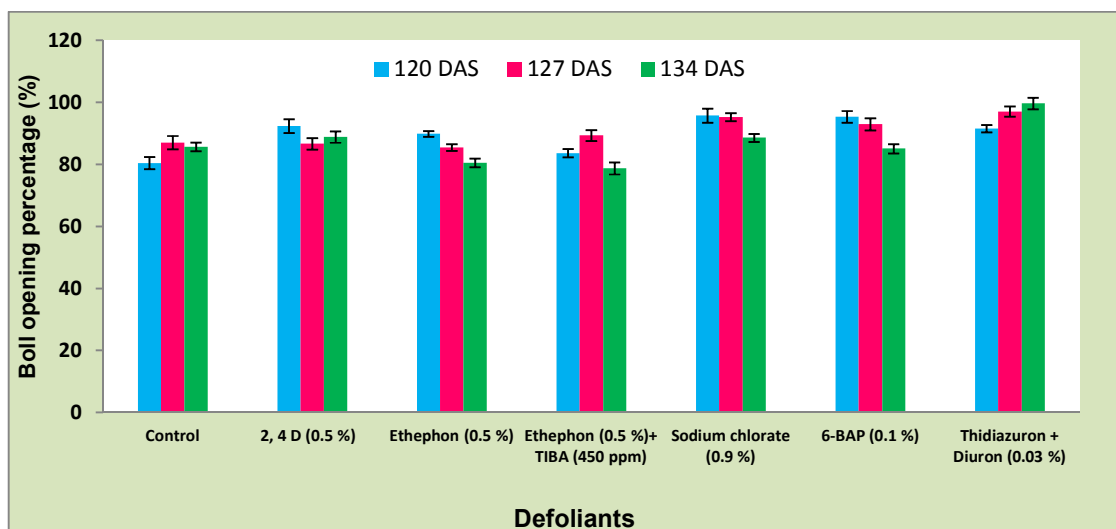


Fig. 1. Effect of defoliants on boll opening percentage (%) of CO 17 cotton variety
Significant from normal control, Mean \pm S.E.M = Mean values \pm Standard error of means of treatments

3.3 Effect of Defoliants on Boll Opening Rate and Yield Attributes

120 DAS registered significantly higher number of bolls. Ethephon (0.5%) (18.3 Nos) and Sodium chlorate (0.9%) (19 Nos) was increased number of bolls in 127 DAS. 120 DAS and 127 DAS registered higher boll weight. Ethephon (0.5%) + TIBA (450 ppm) were recorded higher single boll weight at 120 DAS (6.4 g) and 127 DAS. Sodium chlorate (0.9%) also had higher single boll weight at 120 DAS. [23] and [24] indicated that the seed cotton weight decreased by 14% in late sowing results were coinciding with our study. Ethephon (0.5%) and Thidiazuron + Diuron (0.03%) showed higher yield than other treatments. In other side, time of application and its interaction effect 120 DAS registered higher yield compare to other time of defoliants applications. Ethephon (0.5%) + TIBA (450 ppm) in 120 DAS and Thidiazuron + Diuron (0.03%) at 127 and 134 DAS had good yield. Similar results given by [25] stated that defoliant applied plants give more seed cotton yield than control plants. The use of different defoliants and intervals of their application did not significantly affect the seed index and ginning outturn [26].

Significantly higher boll opening percentage was recorded in 120 and 127 DAS. In treatments effect Thidiazuron + Diuron (0.03%) recorded higher boll opening followed by Sodium chlorate (0.9%). In interaction effect, Sodium chlorate (0.9%) spray at 120 DAS and Thidiazuron + Diuron (0.03%) spray at 127 and 134 DAS were

recorded higher boll opening rate. [27] stated that all applications contributed to more opened bolls than control plots. [14] indicated that defoliant applications formed more opened bolls than control plot. Ethephon is an ethylene precursor that is used as both defoliation and boll-opening compound in cotton. Economically, the application of a single defoliant may induce satisfactory outcome; however, the mixtures would perform better under less desirable defoliation conditions.

4. CONCLUSION

The result of this study explored that the effect of different defoliants and time of application on defoliation, boll opening, physiological and yield of high density Cotton. Thidiazuron + Diuron (0.03%) and Sodium chlorate (0.9%) significantly works better in per cent defoliation within 15 Days after defoliants spray. In this defoliation effect because of the defoliants decreased the SPAD, NDVI values representing the chlorophyll or greenness of leaves and without affecting final yield. These results indicate that the high density Cotton CO 17 possibly mechanized picking with these effective defoliants with high boll opening rate.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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