Impact of Chemical Defoliants on Chlorophyll Fluorescence, Biochemical Parameters, Yield and Fiber Quality of High Density Cotton

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ABSTRACT

Background: The Cotton growing farmers in India are facing major problem at the time of harvest due to labor shortages, asynchronized boll opening, leaf trash in the cotton, which is reducing the boll picking efficiency and fiber quality. Presently, the Indian cotton industry is moving towards mechanical harvesting by cotton harvester. Defoliation or leaf abscission is induced in cotton as a natural physiological process which usually is inadequate for a complete mechanical harvest of cotton. Defoliation before harvest is often induced by managing the plants so that senescence, abscission (separation) layer development and leaf drop are encouraged. Chemical defoliants induce leaf abscission, hasten mature boll dehiscence and inhibit re-growth. Selection of appropriate defoliants is one of the critical decisions in cotton production. Their use can result in increased manual as well as machine harvest efficiency, reducing boll rot and the trash in seed cotton. The physiological basis of defoliation in cotton is essential to understand the role of appropriate defoliants with time of application. Hence, the objective of the study was to evaluate the defoliation efficiency, boll opening percentage and to know the physiological basis of defoliation in response to different defoliants and time of application in high density Cotton cultivation which eases the mechanical harvesting.

Methods: In this field investigation during 2018 - 2019 at Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore was carried with seven different defoliants and three different time of defoliants application were fixed based on crop maturity and duration of the crop. In this study, high density cotton variety CO 17 was used as experimental material. A series of lab and field analysis were determined on defoliation process, physiological attributes, boll opening percentage and seed yield and quality. The collected data were subjected to statistical analysis.

Result: Our investigation exploring the effect of different defoliants on physiological, biochemical, yield and quality parameters of high density Cotton. Among the different defoliants and time of applications, two defoliants and two times of applications works better in terms of better defoliation, boll opening rate, physiology, yield and quality. The physiological and biochemical effects of defoliants on defoliation process were discussed. The present work will be useful for mechanized picking with these effective defoliants without loss of yield and quality loss in cotton.

Key words: Biochemical parameters, Chemical defoliants, Chlorophyll fluorescence, Defoliation percentage, High density cotton.

INTRODUCTION

Cotton cultivation is labor intensive in almost all developing countries. Cotton production demands labor starting from sowing to harvesting which includes several operations like inter-culture, spraying, hand weeding and picking. Chemical defoliants were applied to induce leaf abscission and hastening of mature-boll dehiscence with inhibition of re-growth. Their use can be instrumental in increasing the efficiency of machine harvest and fewer lodged plants. Presently, the Indian cotton industry and cotton growing farmers have to move towards mechanical harvesting by the cotton harvester. In this regard, the farmers were facing major problems at the time of harvesting due to leaf trash were remain in the cotton plants, which is reducing the quality of the produce. Foliages in the plant will disrupt the boll picking efficiency and fiber quality. Previously, scientists have conducted various studies on defoliation using different chemicals and time of defoliants application (Karademir, 2007). Among them, dropp ultra® and ethrel (ethfon) are the chemicals used as better defoliation and widely accepted across the world (Ming-wei, 2013). However, in India, the usage of defoliants could not be exploited much primarily due to their limited availability. However, recent works (Mrunalini et al., 2019 and Raghavendra et al., 2020)
reported the effect of few defoliants on upland cotton in India. With these background, an experiment was conducted to study the impact of defoliants on improving defoliation capacity in cotton.

**MATERIALS AND METHODS**

The field experiment was conducted at Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. In the study CO 17, a cotton variety suitable for High-Density planting was used as study material. The seeds were sown on 5th September 2018 with adapting spacing at an inter-row spacing of 100 cm and intra-row spacing of 10 cm. The experiment was carried out in a split-plot design with seven treatments, four replications and three different times of defoliants application. The main plot comprised of three stage of defoliant spray (M₁ - Spray at 120 DAS, M₂ - Spray at 127 DAS and M₃ - Spray at 134 DAS) and the sub-plots were seven foliar treatments (S₁ - Control, S₂ - 2, 4-D (0.5%), S₃ - Ethephon (0.5%), S₄ - Ethephon (0.5 %)+ TIBA (450 ppm), S₅ - Sodium chlorate (0.9 %), S₆ - 6-BAP (0.1%); S₇ - Thidiazuron + Diuron (0.03%). The control treatment was sprayed with water. The defoliants were applied as a foliar spray when cotton crop attained 60% of the bolls are open. Recommended cultural practices and plant protection measures were followed throughout the crop growing season. Before treatment application, five plants were randomly tagged from the two rows at the center of each plot for the number of green leaves present. Treatment effects were detected by counting and recording the number of green leaves remaining on the same tagged plants 4, 8, 12 and 15 days after treatment.

The defoliation percentage was recorded at 4 days interval by counting the number of green leaves before and days after defoliation from 4 to 15 days in randomly selected 5 plants for 4 replications and the defoliation percentage was calculated by the following equation, Defoliation Percentage = La - Lb/La X 100%, where La = Number of leaves before treatment, Lb = Number of leaves after treatment. Chlorophyll Stability Index (CSI) was determined by the following method of Murthy and Majumdar (1962). The total chlorophyll was estimated by adopting the procedure of Yoshida et al. (1971). Soluble protein content of the leaf was estimated by using Folin Ciocalteau reagent by following the procedure described by Lowry et al. (1950). The level of lipid peroxidation in the leaf tissue was measured in terms of malondialdehyde (MDA) content determined by the thiobarbituric acid (TBA) reaction (Heath and Packer, 1968). Chlorophyll fluorescence (Fv/Fm) was recorded using chlorophyll fluorescence waltz, Germany following the method advocated by (Genty et al., 1989). Seed cotton yield was determined in plots by manual harvesting of the center two rows of each plot and calculated single boll weight (g) recorded by one week after application of the last defoliation treatments. Fiber quality parameters like 2.5% S.L (mm), Bundle strength (g tex⁻¹) and Micronaire (μg/inch) were recorded by using High Volume Instrument (HVI) method. The data collected were subjected to statistical analysis in split-plot design (Gomez and Gomez, 1984).

**RESULTS AND DISCUSSION**

**Effect of defoliants on percent defoliation**

The effects of defoliants on the percent defoliation after defoliants spray are given in Table 1. Defoliation initiated from 4 days after defoliant application, Thidiazuron + Diuron (0.03%) treatment registered significantly higher defoliation percent (66.82, 33.02 and 61.90%) at three different stages. Raghavendra et al., (2020) reported that higher leaf defoliation was observed in Dropp ultra @ 200ml/ha spraying. But interestingly, defoliants spray at 120 and 134 DAS recorded the highest defoliation rate. These results indicated that the defoliation effect was influenced by the time of defoliant application. Defoliation in cotton by using different defoliants was influenced by various factors like the type of chemical, rate of application, crop coverage, time of application and the maturity of the plant (Stewart et al. 2000). In 8 days after defoliant application, 134 DAS registered higher defoliation rate. Among the treatments, Thidiazuron + Diuron (0.03%) application of (83.75, 61.32 and 85.71 %) recorded highest defoliation rate followed by Sodium Chlorate (0.9%). The interaction effect, Thidiazuron + Diuron (0.03%) at 120 and 134 DAS recorded higher defoliation. Under warmer conditions, physiological activity in cotton is higher, so defoliant effects may be more pronounced and rapid when compared with cooler conditions (Silvertooth and Howell 1988).

The defoliation rate increased further 12 days after defoliants spray and recorded higher defoliation rate at 120 DAS. Application of Thidiazuron + Diuron (0.03%) recorded higher defoliation rate (95.94%) at 120 DAS. At 15 days after defoliants spray, the defoliation process completed and defoliants spray at 120 DAS registered highest defoliation. Among the treatments, application of Thidiazuron + Diuron (0.03%) was recorded highest defoliation rate (99.32, 98.11 and 98.83%) followed by Sodium chlorate (0.9%). Thidiazuron is a type of chemical defoliant that significantly induces the abscission zone and leads to leaf shedding. Thidiazuron with diuron treatment biologically triggered leaf abscission process similar to the abiotic stress-triggered leaf abscission (Patharkar et. al., 2016). It can be concluded that the Thidiazuron + Diuron (0.03%) performs better in younger Cotton plants when compared to matured plants.

**Effect of defoliants on biochemical parameters**

The treatments, time of application and their interaction effects had a significant relationship with the total chlorophyll content which is given in Table 2. The lower total chlorophyll content was observed at 120 DAS (1.04 mg g⁻¹). Among the treatments, the lowest chlorophyll content (0.87) was observed in Ethephon (0.5%) + TIBA (450 ppm). In interaction effect, the lower value was observed in
### Table 1: Percent defoliation of CO 17 Cotton variety as influenced by different defoliants and time of application.

| Treatments          | Defoliation % (4 days after defoliants spray) | Defoliation % (8 days after defoliants spray) | Defoliation % (12 days after defoliants spray) | Defoliation % (15 days after defoliants spray) |
|---------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
|                     | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean |
| Control             |         |         |         |      |         |         |         |      |         |         |         |      |         |         |         |      |         |         |         |
| 2, 4 D (0.5 %)      | 41.3    | 21.8    | 38.6    | 33.9 | 58.1    | 64.6    | 64.1    | 62.3 | 66.5    | 73.9    | 73.4    | 71.3 | 81.6    | 77.3    | 79.1    | 79.3 |
| Ethephon (0.5 %)    | 32.9    | 27.9    | 34.8    | 31.9 | 53.2    | 47.3    | 51.1    | 50.6 | 68.5    | 60.5    | 65.5    | 64.8 | 74.6    | 68.1    | 66.4    | 69.7 |
| Ethephon (0.5 %)+   | 43.2    | 22.2    | 41.0    | 35.5 | 52.6    | 40.2    | 54.2    | 49.3 | 69.2    | 50.4    | 63.6    | 61.1 | 73.2    | 61.6    | 68.8    | 67.9 |
| TIBA (450 ppm)      |         |         |         |      |         |         |         |      |         |         |         |      |         |         |         |      |         |         |         |
| Sodium chlorate (0.9 %) | 15.4    | 23.3    | 23.3    | 31.3 | 53.2    | 47.3    | 51.1    | 50.6 | 68.5    | 60.5    | 65.5    | 64.8 | 74.6    | 68.1    | 66.4    | 69.7 |
| 6-BAP (0.1 %)       | 32.9    | 27.9    | 34.8    | 31.9 | 53.2    | 47.3    | 51.1    | 50.6 | 68.5    | 60.5    | 65.5    | 64.8 | 74.6    | 68.1    | 66.4    | 69.7 |
| Thidiazuron + Diuron (0.03 %) | 66.8    | 33.0    | 61.9    | 53.9 | 83.7    | 61.3    | 85.7    | 76.9 | 95.9    | 85.8    | 93.6    | 91.8 | 99.3    | 98.1    | 96.8    | 98.1 |
| Mean                | 32.7    | 23.17   | 38.86   | 55.40 | 75.31   | 81.20   | 87.27   | 81.26 | 33.89   | 28.95   | 26.60   | 29.82 |

Factors: **Denotes significant at the 0.01 level of probability**

### Table 2: Biochemical parameters of CO 17 Cotton variety as influenced by different defoliants and time of application.

| Treatments          | Chlorophyll Content (mg g\(^{-1}\)) | Chlorophyll Stability Index (%) | Soluble Protein content (mg/g) |
|---------------------|-------------------------------------|--------------------------------|-------------------------------|
|                     | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean | \(M_1\) | \(M_2\) | \(M_3\) | Mean |
| Control             | 2.86    | 2.12    | 2.39    | 2.45 | 75.31   | 81.20   | 87.27   | 81.26 | 33.89   | 28.95   | 26.60   | 29.82 |
| 2, 4 D (0.5 %)      | 1.25    | 1.34    | 1.80    | 1.46 | 74.05   | 70.05   | 66.33   | 70.14 | 25.54   | 15.07   | 20.52   |
| Ethephon (0.5 %)    | 0.78    | 1.74    | 0.67    | 1.07 | 59.02   | 75.25   | 72.00   | 69.98 | 28.95   | 22.42   | 18.66   | 23.35 |
| Ethephon (0.5 %)+   | 0.70    | 1.32    | 0.59    | 0.87 | 71.85   | 72.49   | 71.79   | 72.04 | 19.89   | 18.60   | 16.54   | 18.35 |
| Sodium chlorate (0.9 %) | 0.41    | 1.00    | 0.87    | 0.76 | 54.90   | 65.80   | 52.63   | 57.78 | 27.01   | 23.25   | 9.54    | 19.93 |
| 6-BAP (0.1 %)       | 0.70    | 0.89    | 1.52    | 1.04 | 63.58   | 74.79   | 67.01   | 68.46 | 31.89   | 24.85   | 14.84   | 23.74 |
| Thidiazuron + Diuron (0.03 %) | 0.62    | 1.30    | 1.16    | 1.03 | 55.20   | 64.77   | 59.04   | 59.67 | 21.48   | 17.19   | 18.78   | 19.15 |
| Mean                | 1.04    | 1.39    | 1.29    | 1.29 | 64.84   | 72.05   | 68.01   | 68.95 | 21.42   | 17.99   |                   |

Factors: **Denotes significant at the 0.01 level of probability**

*Denotes significant at the 0.05 level of probability
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Thidiazuron + Diuron (0.03%) at 120 DAS (0.62 mg g⁻¹). Chemical defoliants and desiccants create dehydration or stress to the plant tissues. Plant stress may result in various damages in plant tissues and most damage-related parameters that can be measured leaf chlorophyll content. Decreases in leaf chlorophyll content are therefore ultimate indicators of severe stress of the plant. There is some evidence that plant stress may accelerate the loss of leaf chlorophyll and enhance senescence as it was observed in wheat (Yang et al., 2001).

Chlorophyll Stability Index influenced by defoliants, time of application and their interaction effects are given in Table 2. The minimum value of 59.67% recorded in Thidiazuron + Diuron (0.03%). Lesser values of 54.90% were noted in Sodium chlorate (0.9%) at 120 DAS. The Defoliants on MDA content were significantly varied due to the influence of different treatments under study given in Fig 1. 120 DAS maintained its superiority in recording higher MDA content of 2.14 μmol g⁻¹. Among the treatments, the treatment sprayed with 6-BAP (0.1%) had higher MDA content of 2.47 μmol g⁻¹. Significantly higher MDA content of 3.17 μmol g⁻¹ was observed in 6-BAP (0.1%) in 134 DAS. Table 2 explained about a different time of defoliant spray had a marked variation on Soluble protein content. 120 DAS registered significantly higher soluble protein content of 26.95 mg/g. Ethephon (0.5%) + TIBA (450 ppm) recorded minimum soluble protein content of 18.35 mg/g. Sodium chlorate (0.9%) sprayed at 134 DAS which recorded significantly lower values of 9.54 mg/g. A defoliant like sodium chlorate creates salt stress is known to result in extensive lipid peroxidation and reduced soluble protein, which has often been used as an indicator of salt-induced oxidative damage in membranes (Hernandez et al., 2002). The higher values of MDA content obtained with defoliants treated plants might account for the higher lipid peroxidation levels observed and the reduced effect on membrane permeability.

**Effect of chlorophyll fluorescence parameters**

Different times of defoliants spray had a significant influence on defoliants on chlorophyll fluorescence (ETR and Y value). 120 and 127 DAS had a higher Y value of 0.378 compared to 137 DAS. Lesser Y value of 0.213 was recorded in Ethephon (0.5%) + TIBA (450 ppm). 6-BAP (0.1%) sprayed at 120 DAS had recorded higher Y value of 0.463 than other combinations. The least values of 0.164 were noted in Ethephon (0.5%) + TIBA (450 ppm) at 127 DAS. Defoliants creates dehydration of plant tissues impairs plant’s photosynthetic rate and growth, thus potentially disturbing balances while reducing plant productivity in cropping systems. Besides, reduced production of photosynthetic products may also impair osmotic adjustment and the capacity of plants to cope with abiotic stress (Blum, 2017). Fluorescence can be a very powerful tool to study photosynthetic performance, especially when coupled with other non-invasive measurements. The Linear relationship between PSII operating efficiency and linear electron flux allows the use of Fq'/Fm' to estimate the noncyclic electron transport rate through PSII (ETR). Table 4 explained about ETR and Y value of the chlorophyll fluorescence. Different time of application and their interaction effects doesn’t have a significant relationship with the effect of defoliants on ETR. Treatments under study had a significant influence on the defoliants of chlorophyll fluorescence.

NPQ can be calculated as (Fm – Fm’)/ Fm from measurements of maximal fluorescence performed on dark (Fm) and then light-adapted (Fm’) leaves (Kramer et al., 2004). The treatments, different time of defoliants spray and their interaction effect doesn’t have any significant relationship with the effect of defoliants on chlorophyll fluorescence (Photochemical quenching). Non-photochemical quenching values were influenced significantly by different times of application. 137 DAS had noted significantly higher non-photochemical quenching (7.41) compared to 120 DAS, but with 127 DAS. Ethephon (0.5%) + TIBA (450 ppm) recorded superior values of 7.61 compared to other treatments. In interaction effects, 2, 4 D (0.5%) sprayed at 137 DAS recorded higher non-photochemical quenching (7.01) compared to other combinations. All other treatment

![Fig 1: MDA content (μmol g⁻¹) of CO 17 cotton variety as influenced by different defoliants and time of application.](image-url)
Table 4: Fiber quality parameters of CO 17 Cotton variety as influenced by different defoliants and time of application.

| Treatments                          | 2.5% S.L (mm) | Bundle strength (g tex⁻¹) | Micronaire (ìg/inch) |
|-------------------------------------|---------------|---------------------------|----------------------|
|                                     | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean |
| Control                             | 26.9 | 25.4 | 25.9 | 26.07 | 21.3 | 24.2 | 22.5 | 22.67 | 3.38 | 3.06 | 4.31 | 3.58 |
| 2.4 D (0.5 %)                       | 25.0 | 25.1 | 24.7 | 24.93 | 21.2 | 24.1 | 23.1 | 21.90 | 3.16 | 2.33 | 3.96 | 3.15 |
| Etephon (0.5 %)                     | 27.9 | 27.4 | 28.2 | 27.83 | 20.5 | 20.0 | 19.7 | 20.07 | 3.62 | 4.79 | 4.30 | 4.24 |
| Etephon (0.5 %)+ TIBA (450 ppm)     | 27.3 | 26.5 | 26.4 | 26.73 | 23.1 | 21.8 | 22.2 | 22.37 | 3.43 | 4.02 | 3.12 | 3.52 |
| Sodium chlorate (0.9 %)             | 26.7 | 28.3 | 26.2 | 27.07 | 22.3 | 22.9 | 23.3 | 23.83 | 2.39 | 2.67 | 4.16 | 3.07 |
| 6-BAP (0.1 %)                       | 25.7 | 26.7 | 27.4 | 26.60 | 23.0 | 23.4 | 22.4 | 22.93 | 3.79 | 2.63 | 4.27 | 3.56 |
| Thidiazuron + Diuron (0.03 %)       | 26.1 | 25.3 | 28.4 | 26.60 | 21.2 | 23.1 | 21.7 | 22.00 | 3.72 | 3.90 | 4.15 | 3.92 |
| Mean                                | 26.51 | 26.39 | 26.74 | 21.80 | 22.40 | 22.13 | 3.36 | 3.34 | 4.04 |

Factors: M₁ - 120 Days After Sowing, M₂ - 127 Days After Sowing, M₃ - 134 Days After Sowing.

*Denotes significant at the 0.05 level of probability ** Denotes significant at the 0.01 level of probability.
combinations recorded significantly lower values with the least in 2, 4 D (0.5%) at 120 DAS. (Table 3).

**Effect of defoliants on yield and quality parameters**

Yield and quality in upland cotton (*Gossypium hirsutum* L.) are influenced by genetics and environmental conditions (Reddy et al., 1999). Single boll weight (g) had influenced significantly by the yield and quality parameters. A perusal of data showed that 127 DAS had a higher boll weight of 5.08 g compared to other stages (Fig 2). Sodium chlorate (0.9%) recorded more single boll weight of 5.41 g compared to all other treatments. Similarly, the lesser single boll weight of 4.16 g was noted in Thidiazuron + Diuron (0.03%). Among the interaction effect, control attained statistical supremacy by noting more single boll weight (6.35 g) in 137 DAS. All other treatment combinations did record lower single boll weight with the minimum values of 3.09 g at 137 DAS in 6-BAP (0.1%). 137 DAS solely recorded the superior seed cotton yield (56.7 g plant⁻¹). 120 DAS had lesser seed cotton yield of 51.1 g plant⁻¹. Ethephon (0.5%) had higher seed cotton yield of 58.5 g plant⁻¹. Lesser seed cotton yield of 49.6 g plant⁻¹ was observed in Thidiazuron + Diuron sprayed at 0.03%. Ethephon (0.5%) sprayed at 127 days after sowing registered more seed cotton yield (64.8 g plant⁻¹) compared to other combinations. Significantly lesser seed cotton yield of 44.1 g plant⁻¹ was noted in 2, 4 D (0.5%) sprayed at 120 DAS. (Fig 3).

Effect of defoliants on quality parameters of CO 17 cotton variety had given in Table 4. 137 DAS recorded superior 2.5% S.L values (26.74 mm). Ethephon (0.5%) had noted significantly higher 2.5% S.L. Thidiazuron + Diuron (0.03%) sprayed at 137 DAS recorded 2.5% S.L of 28.4 mm compared to other combinations. At 127 DAS, higher bundle strength of 22.40 g tex⁻¹ was observed. Similarly, the bundle strength of 21.80 g tex⁻¹ was observed at 120 DAS. Among the treatments, the higher bundle strength of 22.93 g tex⁻¹ was observed in Ethephon (0.5%) at 137 DAS. Micronaire is a composite measure of maturity and fiber fineness since fiber cells with the same wall width can have different micronaire values (Davidonis et al., 2004). Micronaire tends to increase when there is ample supply of carbohydrates to mature bolls set on the plant. Micronaire was linearly related to the amount of canopy photosynthesis that occurred from 15 to 45 days after flowering. Fiber length, micronaire and strength have

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**Fig 2:** Single boll weight (g) of CO 17 cotton variety as influenced by different defoliants and Time of application.

**Fig 3:** Seed Cotton yield (g/plant) of CO 17 cotton variety as influenced by different Defoliants and time of application.
increased in importance relative to other quality characteristics. The time of application had influenced significantly on micronaire. Higher micronaire of 4.04 μg/inch was noted in 137 DAS.Ethephon (0.5%) recorded significantly higher micronaire of 4.24 μg/inch compared to other treatments. Ethephon (0.5%) sprayed at 127 DAS had micronaire of 4.79 μg/inch compared to other combinations.

**CONCLUSION**

The result of this study explored that the effect of different defoliants and time of application on physiological, biochemical, yield and quality parameters of high density Cotton. Thidiazuron + Diuron (0.03%) and Sodium chlorate (0.9%) performed better and gave 98 to 99 per cent defoliation within 15 Days after defoliants spray. Defoliation was successful because of decreasing the plant physiological, biochemical characters without affecting yield and quality. These results indicate that the high density Cotton CO 17 possibly mechanized picking with these effective defoliants without yield and quality loss.

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**REFERENCES**

Blum, A. (2017). Osmotic adjustment is a prime drought stress adaptive engine in support of plant production. Plant Cell and Environment. 40: 4-10.

Davidonis, G.H., Johnson, A.S., Landivar, J.A., Fernandez, C.J. (2004). Cotton fiber quality is related to boll location and planting date. Crop Science. 96: 42-47.

Genty, B., Briantais, J.M., Baker, N.R. (1989). The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. Biochimica et Biophysica Acta. 990: 87-92.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for agricultural research. (2nd Ed.) John Wiley and sons, NewYork, USA.

Heath, R.L. and Packer, L. (1968). Photoperoxidation in isolated chloroplasts. I. Kinetics and stoichiometry of fatty acid peroxidation. Archives of Biochemistry and Biophysics, 125: 189-198.

Hernandez, J.A., Jimenez, A., Mullineaux, P., Sevilla, F. (2002). Tolerance of pea (Pisum sativum L.) to long-term salt stress is associated with induction of antioxidant defenses. Plant Cell Environment. 23: 853-862.

Kanakoti Mrunalini, M., Sree Rekha, V.R., Murthy, K., Jayalalitha, K. (2019). Impact of harvest-aid defoliants on yield and economics of high density cotton. Indian Journal Agricultural Research. 53: 116-119.

Karademir, E., Karademir, C., Basbag, S. (2007). Determining the effect of defoliation timing on cotton yield and quality. The Journal of Central European Agriculture. 8: 357-62.

Kramer, D.M., Avenson, T.J., Kanazawa, A., Cruz, J.A., Ivanov, B., Edwards, G.E. (2004). The relationship between photosynthetic electron transfer and its regulation. In Chlorophyll a Fluorescence: A Signature of Photosynthesis, ed. GC Papageorgiou, Govindjee, pp. 251-78.

Lowry, O.H., Rosebrough, N.J., Farr, A.L., Randall, R.J. (1950). Protein measurement with the folin phenol reagent. The Journal of Biological chemistry. 193(1): 265-275.

Ming-wei Du., Xiao-li Tian., Liu-sheng Duan., Ming-cai Zhang., Wei-ming Tan., Zhao-hu Li. (2013). Evaluation of harvest aid chemicals for the cotton-winter wheat double cropping system. Journal of Integrative Agriculture. 12: 273-282.

Murthy, K.S. and Majumder, S.K. (1962). Modifications of the technique for determination of chlorophyll stability index in relation to studies of drought resistance in rice. Current Science. 31: 470-471.

Raghavendra, T. and Reddy, Y.R. (2020). Efficacy of Defoliants on Yield and Fibre Quality of American Cotton in Semi-Arid Conditions, Indian Journal Agricultural Research. 54: 404-407.

Reddy, K.R., Davidonis, G.H., Johnson, A.S., Vinyard, B.T. (1999). Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. Agronomy Journal. 91: 851-858.

Silvertooth, J.C. and Howell. D.R. (1988). Defoliation of pima cotton. A College of Agriculture Report, University of Arizona Series P-72.

Stewart, A.M., Keith, L., Edmisten and Wells, R. (2000). Bollopener in cotton: effectiveness and environmental influences. Field Crop Research. 67: 83-90.

Yang, J., Zhang, J., Wang, Z., Zhu, Q., Liu, L. (2001). Water deficit-induced senescence and its relationship to the remobilization of pre-stored carbon in wheat during grain filling. Agronomy Journal. 93: 196-206.

Yoshida, S., Forno D.A., Cock. J.H. (1971). Laboratory manual for physiological studies of rice. IRRI Publication, Philippines, pp. 36-37.

Patharkar, O.R. and Walker, J.C. (2016). Core Mechanisms Regulating Developmentally Timed and Environmentally Triggered Abscission. Plant Physiology. 172(1): 510-20.