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Use of Defoliants for Achieving Improved Productivity and Quality of Cotton: A Review

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ABSTRACT

Cotton is one of the most important cash crop grown for its fibre, which is the raw material for the textile industry. In India, the average yield and profitability of cotton cultivation are low as compared to developing countries. The main reason for this is hand picking of bolls, which is labour intensive resulting into low income of cotton growers. Furthermore, in India, most of the cotton varieties are indeterminate where the bolls do not mature at the same time and thus requires repeated hand pickings. Whereas the developed countries have 100% mechanized cotton picking due to determinate or semi-determinate plant types. Adoption of mechanical harvesting in India is dependent upon the availability of suitable cotton varieties as well as defoliants, desiccants, boll openers, growth hormones and re-growth inhibitors (Thatikunta *et al.,* 2018). Defoliation before cotton harvesting is very important to maintain the quality of produce. In this paper, a comprehensive review is presented on effect and timing of application of defoliants on physiological characteristics of cotton. This will help in developing further research proposals to develop plant types for mechanical harvesting and use of defoliates to produce good fiber quality and increased farm income.

Key words: Chlorophyll fluorescence, Cotton, Defoliants, Mechanical harvest, Photosynthetic rate, Transpiration rate.

In manual picking, two to four pickings are needed to complete the harvesting of cotton. The initial three pickings are expected to cover 85-90 per cent of the seed cotton picked. Subsequent pickings manually are not economically profitable. In India, cotton picking is tedious, highly labour intensive and very expensive, sometimes resulting into 25 per cent of the total cost of cultivation. The demand for labor during the peak season is very high; therefore, timely availability of labour is another constraint. Therefore most of the cotton growing countries have adopted mechanical harvesting of cotton. Australia, Israel and U.S.A switched over to 100% machine-picking of cotton. Greece, Mexico and Spain adopted over 90 per cent mechanical harvest. China, India and Pakistan are the only countries manually picking the cotton bolls (Blaise and Kranthi, 2019).

Effect of time of defoliant application

Defoliation in cotton played a major role to early crop harvest. Untimely application of defoliants may reduce yield and fiber quality. The total yield of cotton increases by the defoliation process only if the defoliant or boll opener increases the number of open bolls at harvest (Fig 1). On the other hand, it reduces boll weight by opening small bolls at the premature stage and further decreases the yield. Recent studies suggest that the defoliation could be initiated before 60 % open bolls if fruiting is compact; however, delayed defoliation requires a plant type with dense fruiting to achieve maximum yields (Du *et al.,* 2013).

The lack of knowledge of proper time of defoliation requires research to develop a more concrete set of recommendations. Effect of timing of defoliation on mature fruiting branches and correlation between three defoliation timing methods, heat unit accumulation after 5 nodes above the white flower, open boll percentage at defoliation, and nodes above cracked boll were evaluated to determine the method which was most consistent for increasing the yield and fiber quality. Harvest-aids were applied when a physiologically mature first position boll was present at 5, 7, 9, 11, or 13 main stem nodes above the first sympodial branch with a harvestable boll (Siebert and Stewart, 2006).

Chlorophyll index (SPAD value) and normalized difference vegetation index (NDVI)

Chlorophyll index (SPAD value) is a measurement of leaf chlorophyll or greenness of leaves. SPAD values decrease due to environmental stresses. Similar to SPAD value, normalized difference vegetation index (NDVI) is also a sign of the vegetative status of a plant. NDVI measures the infrared to the red region radiation and it was indicated that high in green leaves, medium in red leaves and low values in orange to yellow leaves. The SPAD values and NDVI are used to screen stress tolerance because of lower chlorophyll accumulation and degradation of total chlorophyll content.

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Leaf abscission is mainly accompanied by altered leaf water potential and decreased level of total chlorophyll content (Primka and Smith, 2019). Meena *et al.* (2016) found that Thidiazuron chemical defoliant induced the abiotic stress in cotton leaves and severely damaged the cell membrane system. The reduction of chlorophyll content may be due to the defoliants induced water loss, membrane damage, cell death and oxidative injury in cotton leaves, leading to leaf abscission. It is known that biotic or abiotic stresses generate Reactive oxygen species (ROS) accumulation to cause oxidative damage and cell death in plants (Moschou *et al.* 2008) (Fig 1).

Effect of defoliants on Gas Exchange parameters

The changes in gas exchange parameters could potentially be used as screening tool for stress intensification. The decrease in gas exchange parameters *viz*., photosynthesis, stomata conductance and transpiration rate resulted in decreased production of photosynthates and their translocation to sink (Pan *et al.,* 2017). Current photosyn thesis is important for maintaining the plant growth and development. Photosynthesis is severely affected and ceased after application of the defoliants. Excessive reactive oxygen species (ROS) production and leaf cell structure destruction may be the possible reason for reduction of photosynthesis. This is consistent with previous studiesthat ROS could exacerbate the adverse effects on leaf photosynthesis (Xu and Rothstein, 2018). Several studies found that photo-oxidative stress can be caused by the photosynthesis derived ROS. Many abiotic and biotic stresses affect the photosynthesis metabolism leading to the yield reduction (Yoon *et al.,* 2020). However, application of defoliants can significantly decrease the photosynthetic rate (Pn), stomatal conductance (gs) and transpiration rate (E) of cotton leaf.

Hamani *et al.* (2020) conducted a study on effect of defoliants on gas exchange parameters with two cotton cultivars and found that under Thidiazuron treatment, photosynthetic rate, transpiration rate and stomatal conductance rapidly decreased and recorded maximum defoliation percentage.

The leaf photosynthetic rate decreased during senescence of leaves in cotton from 90 to 130 days after sowing due to decrease in the CO_2 assimilatory capacity of mesophyll cells (Djanuguiraman *et al.,* 2009). Chloroplasts are the major source of ROS, even under optimal conditions the photosynthetic electron transport generates the ROS. These, ROS may cause lipid peroxidation and membrane permeability, which lead to decreased photosynthetic capacity and increased cellular damage (Cakmak, 2000).

Spano *et al.* (2003) reported that the duration of active photosynthesis will increase the yield of crops and postpone leaf senescence. A study conducted showed that a maize hybrid with long duration of active photosynthesis produced more than 24 per cent dry matter and assimilated 20 per cent more nitrogen than a short duration maize hybrid during the grain filling stage. An increase in the carbon fixation of 11 per cent is obtained in ryegrass by delaying the onset of the senescence for two days (Jiang and Huang, 2001). An analogous phenomenon was also observed in tobacco (*Nicotian atabacum*), sorghum (*Sorghum bicolor* L.). Defoliation significantly decreased light interception by the crop canopy and light saturated leaf photosynthesis per unit leaf area decreased (Anten and Ackerly, 2001). Stomatal limitation to reduce intercellular CO_2 concentrations and thus alter photosynthesis activity. Carboxylic anhydrase increases CO_2 level at the site of carboxylation, thereby contributing to more Rubisco activity (Khan and Lone, 2005). The excess ROS production and destruction of leaf cell structure affects the photosynthesis and stomatal conductance which shows adverse effects on leaf photosynthesis and stomatal conductance (Xu *et al.,* 2018).

Effect of defoliants on chlorophyll fluorescence parameters

The function of chlorophyll fluorescence is that emission of chlorophyll, complimentary to alternative pathways of de-excitation, which is primarily photoreaction and heat dissipation. Generally, the lowest photoreaction and heat dissipation gives highest fluorescence yield. Therefore, changes in fluorescence yield reflect changes in photochemical efficiency of plants (Cao and Govindjee, 1990). Chlorophyll fluorescence indicates the potential photosynthetic activity of the leaf which is highly correlated with the plant senescence (Paul and Planchon, 1990). It was observed that, chlorophyll fluorescence activity decreased with application of defoliants. The dark-adapted value of Fv/Fm showed the PSII potential quantum efficiency, which is also a sensitive indicator of plant photosynthetic performance (Hailemichael *et al.,* 2016). Fluorescence yield is measured to show the quantum efficiency of photosystem II. Excess light energy dissipated as heat in the reaction centers of PSII can be recorded by measuring the nonphotochemical quenching (NPQ) of chlorophyll fluorescence (Tiez *et al.*, 2017). Chlorophyll fluorescence analysis revealed that photo protection in green leaves at both low and high light is mainly because of higher NPQ values.

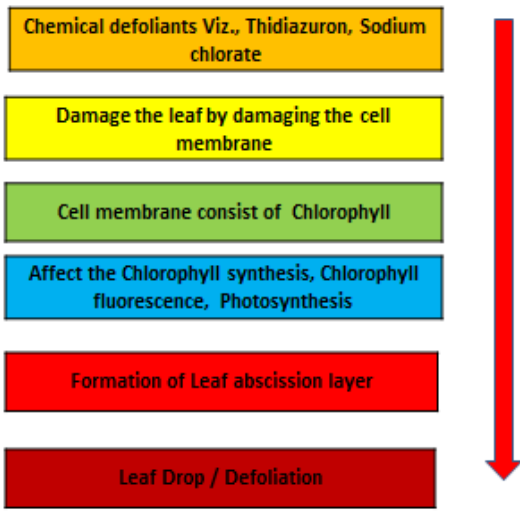

Fig 1: The sequential process of cotton defoliation.

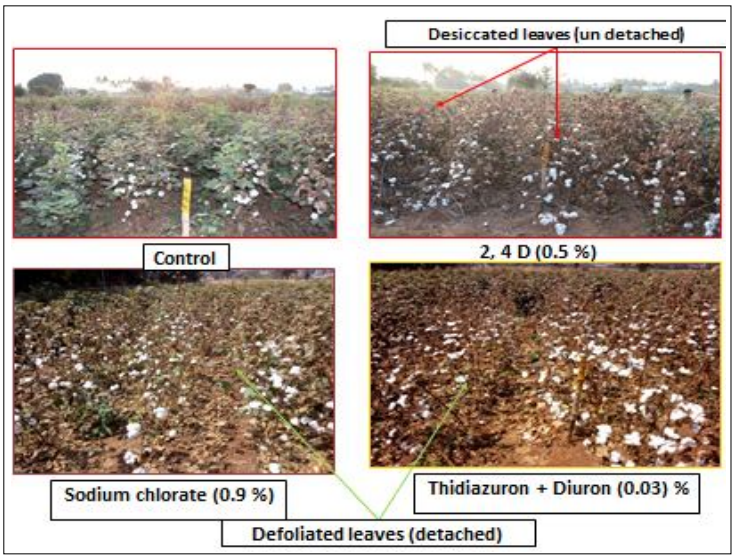

Fig 2: Effect of Defoliants Sodium chlorate and Thidiazuron + Diuron on Cotton CO 17 variety.

The reduced state of photochemical quenching (PQ) present in the green leaves indicates the excess of excitation energy, and thus an inequity between the energy demand and supply (Sperdouli *et al.,* 2019). Beneath such conditions, extreme levels of reactive oxygen species are produced in the chloroplasts (Demmig-Adams *et al.,* 2014). The reduced state of the PQ pool is required for generation of chloroplastic H_2O_2 production in green leaves (Wang *et al.,* 2016). Thidiazuron (TDZ) application significantly increased the superoxide dismutase activity, peroxidase activity, decreased the malondialdehyde content and induced Abscisic acid contents in the cotton leaf than control plants (Wang *et al.,* 2019).

Chen *et al.* (2014) resulted that Ethephon significantly affected chlorophyll fluorescence Fv/Fm compared to control in cotton. The Fv/Fm ratio reduced by increased senescence from 90 DAS to 130 DAS (Djanuguiraman *et al.,* 2009). PSII photochemistry down-regulation in senescence leaves can be attributed to increase in the proportion of closed PSII centers and decrease in the efficiency of excitation energy capture, which leads to increased photoinhibition. Due to closed PSII centres, ROS may accumulate resulting into adverse effect on PSII reaction center complexes (Lu *et al.*, 2011). Hughes *et al.* (2012) revealed, degradation of chlorophyll, production and accumulation of anthocyanin enriched the inactivation process of PSII under high light (Zeng *et al.,* 2010) and maintained a higher quantum yield efficiency of the PSII during the midday (Fv´/Fm´). However, both photosystems were adversely affected by leaf reddening in rose plants, without any evidence of photoprotection by the addition of anthocyanin. Anthocyanins to act as ROS scavengers and reduce oxidative impairment, resulted in a limited excitation pressure, reduced ROS accumulation and lower susceptibility to photoinhibition (Moustaka *et al.,* 2018).

Quantum yield of the PSII in green and reddish leaves under high light declined and elicited an excess excitation energy that significantly reduces the redox state of PQ pool, and closing a fraction of open PSII reaction centers. The higher antioxidant capacity of reddish leaves associated to the greens was mainly due to higher anthocyanin accumulation that was positively interrelated to antioxidant movement (Foyer and Noctor, 2011) (Fig 2).

CONCLUSION

Lack of availability and high cost of labour for cotton picking is becoming a major constraint for cotton growers around the world. Manual picking and collecting of cotton bolls adversely affects the fibre quality. Use of various defoliants described in this paper may help in making a schedule of their application which will help in increasing the yield and lint quality of cotton. Plant gas exchange parameters, chlorophyll content and chlorophyll florescence traits were adversely affected by defoliants resulting into senescence of leaves and plants and increasing boll opening. The paper will also help in identifying the gaps in mechanical harvesting of crop and development of suitable plant types.

Conflict of interest

There is no conflict of interest.

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