and atrazine @ 1.5 kg a.i./ha pre-emergence treatment because of lower cost of cultivation for controlling weeds with Atrazine. These results are in confirmation with the findings of Pandey *et al.* (2002).

Weed-management treatments significantly influenced the weed density, dry matter accumulation of weeds and yield. The weed-free treatment resulted in the lowest weed density, dry-matter accumulation and cob yield, whereas, the highest values of these parameters were recorded in weedy check. Earthing-up and hand-weeding at 30 DAS and 45 DAS recorded the highest benefit: cost ratio and net returns and lowest values of benefit: cost ratio and net returns were recorded in white polyethylene mulch. Thus the results of the study led to the conclusion that to realize higher baby corn yield under Kashmir valley conditions, earthing-up and hand-weeding at 30 days after sowing and 45 days after sowing is recommended. However, the study requires more critical testing at various locations with staggered survey before final recommendations are made.

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Research Paper

Standardize the dose and timing of defoliant application to facilitate synchronized maturity for mechanical harvesting of rainfed cotton (*Gossypium hirsutum*)

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ABSTRACT

A field experiment was conducted at Regional Research Station, Aruppukottai, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during the winter (*rabi*) season of 2016 and 2017 at Aruppukotai, Tamil Nadu, to study the influence of defoliants on 'SVPR 2' (*Gossypium hirsutum* L.) rainfed cotton. The experiment was laid out in randomized block design with 3 replication. The treatments consisted of defoliants spraying at different concentrations and time of application, viz. ethrel @ 1,500 ppm at 135 days after sowing DAS (D_1), ethrel @ 2,000 ppm at 135 days after sowing (DAS) (D_2), ethrel @ 2,500 ppm at 135 DAS (D_3), ethrel @ 1,500 ppm at 150 DAS (D_4), ethrel @ 2,000 ppm at 150 DAS (D_5), ethrel @ 2,500 ppm at 150 DAS (D_6), paraquat @ 1,500 ppm at 135 DAS (D_7), paraquat @ 1,500 ppm at 150 DAS (D_8) and control (D_9). Observations, viz. growth parameters, yield-attributing characters and senescence parameters were recorded at 10 days after spraying and economics were worked out. The highest percentage of the senescence attributes, viz. percentage of of yellow leaves, yellow plants, dried leaves and leaf fall, was observed paraquat @ 1,500 ppm applied at 150 DAS. This was comparable with spraying of paraquat @ 1,500 ppm at 135 DAS and ethrel @ 2,500 ppm at 150 DAS during both years. Ethrel @ 2500 ppm at 150 DAS recorded the highest boll weight and more number of bolls/plant, resulting in significantly highest seed-cotton yield. The higher net income and the benefit: cost ratio were also recorded with the application of ethrel @ 2,500 ppm at 150 DAS.

***Key words**:* Defoliants, Ethrel, Paraquat, Rainfed cotton

Cotton as a crop as well as a commodity plays an important role in the agrarian and industrial activities of the nation and has a unique place in the economy of our country. India having world's largest acreage of 11.99 million (M) ha, with average yield of 512 kg/ha, which is far below the world averages (677 kg/ha) (Rajpoot *et al*., 2018). India ranks first in area with 11.88 M ha, accounting 30% of world average and contributes 22% (351 lakh bales of lint) of the world cotton production, with a lint productivity of 568 kg/ha (DCD, 2017). Nearly 65% of the cotton crop is cultivated under rainfed condition in the country. During 2017, in Tamil Nadu, 1.33 lakh ha was under cotton cultivation with production of 6.5 lakh bales and lint productivity of 620 kg/ha. India has progressed substantially in improving both production and productivity of cotton over the last 5 years, transforming from a net importer of cotton, to becoming one of the largest exporters, shipping 6.9 million bales (2015–16), followed by USA (Kannan *et al*., 2017).

Under rainfed ecosystem, in addition to stress during crop growth due to insufficient soil moisture, increasing labour cost and shortage of labour are the major constraints compelling manual harvesting in a staggered manner. Further, manual harvesting is very expensive and producers would like to increasingly opt for mechanical harvesting. In this context, its research should focus on reducing cost of cultivation substantially by promoting the use of synchronized maturity varieties in cotton and use of defoliants to encourage mechanical harvesting (Nerkar *et al*., 2017). Defoliants are used to eliminate the leaves of a crop plant, so they will not interfere with the harvesting by machinery. Early harvesting with good boll opening can also be achieved by use of defoliants. The use of defoliants also reduces the trash content in picked cotton which will also help in improving the quality of cotton.

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Defoliants, desiccants, and growth-regulators are chemicals used in agricultural production to accelerate the preparation of crops for mechanical harvesting. Defoliation allows to produce an earlier harvest than if the cotton bolls matured naturally, but it can reduce the yield and deteriorate the fibre quality, if the application is premature (Sindarov, 2007). In order to conduct an effective defoliation, it is important to consider the biological development of cotton in a field, plant density, irrigation norm, nutritional factors to provide efficiency of defoliation (Fatullateshaev and Khaitov, 2015). Defoliation at proper timing involves balancing the value of potential yield increases and losses with possible alterations in fibre quality and possible discounts (Sarlach *et al.*, 2010).

Application of ethrel promotes senescence and abscission by promoting the synthesis of cell wall-degrading enzymes, viz. cellulose and dehydrogenase. Synchronized boll opening which was due to increased ethylene production within a boll to hasten opening and speed up dry out of fully-opened bolls. Ethrel accelerates boll dehiscence by increasing ethylene level in cotton leaves. Ethrel allowed for manipulation of physiological processes in plant growth and development for more efficient crop management and increased seed-cotton yield (Singh *et al.*, 2015). Herbicidal defoliants injure the leaf, stimulating the production of ethylene. There is an urgent need to identify suitable defoliant with suitable dose and time of application so as to facilitate mechanical harvesting in rainfed cotton. Keeping all these fact in view, the present study was undertaken to study find out suitable defoliant to promote mechanical harvesting and defoliants with varied action (hormonal and herbicidal) were tried in rainfed cotton

MATERIALS AND METHODS

A field experiment was conducted at Regional Research Station, Tamil Nadu Agricultural University, Aruppukottai, during the winter (*rabi*) season of 2016 and 2017. The crops of 'SVPR 2' cotton was raised on 9 September and 28 August in 2016 and 2017 and harvested on 4 February and 28 January in respective years.

The experimental site experiences tropical climate with dry-summer extending from March to August and winter from August to February. A perusal of 30 years weather data of the site reveals that a mean annual rainfall of 830.4 mm distributed in 38 rainy days. The distribution pattern was as follows: 233.9 mm (29.0%) during South-West monsoon period (June–September), 383.2 mm (47.4%) during North-East monsoon period (October–December), 51.0 mm (6.3%) during the winter season (January–February) and 140 mm (17.3%) during the summer season (March–May). The mean maximum and minimum temperature were 34.8 °C and 22.8 °C respectively. The mean relative humidity ranged at 07.22 hr was 83.4% and at 14.22 hr was 78.8%. The wind velocity ranged between 2.7 to 7.0 km/hr. The pan evaporation ranged from 4.25 to 7.92 mm/day.

During the cropping period in the winter (*rabi*) 2017, the amount of rainfall received during the cropping season was 313.6 mm in 19 rainy days and the mean pan evaporation was 4.2 mm/day. The mean maximum and minimum temperatures were 33.2 ºC and 20.9 ºC respectively. The mean relative humidity recorded was 82.9% (07.22 hr) and 60.8% (14.22 hr). The average bright sunshine hours were 5.3 hr/day, with an average wind velocity of 5.4 km/hr

The study area is geographically situated at 9º 33'N and 78º 05' E at an altitude of 50 m above mean sea-level. The North-East monsoon season is found to be more favourable for cotton in Aruppukottai region since 42% of annual rainfall is being received during this monsoon season. The soil of the experimental fields was medium deep, well-drained and Vertisols (Type Haplustersts), clayey in texture. The soil was low in available nitrogen, available phosphorus and high in available potassium. All package of practices were followed as per recommendation of (CPG, 2020).

The field experiment was laid out in randomized block design with 3 replications. The treatments consisted of defoliants spraying at different concentrations and time of application, viz. ethrel @ 1,500 ppm at 135 days after sowing (DAS, $D\text{-}_1$), ethrel @ 2,000 ppm at 135 DAS ($D\text{-}_2$), ethrel @ 2500 ppm at 135 DAS ($D\text{-}_3$), ethrel @ 1,500 ppm at 150 DAS ($D\text{-}_4$), ethrel @ 2,000 ppm at 150 DAS ($D\text{-}_5$), ethrel @ 2,500 ppm at 150 DAS ($D\text{-}_6$), paraquat @ 1,500 ppm at 135 DAS ($D\text{-}_7$), paraquat @ 1,500 ppm at 150 DAS ($D\text{-}_8$) and control (D_9). Observations on growth parameters, viz. plant height, leaf-area index and sympodial branches, dry matter, yield-attributing characters, namely bolls/plant, boll weight and senescence parameters were recorded 10 days after spraying and economics were worked out.

The varietal duration is 150–160 days. It is moderately resistant to leaf hopper, highly tolerant to drought and suited to summer irrigated and winter rainfed tracts. The average boll weight 3.6 g, seed index 8.4 g, lint index 4.8 g, hinning percentage, 36.4, staple length 24.3 (medium), spinning counts 40.5, seed-cotton yield 2,000 kg/ha (CPG, 2020).

Irrespective of the cropping season, the experiments were laid out with individual gross plot size of 5.0 m × 4.0 m with a net plot size of 3.7 m × 2.75 m.

Healthy and viable seeds of cotton variety 'SVPR 2' were sown @ 20 kg/ha after delinting with concentrated sulphuric acid @ 100 ml/kg of seed. Seeds were hand dibbled, 2 seeds/hill at 45 cm spacing between row and 15 cm between plants. Seeds were also sown separately in polybags, which were used for gap-filling at 15 days after sowing.

Leaf-senescence index was determined by recording the number of yellow leaves/plant due to induced senescence by application of ethylene.

$$\text{Per cent of yellow leaves} = \frac{\text{Number of yellow leaves}}{\text{Total number of leaves}} \times 100$$

$$\text{Per cent of dried leaves} = \frac{\text{Number of dried leaves}}{\text{Total number of leaves}} \times 100$$

$$\text{Per cent of yellow plants} = \frac{\text{Number of yellow plants}}{\text{Total number of plants}} \times 100$$

The percentage of leaf fall was assessed from the tagged plants using the following formula.

$$\text{Percentage of leaf fall} = \frac{\text{Number of fallen leaves}}{\text{Total number of leaf}} \times 100$$

Seed-cotton yield obtained from net plot area was shade dried, weighed at each picking and yields of all picking were added and calculated as kg per plot and then expressed in kg/ha. The data obtained were subjected to statistical analysis and were tested at 5% level of significance to interpret the treatment differences as suggested by Gomez *et al.* (1984).

RESULTS AND DISCUSSION

Growth attributes

Crop-growth attributes, namely plant height, leaf-area index, dry-matter production, percentage of leaf fall, weight of fallen leaves and senescence index, were recorded 10 days after spraying (DAS) and at harvesting. Various observations recorded at different stages of crop growth were statistically analyzed and results are presented.

Different concentrations of ethrel and paraquat sprayed as defoliant and time of spray significantly influenced the plant height (Table 1). Spraying of paraquat @ 1,500 ppm at 135 DAS (D_7) recorded shorter plants than the control plot; however, it was comparable with the other concentrations of ethrel and paraquat sprayed at different concentrations on 135 and 150 DAS in both the years.

Different concentrations of defoliants and time of application significantly influenced the leaf-area index at harvesting stage. From the observations made with leaf-area index, spraying of paraquat @ 1,500 ppm at 135 DAS (D_7) recorded significantly lower leaf-area index than the unsprayed control (D_9). The leaf-area index was higher in the control plot (D_9).

Spraying of ethrel and paraquat at all concentrations had marked influence on the total dry- matter production of rainfed cotton. Spraying of paraquat @ 1,500 ppm at 135 DAS (D_7) recorded significantly lowest production of dry-matter production (DMP) at the time of harvesting than the unsprayed control (D_9) and ethrel sprayed at all the concentrations on 150 DAS (D_4, D_5 and D_6). The maximum dry-matter production was recorded in the control plot (D_9).

Defoliant application at different concentration significantly influenced the growth attributes. In the present investigation, spraying of paraquat @ 1,500 ppm at 135 DAS significantly reduced the plant height, leaf-area index and DMP (Table 1). The reduction may be due to the arrest of growth as well as reduction of leaf size. Further, this may be attributed to the reduced rate of leaf emergence, leaf size, photosynthetic pigments and photosynthesis by the inherent physiological action of paraquat (herbicidal defoliant) at higher concentration (Grewal and Kolar, 1990). The application of defoliants at higher concentration in crop plants decreased the plant height, leaf-area index and

Table 1. Influence of defoliants on plant height (cm), leaf-area index, dry-matter production (DMP, kg/ha) of rainfed cotton (pooled data of 2 years)

Treatment	Plant height (cm)	LAI	DMP (kg/ha)
Ethrel @ 1,500 ppm at 135 DAS	122.5	4.37	4,646
Ethrel @ 2,000 ppm at 135 DAS	126.3	4.58	4,904
Ethrel @ 2,500 ppm at 135 DAS	127.2	4.72	4,984
Ethrel @ 1,500 ppm at 150 DAS	128.4	4.67	5,150
Ethrel @ 2,000 ppm at 150 DAS	130.9	5.00	5,307
Ethrel @ 2,500 ppm at 150 DAS	131.1	5.08	5,353
Paraquat @ 1,500 ppm at 135 DAS	116.8	4.13	4,372
Paraquat @ 1,500 ppm at 150 DAS	119.5	4.35	4,603
Control	132.5	5.54	5,500
Mean	126.1	4.72	4,979
SEm±	7.8	0.29	307
CD (P=0.05)	14.4	0.61	652

DAS, Day after sowing

DMP. Dry-matter production is the function of light interception and leaf area index. Earlier application at 135 DAS resulted in higher reduction of plant height than the late one. This mechanism of reduction in the cell elongation is because of inhibitory effect of paraquat in the biosynthesis of gibberellins in the plant body. All the growth and physiological attributes finally reflected in dry-matter production which is a measure of the physiological basis of yield (Snipes and Baskin, 1994).

Senescence attributes

The observations on the yellow leaves showed that the per cent of yellow leaves getting defoliated was found to be accelerated under all the concentrations of ethrel on 150 DAS and paraquat spray on 135 and 150 DAS. Significantly highest percentage of yellow leaves resulted in spraying of paraquat @ 1,500 ppm at 150 DAS (D_8) (Table 2). However, this was comparable with paraquat @ 1,500 ppm at 135 DAS (D_7) and ethrel @ 2,500 ppm at 150 DAS (D_6). The lowest percentage of yellow leaves was recorded at untreated control plot (D_9).

Due to significant influence on the spraying of defoliants at various levels of concentration and time of application, it was found that the per cent of dried leaves increased with all the concentrations of ethrel and paraquat spray on 150 DAS. Spraying of paraquat @ 1,500 ppm at 150 DAS (D_8) resulted in significantly maximum percentage of dried leaves. This was comparable with spray of paraquat @ 1,500 ppm at 135 DAS (D_7) and ethrel @ 2,500 ppm at 150 days after sowing (D_6). The dried leaves were found to be lowest under control plot (D_9), where no spray was done.

Different concentrations and timings of spraying of defoliants significantly influenced per cent of yellow plants. It was observed that percentage of yellow plants increased with all the concentrations of ethrel and paraquat sprayed on 150 DAS. The data on the per cent of yellow plants revealed that, the application of paraquat @ 1,500 ppm at 150 DAS (D_8) recorded significantly highest percentage. This was on a par with paraquat @ 1,500 ppm at 135 DAS (D_7) and ethrel @ 2,500 ppm at 150 DAS (D_6), in recording dried leaves. And the lowest percentage of yellow plants were recorded in control plot (D_9) during both the years.

A varied level of defoliants and time of application significantly influenced the per cent of leaf fall in the present study. In general, the late-sprayed (150 DAS) defoliant comparatively registered higher percentage of leaf fall than the earlier sprayed ones. The higher per cent of leaf fall was registered with the application of paraquat @ 1500 ppm at 150 DAS (D_8). This was at par with paraquat @ 1,500 ppm at 135 DAS (D_7) and ethrel @ 2,500 ppm at 150 DAS (D_6). Following this, the ethrel sprayed at all the doses of 1,500; 2,000 and 2,500 ppm at 135 DAS and 1500, 2000 ppm at 150 DAS registered higher percentage of leaf fall. The lowest per cent of leaf fall was observed in the control plot (D_9). Senescence and abscission involve active mobilization of cell-wall hydrolases which weaken the cell-wall of the cells in the abscission zone, along with mechanical forces which assist rupture. Ethylene accelerates the leaf abscission in a wide range of plant species (Sexton and Roberts, 1982).

In the present investigation, the senescence attributes, viz. percentage of yellow leaves, percentage of yellow plants, percentage of dried leaves and percentage of leaf fall were significantly influenced by the application of defoliants. Owing to significant influence of spraying of defoliants at various concentrations and time of application,

Table 2. Influence of defoliants on per cent of yellow leaves, per cent of dried leaves, per cent of yellow plants and percentage of leaf fall of rainfed cotton (Pooled data of 2 years)

Treatment	Per cent of yellow leaves	Per cent of dried leaves	Per cent of yellow plants	Percentage of leaf fall
Ethrel @ 1,500 ppm at 135 DAS	39.75	27.97	44.74	27.82
Ethrel @ 2,000 ppm at 135 DAS	41.45	28.35	49.78	29.64
Ethrel @ 2,500 ppm at 135 DAS	43.48	29.58	49.92	35.56
Ethrel @ 1,500 ppm at 150 DAS	51.37	32.72	65.49	39.37
Ethrel @ 2,000 ppm at 150 DAS	57.34	35.73	74.75	41.87
Ethrel @ 2,500 ppm at 150 DAS	59.24	38.01	77.46	49.47
Paraquat @ 1,500 ppm at 135 DAS	60.75	39.04	79.40	49.74
Paraquat @ 1,500 ppm at 150 DAS	65.72	42.09	85.39	55.26
D_9, Control	17.77	13.26	37.28	14.86
Mean	48.54	31.86	62.69	38.18
SEm±	3.30	2.13	4.24	2.74
CD (P=0.05)	6.99	4.52	8.99	5.81

DAS, Days after sowing

it was found that the higher per cent of dried leaves was observed in all the concentrations of ethrel and paraquat when sprayed at 150 DAS. In general, the late-sprayed (150 DAS) crop exhibited higher percentage of leaf fall than the earlier, one (135 DAS). It may be due to the reason that the numbers of intact leaves in the plants were less with defoliant sprayed at 150 days than 135 DAS spray, and thus facilitating the harvest of seed cotton. One possible explanation is that postponing defoliation allows for more carbon assimilation and partitioning of photo-assimilates to develop cotton bolls.

It was further observed that among the 3 concentrations, the senescence percentage was found to be higher when ethrel was applied @ 2,500 ppm than 2,000 ppm and 1,500 ppm. The higher concentration defoliant spray accelerates higher senescence attributes.This was due to the fact that with the application of defoliants at higher concentration, there was mild to severe shedding of leaves (Sarlach *et al.*, 2010).

From the present investigation, it was revealed that the highest percentage of yellow leaves, percentage of yellow plants, percentage of dried leaves and percentage of leaf fall were observed with paraquat @ 1,500 ppm sprayed at 150 DAS. This was comparable with paraquat @ 1,500 ppm at 135 DAS and ethrel @ 2,500 ppm at 150 DAS during both years. The probable reason for the above phenomena could be attributed to the fact that when a defoliant is applied to the plant, the amount of diffusible auxin is reduced. In addition to that, ethylene stimulates IAA oxidase activity which promotes abscission. The cotton responded significantly to K application in years receiving lesser than normal rainfall (Blaise *et al*., 2009).

Yield components and yield of seed cotton

A greater number of sympodial branches/plant is an indication for high seed-cotton yield, because these are considered to be the boll-bearing branches**.** A varied concentration of defoliants and time of application did not have any significantly influence the sympodial branches/plant in both the seasons (Table 3). However, number of sympodial branches/plant was found to be higher during 2017 than 2016. Different level of defoliants and time of application had significant effect influence on boll weight (g/boll) and number of bolls/plant.

Number of bolls/plant is an important yield-contributing parameter in seed-cotton yield. A varied level of defoliants and time of application had significant influenced number of bolls/plant. Ethrel @ 2,500 ppm at 150 DAS (D_6) recorded significantly higher number of bolls/plant. This was comparable with ethrel @ 2,000 ppm at 150 DAS (D_5) and ethrel @ 1500 ppm at 150 DAS (D_4) during both the years. The lower number of bolls/plant was recorded in the control (D_9).

Boll size and weight are directly related to the yield of seed cotton. A varied level of defoliants and time of application had a significant influence on boll weight (g/boll) in both the seasons. Ethrel @ 2,500 ppm at 150 DAS (D_6) recorded higher boll weight than the other treatments. The boll weight was less in the control (D_9).

Total seed-cotton yield is the function of culminated effect of entire yield components exposed under particular set of environmental conditions. The seed-cotton yield was higher during 2017 than 2016. The experimental results indicated that there was no yield reduction due to defoliants.

Significantly higher seed-cotton yield was recorded in ethrel spraying @ 2,500 ppm at 150 DAS (D_6), followed by ethrel @ 2,000 ppm at 150 DAS (D_5). The less seed-cotton yield was recorded in the control (D_9), but it was statistically at par with all the concentrations of ethrel and

Table 3. Influence of defoliants on sympodia/plant, boll weight (g/boll), bolls/Plant, seed-cotton yield (kg/ha) and harvest index of rainfed cotton (pooled data of two years)

Treatments	Sympodia Plant^{-1}	Bolls Plant^{-1}	Boll weight (g boll^{-1})	Seed cotton yield (kg ha^{-1})	Harvest index
Ethrel @ 1,500 ppm at 135 DAS	11.9	15.2	3.68	1290	0.27
Ethrel @ 2,000 ppm at 135 DAS	11.3	15.6	3.70	1367	0.27
Ethrel @ 2,500 ppm at 135 DAS	12.0	15.8	3.72	1376	0.27
Ethrel @ 1,500 ppm at 150 DAS	12.2	17.8	3.78	1386	0.28
Ethrel @ 2,000 ppm at 150 DAS	12.4	18.4	3.85	1453	0.28
Ethrel @ 2,500 ppm at 150 DAS	12.8	19.8	4.32	1686	0.31
Paraquat @ 1,500 ppm at 135 DAS	10.9	13.5	3.56	1276	0.27
Paraquat @ 1,500 ppm at 150 DAS	11.2	14.7	3.62	1280	0.27
Control	12.0	14.4	3.40	1260	0.23
Mean	11.9	16.1	3.74	1375	0.27
SEm±	0.7	13.8	0.22	91	0.02
CD (P=0.05)	1.9	2.2	0.46	193	0.05

DAS, Days after sowing

paraquat sprayed at 135 and 150 DAS.

Defoliants and their application at 135 and 150 DAS had a significant influence on the seed-cotton yield. Significantly higher seed-cotton yield was recorded in ethrel spray @ 2,500 ppm at 150 DAS with an increase of 28% during 2016 and 34% in 2017 over the control. The yield increase owing to defoliants spray might be because of higher translocation of nutrients and carbohydrates towards the reproductive parts soon after the defoliant spray facilitating the immature bolls to develop and burst within short time. Further, due to hastened process of abscission of leaves due to application of ethrel the nutrients diverted toward the boll development and increased boll weight, which in turn, increased cotton yield. Similar results were reported by Bader *et al.* (2001).

In the present study, early application (135 DAS) of defoliants at all the doses leads to severe shedding of young squares, flowers, fruiting bodies and even some developing immature bolls and resulted in significant reduction in biomass and seed-cotton yield. With defoliant spray at 150 DAS, the numbers of intact leaves in the plants were very less and it facilitated the harvesting of seed cotton. At 135 DAS, the boll opening has just started but more boll opening was observed on 150 days crop. It can be concluded that defoliants should not be applied before 150 DAS or before the completion of the physiological processes to safeguard against potential losses in yield. Hence, application of chemical defoliator in the later crop-growth stages resulted in defoliation with less number of leaves and leaf area. Accelerated leaf defoliation occurs by increasing ethylene level in cotton leaves (Suttle, 1985).

It was further observed that among the 3 concentrations, the boll weight, number of bolls/plant and seed-cotton yield were found higher when ethrel was applied @ 2,500 ppm than 2,000 ppm and 1,500 ppm. This may be owing to increase in concentration of defoliant which led to earlier flowering and boll formation and ultimately ratio of harvestable bolls in first picking increased production of ethylene inside the bolls, which tend to weaken and cause dissolution of cell-walls and build-up of internal pressure causing carpels to split apart and allowing bolls to open naturally. Increase in boll opening percentage with increased levels of defoliant several chemicals which contain ethylene help in leaf drop, synchronous and early boll opening owing to full exposure to sunlight. It makes cotton ready for single picking by machine. Hence the better response to defoliants at higher concentration might be owing to relatively higher temperature, resulting quick breakdown of defoliants prevailed during boll-opening periods.

In addition, the number of intact leaves was minimum in paraquat-treated plots which facilitated easy harvesting of seed cotton. Paraquat will desiccate regrowth to prevent staining of the lint and can freeze unopened bolls, so all mature bolls should be open before use of paraquat. Further, in case of herbicidal (paraquat) spray, the abscission process was hastened, but there was no influence on nutrients diversion. That might be the reason for the herbicides treatment not showing any improvement compared to the control. In case of hormonal treatment (ethrel), the nutrients were diverted towards the immure bolls that were intact at the time of spraying and contributed for the final increased yield. The results are in accordance with the findings of Wright and Brecke (2009). Hence, the defoliation not only improves the boll opening and seed-cotton yield but also helps in reducing the trash content in the lint and provides an opportunity for mechanical picking.

The application of ethrel @ 2500 ppm at 150 DAS (D_6) increased the harvest index, followed by ethrel @ 2,000 ppm at 150 DAS (D_5), lowest harvest index was observed in the control plot (D_9). The harvest index, a measure of migration efficiency of photo-assimilates, was significantly enhanced by ethrel spray. The application of ethrel @

Table 4. Influence of defoliants on Influence of defoliants on economics of rainfed cotton (Pooled data of 2 years)

Treatments	Total cost of cultivation ($\times 10^3$ ₹/ha)	Gross income ($\times 10^3$ ₹/ha)	Net income ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Ethrel @ 1,500 ppm at 135 DAS	40.8	64.5	23.6	1.58
Ethrel @ 2,000 ppm at 135 DAS	40.8	68.3	27.5	1.67
Ethrel @ 2,500 ppm at 135 DAS	40.8	68.8	27.9	1.69
Ethrel @ 1,500 ppm at 150 DAS	40.8	69.3	28.4	1.70
Ethrel @ 2,000 ppm at 150 DAS	40.8	72.6	31.8	1.78
Ethrel @ 2,500 ppm at 150 DAS	40.8	84.3	43.4	2.06
Paraquat @ 1,500 ppm at 135 DAS	40.7	63.8	23.0	1.56
Paraquat @ 1,500 ppm at 150 DAS	40.7	64.0	23.2	1.57
Control	40.3	63.0	22.6	1.55
Mean	40.72	68.73	27.93	1.68

DAS, Days after sowing