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Dose and time dependent efficacy alteration of different defoliants on seed cotton yield

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Abstract

Field experiments were conducted during 2012 and 2013 to determine the effect of select defoliants i.e dropp ultra® and ethrel, their optimal dose and suitable time of application on earliness and seed cotton yield in 3 American cotton cultivars. MRC7361BGII (3055.2kg ha^{-1}) and MRC7017BGII (2913.0 kg ha^{-1}) resulted in significantly improved seed cotton yield as compared to F1861 (2346.0 kg ha^{-1}). Dropp ultra® @ 200 ml ha^{-1} revealed highest yield (3018.7 kg ha^{-1}) followed by ethrel @ 2000 ppm (2820.1 kg ha^{-1}) and control (2730.0 kg ha^{-1}) , while statistically least yield (2516.9 kg ha^{-1}) was observed with higher dose of dropp ultra® @ 225 ml ha^{-1}. Defoliants applied 150 days after sowing (DAS) resulted in significantly better yield (2853.3 kg ha^{-1}) as compared to the early application at 140 DAS (2689.5 kg ha^{-1}) owing to improvement in open bolls and boll weight. Pooled data indicated that dropp ultra® @ 200 ml ha^{-1} has potential to promote crop earliness, better boll opening and their retention by keeping vegetative and reproductive growth in harmony to enhance seed cotton yield.

Key words

American cotton, Defoliants, Dropp ultra®, Ethrel, Seed cotton yield

Introduction

Producing cotton (*Gossypium hirsutum* L.) in north-western India, where crop should mature within a defined period, prior to commencement of *Rabi* season, is one of the biggest challenges. In this region, farmers seek to shift cotton from vegetative to reproductive growth in mid-season to assure adequate time for bolls to mature before fall in temperature due to winter season and consequently timely sowing of wheat. Singh *et al* (2013) reported that cotton growers were keen to improve profit margins by adopting improved cotton production practices while maintaining yield. Cotton has a continuous flowering and fruit formation order which changes depending on the cotton genotypes and environmental conditions. Therefore, managing earliness involves limiting cotton's vegetative growth with cultivar selection and use of plant growth regulators (PGRs)/ harvest-aid defoliants (Stewart *et al.*, 2000). Mechanized picking also requires application of harvest-facilitating defoliants to shed leaves before harvesting at an appropriate time and to ensure clean and smooth picking of seed cotton. Chemicals have been widely used in developed nations for cotton production in an attempt to adjust plant growth and to improve lint yield and fibre quality (Larson *et al*, 2002 and Faircloth *et al.*, 2004).Researchers have conducted various studies on defoliation using different chemicals and defoliation methods (Çiçek *et al.*, 2003 and Karademir *et al.*, 2007).Of these, dropp ultra® and ethrel (ethefon) are among chemicals used as mainstay of earliness management and widely accepted in developed countries (Kelley 2011 and Ming-wei *et al.*, 2013) . However, in India, their usage could not be exploited much primarily due to their limited availability. Though, few workers (Buttar and Singh, 2013 and Kumari *et al.*, 2013) have studied the effect of few defoliants on upland cotton in India. Farmers lack information on cultivar differences in response to various defoliants. Due to varied environmental conditions, it is difficult to have a perfectly adapted variety capable of high yielding. At present, no study is available which shows quantitative effects of the studied defoliants (dose and time of application) on growth, earliness induction and yield of American cotton in sub-tropical conditions of North India. Generation of such information through field experimentation is therefore crucial. In the present study effect of harvest-aid defoliants on growth, yield and yield attributes of three diverse

American cotton genotypes were studied to identify suitable defoliant with optimum dose along with ideal time of application to realize high productivity.

Materials and Methods

The experiment was conducted during Kharif 2012 and 2013 at PAU, Regional Research Station, Faridkot in Trans-Gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plains of Punjab . Soil was loamy sand, with normal pH of 8.7, EC 0.21dS^{-m}, O.C 0.39 %, medium in available P (14 kg ha^{-1}) but high in available K (690 kg ha^{-1}).Experiment comprising three cotton cultivars (F1861, MRC7361BGII and MRC7017BGII) in main, four defoliants and their doses [Control; Dropp ultra® {i.e Thiadiuron 36% SC + Diuron 18% SC} @ 200 ml ha^{-1}; Dropp ultra® (DU)@ 225 ml ha^{-1} and Ethrel/Ethephon {i.e 2-Chloroethylphosphonic acid} @ 2000 ppm] in sub and two times of application (140 and 150 DAS) in sub plots was conducted in Split Plot design and replicated thrice. Sowing was performed as on 17.5.2012 and 12.5.2013. Defoliant chemicals were mixed with water (@300 l ha^{-1}) and delivered uniformly using a knapsack sprayer. Data on growth, yield and biomass were recorded from five randomly selected plants in each treatment plot. Seed cotton yield was recorded from the whole plot. Data were analyzed using SAS Proc (SAS Institute, Inc., Cary, NC, 2009). Pooled means were used to discuss results.

Results and Discussion

Defoliation in cotton depends on environmental factors, cultivation techniques as well as genetic factors (Stewart *et al.*, 2000). Pooled results revealed that MRC7361BGII recorded significantly higher plant height (187.2cm) and monopods (4.0) followed by F1861, while MRC7017BGII exhibited statistically lowest values (Table 1). Owing to less height (140.7cm) and consequently low biomass production (107.7q ha^{-1}) coupled with earliness in MRC7017BGII as compared to other cultivars, the effects were more pronounced, leading to statistically higher contribution of first picking (2571.0kg ha^{-1}). Highest biomass under MRC7361BGII (157.9q ha^{-1}) was though statistically at par with F1861 (150.7q ha^{-1}) but significantly better than MRC7017BGII. MRC7361BGII (3055.2kg ha^{-1}) and MRC7017BGII (2913.0 kg ha^{-1}) produced significantly higher SCY as compared to F1861 (2346.0 kg ha^{-1}) due to better sympods, boll weight and bolls per plant (Table 2).

Boll count was significantly higher by 31.1 and 20.6 % for MRC7361BGII (51.0) and MRC7017BGII (46.9), respectively as compared to F1861 (38.9) and it was the main deciding factor for yield variability among the tested genotypes. Contribution of first picking towards SCY was significantly more under MRC7017BGII (2571.0 kg ha^{-1}) i.e 88.1 percent of total SCY as compared to only 82.2% and 81.7 % in F1861 and MRC7361BGII, respectively (Table 3). During second picking, contribution was highest in MRC7361BGII (18.3 %), closely followed by F1861 (17.7 %) and least for MRC7017BGII (11.8 %). This was due to more biomass production by MRC7361BGII and F1861 which took relatively more time for defoliation and consequently boll opening. Boll weight was also significantly higher by 32.8% and 44.9 % for MRC7361BGII (4.55g) and MRC7017BGII (4.17g), respectively as compared to F1861 (3.14g). This may be due to genotypic variability. Similarly, MRC7361BGII and MRC7017BGII recorded 41.3% and 33.0 % higher sympods as compared to F1861. The deleterious effect of higher dose of DU i.e @ 225ml ha^{-1} was more pronounced in cultivars F1861 and MRC7361BGII owing to their vigorous vegetative growth, coupled with higher biomass but relatively late in flowering and fruiting. Faircloth *et al.* (2004) also reported genotypic variations for tested chemicals for defoliation for yield and other parameters. Contrarily, effect of DU was

Table 1 : Growth and biomass parameters under different treatments

Treatments	Plant height (cm)			Monopods			Biomass (q ha^{-1})			Plant stand ha^{-1}		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Genotypes												
F 1861	176.7	168.5	172.6	2.6	3.1	2.9	158.0	143.5	150.7	23852	23182	23517
MRC 7361 BGII	187.6	186.8	187.2	4.0	4.1	4.0	147.6	168.2	157.9	18872	18974	18923
MRC 7017 BGII	145.0	136.3	140.7	2.1	2.3	2.2	102.5	112.9	107.7	19174	18361	18768
LSD(P=0.05)	**10.1**	**6.2**	**4.9**	**0.3**	**0.25**	**0.1**	**22.4**	**8.41**	**9.9**	**597**	**1118**	**526**
Defoliants												
Control	168.4	170.2	169.3	2.8	3.3	3.0	154.8	155.3	155.0	20893	20397	20645
Dropp ultra @ 200 ml ha^{-1}	173.1	163.0	168.1	2.9	3.1	3.0	129.9	148.0	138.9	20373	19825	20099
Dropp ultra @ 225 ml ha^{-1}	167.6	154.8	161.2	2.9	3.0	3.0	119.0	125.3	122.9	20484	20479	20482
Ethrel @ 2000 ppm	170.0	167.4	168.7	3.0	3.2	3.1	140.5	137.3	138.9	20782	19989	20385
LSD(P=0.05)	**NS**	**5.1**	**3.2**	**NS**	**NS**	**NS**	**11.8**	**8.35**	**6.9**	**NS**	**NS**	**NS**
Time of defoliant application												
140 DAS	167.8	162.1	164.9	2.8	3.2	3.0	134.1	137.3	135.7	20566	20166	20366
150 DAS	171.8	165.6	168.7	3.0	3.1	3.1	138.0	145.7	141.8	20699	20179	20439
LSD(P=0.05)	**3.7**	**3.1**	**2.3**	**NS**	**NS**	**NS**	**NS**	**8.2**	**5.6**	**NS**	**NS**	**NS**

minimal in MRC7017BGII owing to its early flowering, fruiting and boll bearing nature and comparatively less biomass.

Biomass and yield contributing parameters such as boll weight and open boll count was significantly affected by defoliants and dose of application. This not only affected SCY significantly but also the quantity/per cent share from the first and second pick towards total seed cotton yield. Biomass was significantly the highest in control (155.0 q ha^{-1}), followed by ethrel @2000 ppm (138.9 q ha^{-1}) , DU @ 200 ml ha^{-1} (138.9 q ha^{-1}) and statistically least under DU @ 225 ml ha^{-1} (122.9 q ha^{-1}).This was due to application of defoliants causing mild to severe shedding of leaves, young flowers and fruiting bodies and even some developing bolls. Significant reduction in biomass under DU @ 225 ml ha^{-1} was recorded due to toxic effects resulting in severe shedding of leaves, young flowers and fruiting bodies and even developing / immature bolls as compared to rest of the treatments (Table 1).Therefore, least number of open bolls (42.6) was observed under DU @ 225 ml ha^{-1} (Table 2). Toxicity of DU at this dose caused severe reduction in yield contributing characters leading to decline in yield. Significant reduction in boll weight (3.79g) with application of DU @ 225 ml ha^{-1} was also indicative of toxicity/injury to the crop (Table 2). However, application of DU @ 200 ml ha^{-1} resulted in statistically highest opened bolls per plant (50.0) which in turn contributed towards higher SCY. Although, bolls per plant under control (44.0) were statistically same as under DU @ 225 ml ha^{-1} (42.6), but significantly improved boll weight in control (4.09 g) helped in realizing statistically better yield. Ming-wei *et al.* (2013) reported beneficial effect of three defoliants (dimethipin, thidiazuron, and thidiazuron-diuron) and one boll opener (ethephon) in increased defoliation and/or boll opening. DU @ 200 ml ha^{-1} exhibited significantly better SCY (3018.7 kg ha^{-1}) as compared to its higher dose i.e., 225ml ha^{-1} (2516.9 kg ha^{-1}) as well as ethrel @ 2000 ppm (2820.1 kg ha^{-1}) and control (2730.0 kg ha^{-1}). This lead to an increased yield by 10.6, 19.9 and 7.0 % over control, DU @ 225 ml ha^{-1} and ethrel @ 2000 ppm, respectively. However, the percent contribution of first pick towards SCY was more in DU @ 225 ml ha^{-1} (91.9 %) followed by DU @ 200 ml ha^{-1} (89.9%) , ethrel @ 2000 ppm (81.3%) and control (72.9%) and all these treatments differed significantly (Table 3). Ming-wei *et al.* (2013) also observed significantly increased first harvest of seed cotton with defoliant-ethephon mixtures. However, Stewart *et al.* (2000) reported ethephon alone to be less effective in boll opening whereas products containing ethephon plus synergists like cyclanilide (1-(2,4-dichlorophenyl aminocarbonyl)) or AMADS (1-aminomethana- mide dihydrogen tetraoxosulfate) were found to have higher rates of boll opening. Sarlach *et al.* (2010) observed ethrel @ 2000 ppm to be effective in improving boll opening percentage to get higher yield potential from late maturing *Bt* hybrids without having any adverse affect on fibre quality traits. However, Kumari *et al.* (2013) found ethrel dose@3000ppm to be effective, causing significantly increased SCY in Southern Indian conditions. The response at higher dose might be due to relatively higher temperature, resulting in quick breakdown of ethrel prevailing during boll maturity/opening periods in South India as compared to the present investigations carried in North India where relatively cool temperatures prevailed during that phase.

In the present study, application of ethrel and dropp ultra resulted in an earliness in crop maturity over that of control by 9 days and 14 days respectively. Contrarily, more share (27.1 %) was contributed by control in second picking, thereby clearly indicated its delayed maturity as compared to chemical treatments. Significantly, least contribution in second pick (8.1%) with DU @ 225 ml ha^{-1} was recorded, indicating hastened boll opening followed by enforced maturity at this dose in line with the findings of Ming-wei *et al.* (2013). Application of ethrel @ 2000

Table 2 : Yield and yield attributes under different treatments

Treatments	Seed cotton yield (kg ha^{-1})			Open bolls/plant			Boll weight (g)			Sympods/plant		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Cultivars												
F 1861	2479.5	2212.5	2346.0	42.9	34.8	38.9	3.13	3.15	3.14	21.0	19.6	20.3
MRC 7361 BGII	3078.0	3032.5	3055.2	49.7	52.3	51.0	4.37	3.98	4.17	27.2	30.2	28.7
MRC7017 BGII	3000.4	2825.6	2913.0	48.0	45.9	46.9	4.57	4.54	4.55	25.2	28.8	27.0
LSD(P=0.05)	**295.1**	**190.7**	**145.9**	**1.52**	**2.78**	**1.31**	**0.32**	**0.19**	**0.15**	**1.44**	**2.3**	**1.1**
Defoliants												
Control	2841.7	2618.3	2730.0	44.4	43.6	44.0	4.14	4.04	4.09	24.0	26.7	25.4
Dropp ultra® @ 200 ml ha^{-1}	3047.3	2990.0	3018.7	50.1	49.8	50.0	4.05	3.90	3.98	24.9	26.3	25.6
Dropp ultra® @ 225 ml ha^{-1}	2623.9	2409.9	2516.9	46.5	38.6	42.6	3.86	3.72	3.79	24.0	25.2	24.6
Ethrel @ 2000 ppm	2897.6	2742.6	2820.1	46.5	45.2	45.8	4.04	3.89	3.96	24.9	26.6	25.8
LSD(P=0.05)	**169.6**	**173.1**	**117.0**	**2.10**	**3.27**	**1.87**	**0.18**	**0.13**	**0.11**	**NS**	**NS**	**NS**
Time of defoliant application												
140 DAS	2754.6	2624.3	2689.5	45.2	41.8	43.5	3.93	3.86	3.89	24.3	26.2	25.3
150 DAS	2950.7	2756.0	2853.3	48.6	46.8	47.7	4.12	3.91	4.02	24.6	26.2	25.4
LSD(P=0.05)	**119.5**	**67.7**	**66.9**	**1.57**	**2.26**	**1.34**	**0.14**	**NS**	**0.08**	**NS**	**NS**	**NS**

Table 3 : Proportion of seed cotton yield in pickings under different treatments

Treatments	1st pick (kg ha-1)			2nd pick (kg ha-1)			1st pick % over SCY			2nd pick % over SCY		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Cultivars												
F 1861	2114.2	1757.3	1935.8	365.2	455.1	410.2	85.2	79.2	82.2	14.7	20.7	17.7
MRC 7361 BGII	2509.9	2475.8	2492.9	568.0	556.6	562.3	81.5	81.8	81.7	18.4	18.2	18.3
MRC 7017 BGII	2644.7	2497.2	2571.0	355.6	328.4	342.0	88.1	88.2	88.1	11.8	11.8	11.8
LSD(P=0.05)	**251.9**	**186.2**	**130.1**	**65.2**	**66.9**	**38.8**	**1.1**	**2.3**	**1.0**	**1.1**	**2.4**	**1.1**
Defoliants												
Control	2094.9	1900.2	1997.5	746.8	718.0	732.4	73.6	72.2	72.9	26.3	27.7	27.1
Dropp ultra® @ 200 ml ha-1	2758.4	2678.5	2718.5	288.9	311.4	300.1	90.5	89.4	89.9	9.4	10.6	10.0
Dropp ultra® @ 225 ml ha-1	2418.8	2217.8	2318.3	205.0	192.0	198.5	92.1	91.7	91.9	7.8	8.3	8.1
Ethrel @ 2000 ppm	2419.7	2177.2	2298.5	477.8	565.3	521.5	83.6	79.0	81.3	16.3	20.9	18.7
LSD(P=0.05)	**163.0**	**164.9**	**111.9**	**67.6**	**57.5**	**42.8**	**2.3**	**2.0**	**1.5**	**2.3**	**2.1**	**1.5**
Time of defoliant application												
140 DAS	2323.4	2168.4	2245.9	431.2	455.9	443.5	84.5	82.3	83.4	15.4	17.6	16.5
150 DAS	2522.5	2318.5	2420.5	428.1	437.4	432.8	85.4	83.8	84.6	14.5	16.2	15.4
LSD(P=0.05)	**115.1**	**72.5**	**66.2**	**NS**	**NS**	**NS**	**0.77**	**1.3**	**0.7**	**0.7**	**1.4**	**0.76**

ppm resulted in increased yield by 3.3% and 12.0 % over control and DU @ 225 ml ha^{-1} respectively.

Application time of defoliants not only affected growth parameters like plant height and biomass significantly but also yield parameters such as boll weight, opened bolls and overall SCY. Earlier application at 140DAS resulted in significant reduction of plant height (164.9cm) over the later (168.7cm) application (Table 1).Similarly, biomass production statistically improved under later (141.8 q ha^{-1}) as compared to the early application (135.7 q ha^{-1}). Defoliants applied at 150DAS resulted statistically higher SCY (2853.3 kg ha^{-1}) as compared to the application at 140DAS (2689.5 kg ha^{-1}) owing to significantly improved boll count (47.7) and boll weight (4.02g). The number of bolls and boll weight were significantly improved by 9.6% and 3.3% at 150 DAS, indicating better boll retention and consequently, less shedding under later application (Table 2).Similar results were reported by Locke *et al.* (1996).However, Çopur *et al.* (2010) found that application times of defoliants (droppultra® and round up) had significant differences for pickable bolls but exhibited non-significant differences for types of defoliant. In the present study, early application (140 DAS) of DU at both the doses lead to severe shedding of young squares, flowers, fruiting bodies and even younger bolls as indicated by significantly reduced biomass (Table 1). This in turn exhibited negative effect on SCY. Similarly, mild shedding of young squares and flowers was observed with ethrel @ 2000 ppm applied at 140 DAS. Buttar and Singh (2013) also observed significantly improved SCY with the application of ethrel at 145 DAS over early application at 130 DAS. However, Sarlach *et al.* (2010) observed that ethrel at 145 and 160 DAS was found most effective in improving boll opening percentage as compared to other application timings. Data on picking further substantiated that first picking was significantly reduced in early (2245.9 kg ha^{-1}) than the later application (2420.5 kg ha^{-1}) whereas for second picking differences were non-significant (Table 3). Delayed defoliant application at 150 DAS resulted in higher yield percentage towards the first pick (84.6%) whereas contrarily, in earlier application at 140 DAS, second picking was significantly higher (16.5 %) over the delayed application. Owing to all the above factors, significantly better SCY was observed in later application at 150 DAS. These results showed that SCY was significantly and negatively affected by early defoliation. Kelley (2011) also reported that extreme early application of harvest aids like ethefon and thidiazuron/diuron and their combinations significantly reduced seed cotton yield in Texas whereas their application after 60 % boll opening proved more beneficial. Ming-wei *et al.* (2013) also suggested that tank mixes of ethephon with thidiazuron can be used effectively and safely in Cotton- Wheat cropping system to improve yield without adverse effects on seed and fibre quality. One possible explanation is that postponing defoliation allowed more carbon assimilation and better partitioning of photo assimilates to develope cotton bolls. These results are in agreement with those of Snipes and Baskin (1994), Larson *et al.* (2002), Çiçek *et al.* (2003) and Karademir *et al.* (2007). Çopur *et al.* (2010) also found that delaying crop termination with Dropp ultra® and Round up defoliants recorded better boll formation and SCY than control. Kumari *et al.* (2013) also reported similar findings in South India.

It can be concluded from two years studies that use of defoliants in cotton under semi-arid conditions of north-western India could be a useful production practice for managing plant growth and enhancing yield. Application of dropp ultra® @ 200 ml ha^{-1} at 150 DAS can be a good management decision necessary for enhancing earliness for timely sowing of wheat besides reaping higher yield of American cotton.

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References

Buttar, G.S. and S. Singh: Effect of ethrel dose and time of application on growth, yield and duration of *Bt* cotton in semi arid region of Punjab. *J. Cott. Rese. Develo.,* **27**, 60-62 (2013).

Çiçek, B., M. O_lakçi and O. Çopur: Effect of defoliation on cotton yield and quality components. *J. Facu. Agricult.,* **7**, 45-52 (2003).

Çopur, O., U. Demirel, R. Polat and M.A. Gür: Effect of different defoliants and application times on the yield and quality components of cotton in semi-arid conditions . *Afri. J. Biotechnol.,* **9**, 2095-2100 (2010).

Faircloth, J.C., K.L. Edmisten, R Wells and A.M. Stewart: The influence of defoliation timing on yield and quality of two cotton cultivars. *Crop Sci.,* **44**, 165-72(2004).

Karademir, E., C. Karademir and S. Basbag: Determining the effect of defoliation timing on cotton yield and quality. *J. Cent. Euro. Agricult.,* **8**, 357-62 (2007).

Kelley, M. Shelton: Harvest aid combination and application timing effects on lint yield and fibre quality. (2011).

Kumari, S.R., M. George and K. Hema: Effect of growth regulators and weedicides as defoliants on seed cotton yield of cotton. *J. Cott. Rese. Develop.,* **27**,56-59 (2013).

Larson, J.A., C.O. Gwathmey and R.M. Hayes: Cotton defoliation and harvest timing effects on yields, quality and net revenues. *J. Cott. Sci.,* **6**, 13-27(2002).

Locke, D., J.A. Landivar and D. Moseley: Effects of rate and timing glyphosate applications on defoliation efficiency, lint yield, fibre quality. *Beltwide Cotton Conferences, National Cotton Council, San Antonio, Texas, USA. pp: 1088-90* (1996).

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

Sarlach, R.S., R.S. Sohu and M.S. Gill: Effect of ethrel on yield and fibre quality traits in upland cotton. *Crop Improv.,* **37**, 83-86 (2010).

SAS Institute Inc. *SAS® 9.2 Macro Languages: Reference*. Cary, NC: SAS Institute Inc., Copyright © 2009 Cary, NC, USA (2009).

Singh, K., H. Singh, K. Singh and P. Rathore: Effect of transplanting and seedling age on growth, yield attributes and seed cotton yield of *Bt* cotton (*Gossypium hirsutum*). *Ind. J. Agric. Sci.,* **83**, 508-13 (2013).

Snipes, C.E. and C.C. Baskin: Influence of early defoliation on cotton yield, seed quality and fibre properties. *Fie. Crop Res.,* **37**, 137- 43 (1994).

Stewart, A.M., K.L. Edmisten and R. Wells: Boll openers in cotton: effectiveness and environmental influences. *Fie. Crop Res.,* **67**, 83–90 (2000).