NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 34, 2017
www.incda-fundulea.ro Print ISSN 1222-4227; Online ISSN 2067-5720

ENHANCEMENT OF PRODUCTIVITY AND FIBRE QUALITY BY DEFINING IDEAL DEFOLIATION AND HARVESTING TIMING IN COTTON

Ozgul Gormus[1*], Ali Ihsan Akdag[1], Ayman El Sabagh[2] and Mohammad Sohidul Islam[3]

[1]Department of Field Crops, Faculty of Agriculture, University of Cukurova, Turkey

[2]Department of Agronomy, Faculty of Agriculture, Kafrelsheikh University, Egypt.

[3]Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Bangladesh

[*]Corresponding author. E-mail: ogurmus@cu.edu.tr

ABSTRACT

Timing of defoliation and harvest can affect cotton yield and quality. Careful consideration of defoliating is necessary, because too early or too late defoliation may have a negative impact on yield potential and fibre quality. Therefore, field experiments were conducted during 2011 and 2012 to determine the effects of defoliation and harvesting timing of an early maturing and a medium-late maturing cotton cultivar for identifying ideal time of application to realize high productivity and fibre quality. The experiment was conducted in the split-split plot arrangement with three replications. Cultivars were the main plots (DP 499, and SG-125), defoliation times were the sub-plots (50 (early), 70 (mid), and 90 (late) percent open boll), and harvest times were the sub-sub plots (pickings at two and four weeks after defoliation treatments). The result revealed that yields of the early harvest at late defoliation timing and late harvest at mid defoliation timing were significantly higher than the yields of all other treatments both in 2011 and 2012. When the cotton crop was defoliated at 70% open boll, early harvest produced the longest fibre in 2011. Early harvest at early defoliation and late harvest at mid defoliation treatments produced the finest fibres. The largest strength value was observed for cotton defoliated at 70% open boll. On the basis of these results it is suggested that defoliation at 90% open boll for early maturing cultivar and defoliation at 70% open boll for medium-late maturing cultivar could be recommended for higher yields without undesirable changes in fibre quality.

Key words: cotton maturity groups, defoliation time, harvesting time, fibre strength, percent open boll.

INTRODUCTION

Cotton (*Gossypium* spp.) is one of the most important fibre producing crops in the world and it not only provides fibre for the textile industry, but also plays a role in the feed and oil industries with its seed, rich in oil (18-24%) and protein (20-40%). It is also one of the most important agricultural as well as industrial crops of the Southeast Anatolia Region of Turkey (Copur et al., 2010) and approximately 50% of Turkish cotton production occurs in this region (Cetin et al., 2015). In recent years, cotton sowing area and fibre production increased significantly due to increase in irrigated area by Southeastern Anatolia Project (GAP). In addition, large field owners prefer mechanical harvesting of cotton instead of hand harvesting and therefore, they have to apply defoliation materials before harvest (Karademir et al., 2007).

Since the mechanization of cotton harvesting, harvest aid chemicals have been introduced to facilitate machine harvesting. Even after almost three decades of research in this area, results sometimes still can not be predicted and sometimes are even undesirable. Further research is still needed on present day of cotton defoliants (dose and time of application). The timing of harvest aid application is an important management practice for producers. Due to the fruiting nature of the cotton plant, the correct harvest aid application timing is a compromise between maturation of later developing bolls and reducing degradation of earlier-developed open bolls (Brecke et al., 2001). This aspect is gaining importance with new product testing and registration and consequently rising

Received 7 March 2016; accepted 16 May 2016. First online: February, 2017. DII 2067-5720 RAR 2017-39

availability in last couple of years, besides sought after mechanization required for cotton picking.

The quantity of cotton leaves remaining on the plant at harvest time is a logical contributing factor, including green leaves and leaves desiccated during the pre-harvest application of harvest aid products (Supak and Snipes, 2001). Rayburn (1988) observed that significant grade increases can be expected with smooth leaf cultivars. Hairy leaves are one of the defoliation problems that decrease cotton leaf drop and hamper the harvest of clean, dry seed cotton. In mechanically harvested cotton, leaf hairs promote adherence of leaf particles to the stem, which ends up contaminating the lint during picking, resulting in trashy seed cotton. When the cotton industry made the transition from hand picking to machine harvesting, complete removal or desiccation of leaf tissue (defoliation) in preparation for harvest became a necessity. Proper timing of defoliation involves to establish a balance between yield and fibre quality. When plants are defoliated, the fibre and seed development essentially stops. Therefore, if too many bolls are immature at the time of defoliant application there can be a reduction in yield and quality associated with the treatment. Defoliating too late or early can negatively impact fibre quality, including micronaire and staple length. Delayed defoliation can possibly result in yield or quality losses due to adverse weather conditions (Faircloth et al., 2004). Some authors reported that defoliation timing did not affect fibre quality properties, including micronaire, length and strength (Karademir et al., 2007; Balkcom et al., 2010). It is generally safe to defoliate when about 60 per cent of the bolls are open. However, variability in crop development may alter this recommendation. The boll population may be of various stages of maturity near the time of harvest, due to the indeterminate growth habit of cotton (Stewart et al., 2000) and the crop can be set more quickly or more slowly than normal. In some situations, defoliation at 60 per cent open may be premature and cut short the development of bolls in the upper canopy. On the other hand, a crop set in a short period of time could be safely defoliated at 40-50% open boll. Many producers tend to underestimate per cent open boll and may actually be waiting until 70-80% open to defoliate. Optimal defoliation timing and harvest timing may vary between cultivars of different maturity groups, as some groups have more compact fruiting and possibly more rapid boll development or boll opening characteristics. Harvest timing, maturity at the time of harvest and harvest date are all important factors affecting quality (Anthony and Bragg, 1987). Harvesting timing is also an important part of managing for yield and fibre quality. Picking of the crop should occur as soon as all leaves are off the crop and most bolls are open. Delaying picking gives greater potential for grade losses due to rain and loss of yield on lower branches through ageing and wind damage. Therefore, considering the above facts, the present work was intended to know the effect of harvest-aid defoliants on yield and monetary parameters, identify suitable defoliant time with ideal time of harvest to realize high productivity and fibre quality of cotton under Mediterranean climate conditions.

MATERIAL AND METHODS

Plant material and culture conditions

The experiment was conducted during 2011 and 2012 at the experimental farm of Cukurova University, Adana (37°02"N to 35°18"E), Turkey. The climate of the study site is typically Mediterranean. Monthly minimum, maximum and mean temperatures, total rainfall and heat unit accumulations are given in Table 1. A medium late maturing cultivar (DP 499) and an early maturing cultivar (SG-125) were planted on 3 May 2011 and 10 May 2012. Plots contained six rows 12 m long, spaced 0.70 m apart. Treatments represented three defoliation times based on percent open boll and two harvest times. Defoliation times were 50 (early), 70 (mid), and 90 (late) per cent open boll. Harvest times included an early harvest (two weeks after defoliation) and a late harvest (four weeks after defoliation). The experimental design consisted of a split-split-plot design with four replications.

Cultivars were the main plots, defoliation times were the sub-plots, and harvest times were the sub-subplots.

Table 1. Monthly minimum, maximum and mean temperatures, total rainfall and heat unit accumulations for Adana in 2011 and 2012

Month	2011					2012				
	Mean (°C)	Max. (°C)	Min. (°C)	HU (HU)	Rainfall (mm)	Mean (°C)	Max. (°C)	Min. (°C)	HU (HU)	Rainfall (mm)
May	20.2	26	14.8	150	29.1	20.8	26.4	15.4	170	126
June	24.5	301	19.3	265	--	26.7	32.6	21	339	36
July	27.9	33.3	23.1	395	--	29.3	35.6	23.1	429	18.3
August	28.8	34.8	23.2	418	--	29.2	36	22.5	427	--
September	26.9	33.3	20.4	343	--	27	34.2	20.8	344	--
October	20.8	27.5	14.2	166	6	22.6	28.6	16.5	220	52

Calculation of HU was made by the following equation: [(daily high °C + daily low °C/2)] –15.5°C.

Percent open boll measurements were recorded on ten plants chosen randomly in each plot. All plots were defoliated each year when the targeted percent of open bolls was reached. A standard mixture of 120 g/l Thidiazuron + 60 g/l Diuron was used. The early defoliation treatments were applied on 15 September 2011 and 19 September 2012. The mid defoliation treatments were performed on 24 September 2011 and 27 September 2012.

The late defoliation treatments were done on 1 October 2011 and 5 October 2012. Defoliation treatments were applied using a CO_2-pressurized backpack sprayer with pressure set to 4.22 kg cm^2.

Plant sampling and measurements

Plots were harvested at two and four weeks after defoliation treatments. Seed cotton yields were determined by harvesting the middle four rows of each plot. Sub-samples were collected for fibre quality analysis measured by using HVI (High Volume Instruments). Data included seed cotton yield, micronaire, length and strength.

Statistical analysis

The results were statistically evaluated by using MSTAT-C procedures and mean separations were made on the basis of least significant differences (LSD) at p=0.05.

RESULTS AND DISCUSSION

Seed cotton yield

It is evident from data given in Table 2, that the cultivar main effect for seed cotton yield was insignificant. However, the defoliation time main effect for seed cotton yield was significant in both years. Interactions of cultivar and defoliation timing, as well as defoliation timing and harvesting timing, were significant in both years. In 2011, seed cotton yields of plots defoliated at 70-90% open boll were significantly higher than that of plots defoliated at 50 percent open boll. This was due to improved yield with better boll opening/retention and consequently less shedding under later application. Yields of defoliated at 70% open boll were significantly higher than the yields of the early and late defoliation timings in 2012 (Table 2). Singh et al. (2015) reported that seed cotton yield was significantly and negatively affected by early defoliation. Çopur et al. (2010) observed better boll formation and yield by delaying defoliation. It was observed that, yields of the late defoliation timing for SG-125 and the mid defoliation timing for DP 499 were significantly higher than the other defoliation timings for both years (Table 2). Regarding the harvest timing, main effect was significant for seed cotton yield in 2012, but not in 2011. Late harvest resulted in higher seed cotton yield than early harvest. The harvest timing by defoliation timing interaction was significant for seed cotton yield in both years. Defoliating early (50% open boll) resulted in lowest seed cotton yield among all defoliation and harvesting timings.

Table 2. Seed cotton yields of two cultivars at different defoliation timings in 2011and 2012

Factor	2011			Mean	Factor	2012			Mean
	Defoliation timing (% OB)					Defoliation timing (% OB)			
Cultivar	50	70	90		Cultivar	50	70	90	
SG-125	2867 d*	3628 b	4128 a	3541	SG-125	3003 c	3788 b	4092 ab	3628
DP 499	2975 cd	4013 a	3307 bc	3432	DP 499	3168 c	4243 a	3150 c	3521
Mean	2921 b+	3821 a	3718 a		Mean	3086 c+	4016 a	3621 b	

*) The means of cultivar – defoliating time combinations with the same letters are not significantly different according to LSD test at p=0.05.

+) The means with the same letter in the line are not significantly different according to LSD test at p=0.05.

In 2011, maximum seed cotton yields were achieved by defoliating late and harvesting early or defoliating medium and harvesting late. In 2012, defoliating medium and harvesting late produced higher seed cotton yields than all other defoliation and harvesting timings (Table 3). These findings suggest that delaying harvest in plots defoliated at 70% open boll allowed for additional yield formation. These yields indicate that for cotton defoliated at 70% open boll, there may be a yield advantage to late harvesting the cotton. Also for early harvested cotton, defoliating cotton at 70-90% open boll or avoiding the early defoliating, irrespective the harvest timings, may result in a yield advantage. Çopur et al. (2010) observed that delaying crop termination defoliants, lint yield was statistically improved under later application as compared to early application. This was primarily due to improved yield owing to better boll opening/retention and consequently less shedding under later application.

Table 3. Defoliation time and harvest time interaction effects on seed cotton yield in 2011 and 2012

Factor	2011			Mean	Factor	2012			Mean
	Defoliation timing (% OB)					Defoliation timing (% OB)			
Harvest timing	50	70	90		Harvest timing	50	70	90	
Early	2725e*	3672 b	4065 a	3487	Early	2842e*	3825 b	3547 c	3404 b1
Late	3117 d	3970 a	3370 c	3486	Late	3330 d	4207 a	3695bc	3744 a
Mean	2921b+	3821 a	3718 a		Mean	3086 c+	4016 a	3621 b	

*) The means of harvest time – defoliating time combinations with the same letters are not significantly different according to LSD test at p=0.05.

+) The means with the same letter in the line are not significantly different according to LSD test at p=0.05.

1) The means with the same letter in the column are not significantly different at p=0.05.

Micronaire (mic)

The cultivar main effect for micronaire was not significant in both years (Table 4). The defoliation timing main effect and the cultivar by defoliation timing interaction were significant for micronaire in 2012 (Table 4). The harvest timing main effect and the harvest timing by cultivar interaction were significant for micronaire in 2011. Micronaire values of the mid and late defoliation timings for SG-125 and early and late defoliation timings for DP 499 were not significantly different from each other (data not shown). Micronaire values of the delayed harvest were significantly lower than the micronaire values of the early harvest (Table 4). At the late harvest, the medium-late maturing cultivar, DP 499, had significantly higher micronaire values than early maturing cultivar, SG-125; however at the early harvest timings, micronaire values of the two cultivars were not significantly different from each other. The micronaire value of SG-125 at late harvest was significantly lower compared to the other cultivar, probably due to earlier maturity, indicating that delaying harvest could reduce fibre micronaire (data not shown). In 2012, micronaire value increased significantly when defoliation was delayed. Increase in micronaire with the late defoliation support the hypothesis that delayed defoliation allows more carbon assimilation and/or partitioning of photo-assimilates to developing cotton bolls. For SG-125, the mid defoliation timing produced coarser fibre (higher micronaire), as micronaire value increased by 10.3% when defoliation was delayed from 50-70% open boll. A small decrease (4%) of micronaire also occurred by delaying defoliation from 70-90% open boll. In DP 499, late defoliation timing resulted in higher micronaire value compared to the mid defoliation timing. Fibre quality parameters at similar defoliation time varied between the cultivars and most likely reflected the differences in the seasonal growing conditions by all bolls in each maturity category. Temperature during boll filling is known to affect micronaire (Kelly et al., 2008).

Table 4. Defoliation timing and harvest timing interaction effects on micronaire in 2011and 2012

Factor	2011			Mean	Factor	2012			Mean
	Defoliation timing (% OB)					Defoliation timing (% OB)			
Harvest timing	50	70	90		Harvest timing	50	70	90	
Early	4.47 c*	4.97 a	4.73 ab	4.72 a[1]	Early	4.62b	5.10 a	4.97 a	4.89 a[1]
Late	4.65 bc[+]	4.15d	4.65 bc	4.48 b	Late	4.35 c	4.28 c	4.45 bc	4.36 b
Mean	4.56	4.56	4.69		Mean	4.48b	4.69 a	4.71 a	

*) The means of cultivar–defoliating time combinations with the same letters are not significantly different according to LSD test at p=0.05.
[1]) The means with the same letter in the column are not significantly different according to LSD test at p=0.05.
+) The means with the same letter in the line are not significantly different according to LSD test at p=0.05.

The defoliation timing by harvest timing interaction was significant for micronaire in both years (Table 4). Micronaire values of the delayed harvest at the mid defoliation timing were significantly lower than the other defoliation timing and early harvest timing in 2011. The micronaire increased significantly with the delay harvesting at the mid and late defoliation timing (Table 4). In 2012, micronaire values of the early harvest defoliated at the early defoliation timing was significantly lower than the early harvest of the both defoliation timing. At the late harvest, there were no differences in micronaire values among the three defoliation timings (Table 4). This effect is also possibly a result of either the increases in opening of less mature bolls or the significant rainfall events that occurred between defoliation and harvest in 2012. Since the mature fibres are coarser (higher micronaire) and stronger (higher strength) than the immature fibres, there is more deposition of new daily rings of cellulose during extended period in the early formed bolls. Thus, earlier harvest resulted in mature fibre, higher micronaire value and higher strength. Only stresses during the last stage of boll development, such as premature crop termination is detrimental to quality. If stresses such as premature defoliation interrupt the development of bolls, low micronaire may result. The results are in agreement with the results of Faircloth et al. (2004), who reported that micronaire values decreased with early defoliation. Similar results were also observed by Duncan et al. (2003) and they reported that micronaire decreased with late harvest. At all defoliation times, micronaire values of the delayed harvest were not different from each other, indicating that delayed harvest and early defoliating may help reduce micronaire values in years subject to yielding high micronaire. There were no significant differences in fibre strength according to defoliants and application times (Çopur et al., 2010).

Fiber strength (g tex^{-1})

Main effects of the defoliation and harvest timings on the fibre strength were significant in both years. The defoliation timing by harvest timing interaction was significant in 2011. Fibre strength decreased by 2.6% and 5.2 % as harvest was delayed in 2011 and 2012, respectively. This may be due to prolonged field exposure (Table 5). The largest strength values of 31.7 and 31.6 g tex^{-1} were obtained for cotton defoliated at 50% open boll in 2011 and 2012, respectively.

This was attributed to the physiological shedding of younger bolls, leaving a higher percentage of older bolls; more mature bolls contain fibre of greater strength. Singh et al. (2015) observed the largest strength value by the early defoliation. Our result is contradictory to the finding of Balkcom et al. (2010), who reported fibre properties were not affected by different defoliation timings. Fibre strength decreased significantly with the delayed harvesting when cotton was defoliated at the early and late defoliation timings. However, there was no significant difference between harvest timings when defoliationwas was done at 70% open boll. There was a trend toward diminishing fibre strength with increasing percent open boll in the late harvest (Table 5). Fibres became weaker in the premature and late crop termination in late pickings. Prolonged field exposure to weathering is likely responsible for these effects.

Table 5. Defoliation and harvest timing interaction effects on fibre strength in 2011 and 2012

Factor	2011 Defoliation timing (% OB)			Mean	Factor	2012 Defoliation timing (% OB)			Mean
Harvest timing	50	70	90		Harvest timing	50	70	90	
Early	32.4 a*	29.7 c	29.4 c	30.5 a[1]	Early	32.5	30.1	29.6	30.7 a[1]
Late	31.0 b	29.7 c	28.4d	29.7 b	Late	30.7	28.5	28.3	29.2 b
Mean	31.7 a[+]	29.7 b	28.9 c		Mean	31.6 a[+]	29.3 b	29.0 b	

*) The means of harvest time –defoliating time combinations with the same letters are not significantly different according to LSD test at p=0.05.
+) The means with the same letter in the line are not significantly different according to LSD test at p=0.05.
1) The means with the same letter in the column are not significantly different at p=0.05.

Fibre length (mm)

The effects of cultivars, defoliation timings and harvest timings were significant for fibre length in both years. SG-125 and DP 499 produced longer fibres in both 2011 and 2012. In 2011, fibre length value decreased by 1.4% as harvest was delayed while fibre length value increased by 3.0% as harvest was delayed in 2012 (Table 6).

Table 6. Fibre length obtained by defoliation and harvest timing interaction in 2011and 2012

Factor	2011 Defoliation timing (% OB)			Mean	Factor	2012 Defoliation timing (% OB)			Mean
Harvest timing	50	70	90		Harvest timing	50	70	90	
Early	28.4 cd*	29.8 a	28.5 c	28.9 a[1]	Early	27.9 d*	28.8 c	29.4 b	28.7 b[1]
Late	28.9 b	28.2d	28.4 cd	28.5 b	Late	29.2 bc	30.3 a	29.1bc	29.5 a
Mean	28.7 b[+]	29.0 a	28.4 b		Mean	28.5 c[+]	29.6 a	29.2 b	

*) The means of harvest time –defoliating time combinations with the same letters are not significantly different according to LSD test at p=0.05.
+) The means with the same letter in the line are not significantly different according to LSD test at p=0.05.
1) The means with the same letter in the column are not significantly different at p=0.05.

Differences between harvest timings were not significant for SG-125 and DP 499 in 2011 and 2012 (data not shown).

The interaction among the treatments was significant for fibre length in both years. Higher fibre length values were achieved by harvesting early and delaying harvest in 2011 and 2012 for both DP 499 and SG-125 (data not shown). In both years the mid defoliation timing yielded higher lengths than the early or late defoliation timings (Table 6). At the late defoliation timing length values of the early and delayed harvests were not different statistically, whereas length values decreased significantly as harvest was delayed for both the early and mid defoliation timings in 2011. In 2012, at the late defoliation timing, length values of the early and late harvest timing were not different statistically, whereas length values increased significantly as harvest was delayed for both the early and mid defoliation timings, possibly due to extensive heat unit accumulation. The reverse effect occurred at the late defoliation timing, likely a result of significant amounts of rainfall during the harvest period. Maximum fibre length values were achieved by defoliating early and delaying harvest, or defoliating late and harvesting early. These trends, again, indicate that achieving an early harvest may be more important when defoliation is delayed, due to increased weathering potential. Similar to the finding of Kelley et al. (2000), fibre length values decreased with early defoliation. Results from this study differ from those of Bednarz et al. (2002) and Clay et al. (2006). Early application of defoliation had a negative effect on fibre development and may cause contraction of fibres (Çopur et al., 2010).

CONCLUSIONS

The success of a particular defoliation and harvest program is strongly dependent upon favourable environmental and crop conditions that prevail during and following defoliation and harvest. The results of present study suggest that yields of the mid defoliation timing for medium-late maturing cultivar and late defoliation timing for early maturing cultivar were significantly higher than the two other defoliation timings. It is also evident that higher micronaire and strength corresponded to harvesting early and lower micronaire values were achieved by defoliating mid and delaying harvest. Consequently, it should be considered that a useful production practice for enhancing cotton as well as, proper implementation of a successful and profitable defoliation or harvest program, requires timing defoliation and harvest to balance potential yield gains with quality losses under semi-arid conditions.

REFERENCES

Anthony, W.S. and Bragg, C.K., 1987. *Response of cotton fiber length distributions to production and ginning practices.* Transactions of the ASAE, 30(1): 290-296.

Balkcom, K.S., Bergtold, J.S., Monks C.D. and Price, A.J., 2010. *Planting and defoliation timing impacts on cotton yield and quality.* 2010. Proc. Beltwide Cotton Conferences, New Orleans, Louisiana, Jan. 4-7, 2010: 125-130.

Bednarz, C.W., Shurley, W.D. and Anthony, W.S. 2002. *Losses in yield, quality, and profitability of cotton from improper harvest timing*. Agron. J., 94: 1004-1011.

Brecke, B.J., Banks, J.C. and Cothren., J.T., 2001. *Harvest-aid treatments: products and application timing*. In: Cotton Harvest Management: Use and Influence of Harvest Aids. (Editors J.R. Supak and C.E. Snipes): 119-142. The Cotton Foundation Book Series. Memphis, TN, USA.

Cetin, O., Uzen, N. and Temiz, M.G., 2015. *Effect of N-fertigation Frequency on the Lint Yield, Chlorophyll, and Photosynthesis Rate of Cotton*. J. Agril. Sci. Tech., 17: 909-920.

Clay, P.A., Young, K.M. and Taylor, E.R., 2006. *Effect of heat unit accumulation on cotton defoliation, lint yield, and fiber quality.* Arizona Cotton Report, 145: 245-250.

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

Duncan, S.R., Staggenborg, S.A. and Heer, W.F., 2003. *Harvest delay effects on machine stripped cotton yield and quality.*In Proc. Beltwide Cotton Conf., Nashville, TN 6-10 Jan. 2003. Natl. Cotton Counc. Am., Memphis, TN: 1926-1929.

Faircloth, J., Edmisten, K., Wells, R. and Stewart, A., 2004. *Timing defoliation applications for maximum yields and optimum quality in cotton containing a fruiting gap*. Crop Sci., 44(1): 158-164.

Karademir, E., Karademir, C. and Basbag, S., 2007. *Determination the effect of defoliation timing on cotton yield and quality.* J. Central European Agric., 8(3): 357-362.

Kelley, M., Boman, R. and Hopper, N., 2000. *Harvest-aid combinations and application timing effects on lint yield and quality of fiber and seed*. Proc. Beltwide Cotton Conferneces, San Antonio, TX, 4-8 Jan. 2000. Natl. Cotton Counc. Am., Memphis, TN: 702-702.

Kelly, D., Bange, M.P. and Constable, G.A., 2008. *Unravelling the micronaire challenge*. In Proc. 14th Aust. Cotton Conf., Gold Coast, Qld, Aust., 12-14 Aug. 2008. The Aust. Cotton Growers Res. Orgn.: 24-26.

Rayburn, S.T.Jr., 1988. *A leaf hairiness index for nine cotton cultivars*.p. 474. In: Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV, 4-9 Jan. 1986, Natl. Cotton Counc.Am., Memphis, TN.

Singh, K., Rathore, P. and Gumber, R.K., 2015. *Impact of harvest-aid defoliants on yield of American cotton and their monetary evaluation.* Vegetos, 28(2): 41-46.

Stewart, A.M., Edmisten, K.L. and Wells, R., 2000. *Boll openers in cotton: effectiveness and environmental influences.* Field Crops Res., 67: 83-90.

Supak, J.R. and Snipes, C.E., 2001. *Cotton Harvest Management*: *Use and Influence of Harvest Aids.* Ref. Book Series No. 5.Cotton Foundation, Memphis, TN.