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Full Length Research Paper

Effect of different defoliants and application times on the yield and quality components of cotton in semi-arid conditions

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This study was conducted to determine the effect of different defoliants (Dropp ultra® (DU): thidiazuron+diuron and Roundup (RU): glyphosate) and application times [60, 75 and 90 days after flowering (DAF)] on cotton. The research was carried out at the Harran University, Faculty of Agriculture Research and Application Center in 2001 and 2002 using cotton variety cv. Stoneville-453. Experiments were arranged as split plot design with three replications. Defoliations were at the main plots and application times at the subplots. Experimental plots were consisted of six rows, 10 m in length, inter-row was 0.70 m and intra-row spacing was 0.20 m. The results of the study indicated that the application of DU defoliant at 60 days after flowering reduced seed cotton yield, number of bolls, boll weight and lint index. With this, seed cotton yield, number of bolls, boll weight and lint index increased with delayed defoliation time in both years. Also, there were no statistically significant differences between the treatments in terms of ginning outturn, fiber length, fiber strength and fiber fineness. It was also found that the application of 2000 cc ha^{-1} RU was not enough as a dose to affect leaf defoliation and other investigated components.

Key words: Cotton, *Gossypium hirsutum* L., yield, yield components, defoliation.

INTRODUCTION

Cotton production comprises approximately 91% of the area of fiber plants globally (FAO, 2008). Within Turkey, cotton accounts for 98.9% (384,000 ha) of fiber plant coverage. Cotton is one of the most important industrial crops of the Southeast Anatolia Region of Turkey. Cotton sowing area and fiber production have increased significantly because of increase in irrigated lands following the GAP (Southeastern Anatolia Project). Cotton production consists of different phases, from seed sowing to ginning. One of these phases is the cotton harvest.

Normally, cotton is picked by hand in Turkey. However, increased cotton production has led to a shortage of workers to pick the cotton and in turn, producers have introduced mechanized harvesting. There are 600 harvest machines actively used in Turkey. Mechanized harvesting of cotton requires the application of harvest-facilitating defoliants, chemicals to shed the leaves before harvesting at an appropriate time and to ensure cleaning and smooth picking of the seed cotton. Cotton has a continuous flowering and fruit formation order, which changes depending on the cotton genotypes and environmental conditions. Due to this characteristic, attention is given to the plant in defoliation process because of the obser-vance of squares, flowers, immature, mature and opened cotton bolls on the cotton plant. Therefore, early defoliation results not only in the loss of bolls younger than 14 days old, as well as squares and flowers, but also in the failure of young bolls (younger than 35 days) and immature bolls to open fully. Previous studies have shown deterioration in seed cotton yield and the technological properties of cotton fiber (fiber length, fineness and strength) (Brown, 1973; Oğlakçi and Kaynak, 1992; Faircloth et al., 2004). In comparison to late-phase defoliation, it is impossible to fully achieve effective defoliation due to low temperatures and long-term sun exposure of the opened bolls may result in yellowing, staining and loss of seed cotton.

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Producers of cotton have stated that they experience weed problems in the harvest, and that these weeds negatively affect the performance of harvesting machines. They also demanded information about whether total herbicides can be used for defoliation purposes in tackling weeds during the harvest. During cotton harvesting, producers often experience problems with "weeds". In mechanized cotton harvesting, weeds in the cotton fields have to be removed. To this end, glyphosate-based total herbicides can be used to remove weeds, to achieve defoliation and to facilitate boll opening.

Previous researchers have conducted various studies on defoliation, using different chemicals and defoliation methods (percentage of opened bolls, number of nodes above white flower (NAWF) and number of nodes above the cracked boll (NACB), sharp knife method) (Oğlakçi and Kaynak, 1992; Çiçek et al., 2003; Faircloth et al., 2004; Karademir et al., 2007). One of the defoliation methods used is based on the number of days from cotton sowing to flowering.

The objective of the present study was to determine the effect of two defoliants (Dropp ultra (DU)®: thidiazuron+ diuron and Roundup (RU): glyphosate) and application time (DAF of 60, 75 and 90 days) on seed cotton yield and fiber quality and to establish the optimal defoliation time to maximize cotton harvest within the South Eastern Anatolia Region of Turkey, which is the major cotton production area in Turkey.

MATERIALS AND METHODS

Field experiments were conducted in 2001 and 2002 at an experimental area of the Harran University, Faculty of Agriculture research and application center. The experimental field is located in Harran Plain (altitude: 465 m; 37°08' North and 38°46' East), near the Turkish-Syrian border. The experimental area has a flat topography and nearly flat, calcium content (32%), soil type is vertic calciorthid aridisol. All soil profiles have high clay content (60%), soil pH is between 7.3 - 7.4, low in organic material (0.8%) and salinity (0.08%), with high cation exchange capacity (57.1 meq/100 g) and low Na content (1.4) in the 0 - 150 cm profile. The soil was classified as Ikizce soil series (Dinç et al., 1988)

Generally, Mediterranean continental climates are dominant in this region. The annual average temperature was 18.6°C, total annual rainfall was 437 mm and the average relative humidity was approximately 54%. The average temperature can reach 33°C in July and August in the region. The lowest average temperature can be - 2.2°C in December and January. The earliest frost in the region is usually at the end of October and the last frost is around the end of April. Most rainfall during the growing season occurs in April and there is almost no rainfall from June to September. The highest humidity (76%) occurs in December, and the lowest (34%) in June and July (Anonymous, 2003). Since most of the rainfall occurred between October and April, cotton was irrigated every 7 - 10 days, on average, between the last week of May and the first week of September.

Cotton variety (*Gossypium hirsutum* L.) cv. Stoneville-453 was used as plant material. The experiment was laid out in a randomized complete block design with split plot arrangement and three replications. Defoliants DU and RU comprised the main plot and application times comprised the subplot. Plots consisted of six rows 10 m in length with inter-row spaces, 0.70 m and intra-row spaces, 0.20 m. Plot area of 22.4 m^2 was harvested for yield.

Cotton seeds were sown in each plot at 40 - 50 mm depth by an experimental driller on May 5, 2001 and 2002. At sowing 70 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1} was applied as 20-20-0 fertilizer to each plot followed by 90 kg N ha^{-1} N as urea applied at the initiation of flowering. Soil tillage and other cultural practices (hoe, weeds, pest management and irrigation) were applied as needed, according to recommendations of regional agricultural experiment station.

In both years, 600 cc ha^{-1} of DU and 2000 cc ha^{-1} of RU were applied as defoliant recommended by producers. Both chemicals were mixed with water (300 L ha^{-1}) and delivered using a backpack sprayer with pressure set to 4.22 kg cm^{-2}. The sprayers were calibrated for a 4.80 km h^{-1} walking speed before each application. Four defoliation treatments were tested as follows: T_0 = water spray (control plot); T_1 = 60 DAF (days after flowering) T_2 = 75 DAF; T_3 = 90 DAF. In both years, all treatments were applied on three successive dates: September 5th (T_1), September 20th (T_2) and October 5th (T_3). The four center rows of each plot were picked by hand 15 days after treatment application. The plots were harvested again two weeks after the first harvest and data were used to calculate total yields. 30 bolls were collected to calculate average boll weight. Approximately, 300 g of seed cotton sample from each plot was retained and ginned. Lint was weighed to calculate ginning outturn (GO) and a sub-sample of lint was analyzed by high volume instrument (HVI) for fiber length (mm), fineness (mic) and strength (g tex^{-1}). Also, seeds obtained from samples were used to calculate fiber index. Treatment response data were collected from each plot, including defoliation of leaves and time of application (the number of leaves of removed by treatment, measured at application before and 15 days after treatment).

Statistical analysis was performed using the MSTATC statistical program (Michigan State University, East Lansing, MI). Means were separated using Fisher's protected least significant differences (LSD) test and P = 0.05 denotes the level of significance.

RESULTS AND DISCUSSION

Seed cotton yield (kg ha^{-1})

The means and LSD groupings regarding the characteristics measured are given in Tables 1, 2, 3 and 4. Application times and the effect of harvest-aid chemicals on seed cotton yield are given in Table 1.

The means of seed cotton yield ranged from 3836.2 to 4359.5 kg ha^{-1}, with an average of 4149.8 kg ha^{-1} in 2001 and ranged from 4041.8 to 4488.0 kg ha^{-1} with an average of 4310.8 kg ha^{-1} in 2002 (Table 1). There were significant differences between the treatment means for seed cotton yields, but no significant differences between DU and RU was observed. The highest seed cotton yields in 2001 were obtained from treatment of 75 and 90 DAF while it was obtained from control plot and 90 DAF in 2002. These results showed that seed cotton yield was significantly and negatively affected by early defoliation. One possible explanation is that postponing defoliation allows for more carbon assimilation and partitioning of photo assimilates to develop cotton bolls. However, when the defoliants were applied later, cotton leaves could not be defoliated due to low temperatures. Therefore, the optimal timing for defoliation was established as 75 DAF.

Table 1. Mean seed cotton yields (kg ha^{-1}) and LSD grouping of two defoliants and application times in 2001 and 2002.

Treatments	Seed cotton yield (kg ha^{-1})					
	2001			2002		
	Dropp ultra	Roundup	Average	Dropp ultra	Roundup	Average
Control plot	4054.7 c*	4054.7 c	4054.7 b	4488.0	4480.0	4488.0 a
DAF of 60 days	3630.0 d	4042.3 c	3836.2 c	3860.0	4223.7	4041.8 b
DAF of 75 days	4378.3 ab	4340.7 ab	4359.5 a	4352.7	4208.3	4280.5 ab
DAF of 90 days	4417.7 a	4279.7 b	4348.7 a	4486.7	4379.3	4433.0 a
Means	4120.2	4179.3	4149.8	4296.8	4324.8	4310.8
LSD (0.05)	Defoliants (ns), Means (88.0) Defoliants XAT (124.5)			Defoliants (ns), Means (279.6) Defoliants XAT (ns)		
CV (%)	4.69			5.16		

*Means in each column followed by the same letter are not significantly different ($p < 0.05$).
ns, Non-significant; AT, application times.

Table 2. Means of boll number ($plant^{-1}$), boll weight (g) and ginning outturn (%) and LSD grouping of two defoliants and application times in 2001 and 2002.

Treatments	Boll number ($plant^{-1}$)		Boll weight (g)		Ginning outturn (%)	
	2001	2002	2001	2002	2001	2002
Control plot	17.33 a*	18.73 b	5.78	5.31 bc	39.24	39.69
DAF of 60 days	15.80 b	15.53 c	5.60	5.20 c	38.57	39.08
DAF of 75 days	17.65 b	18.63 b	5.72	5.64 ab	38.51	39.75
DAF of 90 days	17.77 a	20.92 a	5.82	5.76 a	38.96	39.62
LSD (0.05)	1.32	1.24	ns	0.42	ns	ns
Dropp ultra	17.08	18.13	5.78	5.55	38.77	39.79
Roundup	17.20	18.78	5.67	5.40	38.87	38.28
Means	17.14	18.46	5.73	5.75	38.82	39.54
LSD (0.05)	ns	ns	ns	ns	ns	ns
CV (%)	6.13	5.35	4.90	6.04	1.25	2.77
Defoliants X AT	ns	ns	ns	ns	ns	ns

*Means in each column followed by the same letter are not significantly different ($p < 0.05$).
ns, Non-significant; AT, application times.

Similar results were reported by Oğlakçi and Kaynak (1992), Locke et al. (1996) and Çiçek et al. (2003). Kerby et al. (1992) also stated the need for an early harvest under some ambient conditions to avoid losses of fiber quality due to later severe weather.

Boll number (per plant), boll weight (g) and ginning outturn (%)

The effect of the two defoliants and defoliation times on the boll number ($plant^{-1}$), boll weight (g) and ginning outturn (%) are given in Table 2.

In both years, number of bolls showed significant differences according to application times but non-significant differences according to the type of defoliant (Table 2). Average boll number was 17.14 and 18.46 per plant in 2001 and 2002, respectively. In both years, the control plot and DAF of 90 days treatments produced the highest number of bolls per plant. The lowest number of bolls was obtained at 60 DAF. Number of bolls was increased when defoliation was postponed by four weeks. These findings suggest that delaying crop termination allowed for boll formation and maturity. 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).

Average boll weight was 5.73 and 5.75 g in 2001 and 2002, respectively (Table 2). In both years, treatment at DAF of 90 days produced the highest boll weight (5.82 g in 2001 and 5.76 g in 2002) and treatment at 60 DAF produced the lowest boll weight (5.60 g in 2001 and 5.20 g in 2002). According to the LSD test, there was no significant difference between the treatments for boll weight in 2001, but significant differences were recorded for application times in 2002. One reason could be annual variations in climate and soil conditions. Similar

Table 3. Means of fiber length (mm), fineness (mic) and strength (g tex^{-1}) and LSD grouping of two defoliants and application times in 2001 and 2002.

Treatments	Fiber length (mm)		Fiber fineness (mic)		Fiber strength (g tex^{-1})	
	2001	2002	2001	2002	2001	2002
Control plot	30.80 a	30.77	4.78	4.07	34.20	33.70
DAF of 60 days	30.12 ab	29.73	4.75	4.47	33.78	30.68
DAF of 75 days	29.48 b	29.57	4.75	4.58	32.55	30.50
DAF of 90 days	30.20 ab	29.13	4.72	4.70	32.40	30.22
LSD (0.05)	0.82	ns	ns	ns	ns	ns
Dropp ultra	30.09	29.88	4.70	4.45	33.75	31.62
Roundup	30.16	29.71	4.80	4.46	32.72	30.93
Means	30.13	29.80	4.75	4.45	33.23	31.28
LSD (0.05)	ns	ns	ns	ns	ns	ns
CV (%)	2.17	3.38	1.86	9.02	4.15	7.45
Defoliants X A.T.	ns	ns	ns	ns	ns	ns

*Means in each column followed by the same letter are not significantly different ($p < 0.05$).
AT, Application times.

Table 4. Mean fiber index (g) and LSD grouping of two defoliants and application times in 2001 and 2002.

Treatments	Fiber index (g)	
	2001	2002
Control Plot	6.60 ab*	5.85 b
DAF of 60 days	5.91 c	5.82 b
DAF of 75 days	6.23 bc	6.47 a
DAF of 90 days	6.78 a	6.59 a
LSD (0.05)	0.38	0.55
Dropp ultra	6.35	6.19
Roundup	6.41	6.17
Means	6.38	6.18
LSD (0.05)	ns	ns
CV (%)	7.22	7.10
Defoliants XAT.	ns	ns

*Means in each column followed by the same letter are not significantly different ($p < 0.05$).
ns, Non-significant; AT, application times.

results were reported by Brown (1973), Cathey and Lucket (1980) and El-Kasabby and Kandil (1986).

The average ginning outturn was 38.82% in 2001 and 39.54% in 2002 (Table 2). There was no significant difference in ginning outturn based on defoliant type and application times. Similar results were reported by Thakral et al. (1991), Snipes and Baskin (1994), Çiçek et al. (2003), Karademir et al. (2007) and Denizdurduran and Efe (2009).

Fiber length (mm), fiber fineness (mic) and fiber strength (g tex^{-1})

The effect of the two defoliants and three applications times on fiber length (mm), fineness (mic) and strength (g tex^{-1}) are given in Table 3.

Fiber length values changed between 29.48 - 30.80 mm in 2001 and 29.13 - 30.77 mm in 2002. Average fiber length was 30.13 mm in 2001 and 29.80 mm in 2002. Compared with the control plot, fiber length showed a low but significant difference according to application times in 2001, but no difference in 2002. This situation could be related to changing soils and climatic conditions year by year. Also, early application of defoliation had a negative effect on fiber development and may cause contraction of fibers. Similar results were reported by El-Kassaby and Kandil (1986), Snipes and Baskin (1994), Locke et al. (1996), Çiçek et al. (2003), Karademir et al. (2007) and Denizdurduran and Efe (2009).

The average fiber fineness was 4.75 micronaire in 2001 and 4.45 micronaire in 2002. There were no significant differences for fiber fineness according to defoliants and defoliation times in both years. Similar results were reported by Snipes and Baskin (1994), Larson et al. (2002), Çiçek et al. (2003), Karademir et al. (2007) and Denizdurduran and Efe (2009), who reported that the timing of defoliation did not affect the fiber fineness.

The average fiber strength was 33.23 g tex^{-1} in 2001 and 31.28 g tex^{-1} in 2002. There were no significant differences in fiber strength according to defoliants and application times. Similar results were reported by Nagwekar et al. (1985), Snipes and Baskin (1994), Çiçek et al. (2003), Karademir et al. (2007) and Denizdurduran and Efe (2009).

Fiber index (g)

The effect of two defoliants and defoliation times on the fiber index (g) are given in Table 4. Table 4 indicates that in 2001, while average fiber index was 6.38 g, the highest

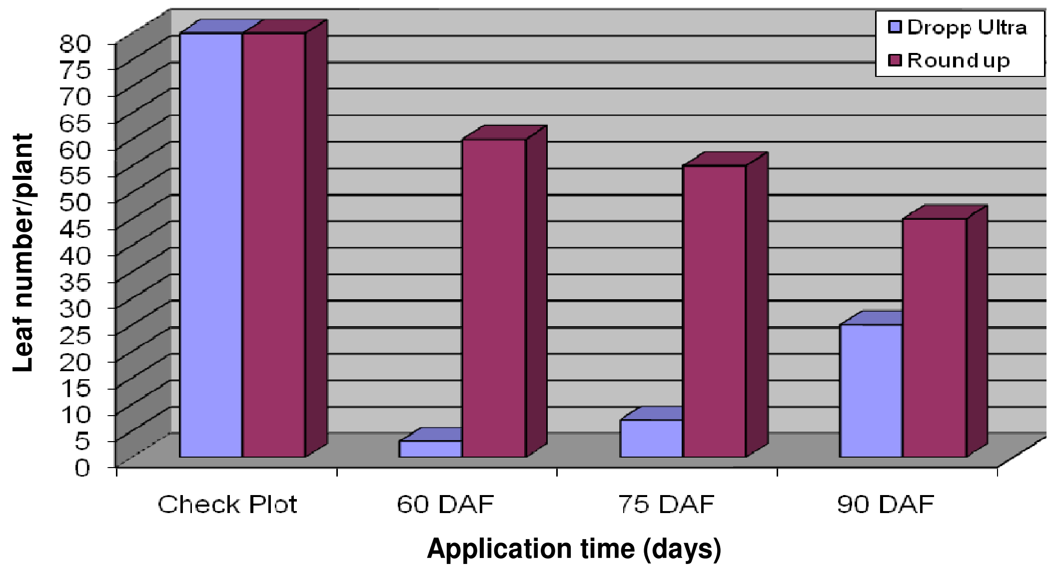

Figure 1. Number of leaves obtained from DU and RU applications in different periods of 2001.

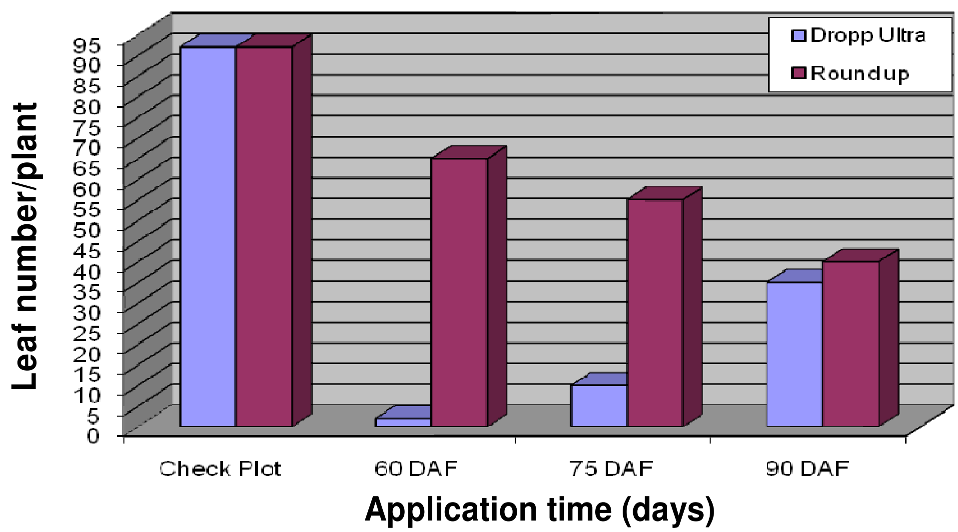

Figure 2. Number of leaves obtained from DU and RU applications in different periods of 2002.

fiber index value was 6.78 g (DAF of 90 days) and the lowest was 5.91 g (DAF of 60 days). In 2002, the average was 6.18 g, while the highest was 6.59 g (DAF of 90 days) and the lowest was 5.82 g (DAF of 60 days). Mean fiber index was higher in 2001 (6.38 g) than in 2002 (6.18 g) (Table 4). According to the LSD test, there were significant differences between the means in both years, according to application time. However, there were no significant effects for defoliant types and defoliant types x application time interaction. Early application of defoliation (approximately 60 days after flowering) might negatively affect the fiber index values due to incomplete fiber maturation. Similar results were reported by Cathey and Luckett (1980) and El-Kassaby and Kandil (1986).

Number of leaves

Figures 1 and 2 show that the average number of leaves in the control plot just before defoliation was 80 leaves per plant in 2001 and 92 leaves per plant in 2002. Using DU, the average number of leaves for 60, 75 and 90 DAF applications was 3, 7 and 25 leaves per plant in 2001 and 2, 10 and 35 leaves per plant in 2002. Using RU, the average number of leaves for 60, 75 and 90 DAF applications was 60, 55 and 46 leaves per plant in 2001 and 65, 53 and 40 leaves per plant in 2002, respectively.

Defoliation in cotton plant depends mainly on environmental factors, as well as genetic factors and cultivation techniques (Whitwell et al., 1987). The minimum temperature for defoliation should be 12.7 - 15.6℃ (Hake et al., 1996). In DU applications, defoliation was found to be satisfactory in the applications made 60 days after flowering; however, delayed application was found to reduce defoliation due to low temperature. Therefore, taking into consideration the temperature factor and loss in seed cotton yield, the optimal defoliation time for DU applications is suggested as 75 days after flowering. In RU applications, partial defoliation was observed in both years, depending on the time of application but the remaining leaves dried and remained on the plant. This situation results in contamination of seed cotton, which requires additional cleaning costs. Roundup (total herbicide) was found to speed up boll opening, as it dries the leaves; however, it was also found to result in poor defoliation.

Conclusion

Results of the study showed that defoliation of 75 and 90 days after flowering was better in terms of number of bolls on the plant and seed cotton yield when compared to defoliation on 60 day after flowering. This suggests that defoliation can be performed 75 or 90 days after flowering. However, defoliation at 90 days after flowering results in poor defoliation due to low temperature. Therefore, defoliation should be performed 75 days after flowering. No statistically significant difference was recorded between defoliants and application time in terms of average boll weight and ginning outturn. Defoliation did not significantly affect the properties of fiber length, strength and fineness. In addition, the 2000 cc ha^{-1} dosage of RU used in the experiment was found to be insufficient for defoliation. For that reason, RU should be use in combination with other defoliants, rather than alone, in defoliation applications. However, further studies should be conducted on the appropriate mixture and dosage.

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