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A Preliminary Study on the Determination of Carpel Characteristics, Yield Losses and Free Fatty Acid Content of Seed under Pre-Harvest Precipitation in Cotton (Gossypium hirsutum L.)

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ABSTRACT: *Pre-harvest precipitation in some years in many cotton-growing regions may adversely affect cotton yield and quality. The effect of carpel characters of cultivars on fall out (ground losses) and free fatty acid of seed under different precipitation amounts were investigated. The experiment was arranged in a two-factor Randomized Complete Block Design with four replications. The precipitation x cultivar interaction for carpel depth, free acid content and fall out were significant. Fall out values were between 38.9 kg ha^{-1} at 20 mm precipitation and 234.2 kg ha^{-1} at 125 mm precipitation. The amount of fall out in all varieties was negatively affected by the increase in precipitation. Gloria cultivar with a wide carpel had the lowest yield losses on the ground.*

Keywords: *Carpel openness, carpel angle, fall out, cotton, free fatty acid content, precipitation.*

Pamukta (Gossypium hirsutum L.) Hasat Öncesi Yağış Koşullarında Çenet Özellikleri, Verim Kayıpları ve Tohum Serbest Yağ Asitlerinin Belirlenmesi Üzerine Bir Ön Çalışma

ÖZ: *Birçok pamuk ekim bölgesinde bazı yıllarda gerçekleşen hasat öncesi yağışlar, verim ve kaliteyi olumsuz etkilemektedir. Farklı yağış miktarlarının pamuk çeşitlerinde dökülme oranı, çenet özellikleri ve tohum serbest yağ asitleri üzerine etkisi araştırılmıştır. Deneme iki faktörlü Tesadüf Blokları Deneme Desenine göre 4 tekrarlamalı olarak düzenlenmiştir. Çenet derinliği, serbest yağ asitleri oranı ve dökülme oranı yönünden yağış x çeşit interaksiyonu önemli bulunmuştur. 20 mm yağış koşullarında 3,89 kg da^{-1} olan hasat kayıplarının 125 mm de 23,42 kg da^{-1} değerine ulaştığı saptanmıştır. Tüm çeşitlerde yağış miktarının hasat kayıplarını artırdığı belirlenmiştir. Geniş çenet yapısına sahip olan Gloria çeşidinin hasat kayıplarının daha az olduğu sonucuna varılmıştır.*

Anahtar kelimeler: *Çenet açıklığı, çenet açısı, dökülme oranı, pamuk, serbest yağ asitleri, yağış.*

INTRODUCTION

Effectively cotton harvest is essential for farmers and seed producers as the detrimental effects of pre-harvest season weather on lint yield and fiber quality cause economic losses in many areas of cotton growing (Bednarz *et al.*, 2002; Williford *et al.*, 1995; Parvin *et al.*, 2005). Although precipitation is beneficial for planting, germination and vegetative development in cotton cultivation, precipitation during boll opening and harvesting is quite harmful (Chattopadhyay *et al.*, 2008). The probability of receiving different amounts of rainfall between the first boll opening and harvest is very high in some years. When it rains in September-October before harvest, precipitation is absorbed by the lint, weighing the lint down and causing it to string-out (on the plant). Rain and strong wind break the boll connection of the seed cotton and the yield decreases due to falling (Rubio, 2018). In addition, cotton wet by heavy rains will experience fewer sunny days and take longer to dry (Anonymous, 2019). The components of seed dispersal include two traits that appear adversarial: bolls must be open enough to allow easy removal of the locks of seed cotton but the locks cannot be allowed to fall out before picking (Stephens, 1958). It was demonstrated that locks with high resistance to breaking off and with high moisture had tolerance to string-out and fall out (Coskun, 2002), in other words, varieties requiring higher force to pull seed cotton locks had lower losses on the ground (Gemtos and Mygdakos, 1998). It was concluded that significant differences exist among cultivars in terms of seed cotton loss during the latter part of the growing season and storm resistance of spindle-picked upland cotton cultivars should be selected (Faircloth *et al.*, 2004). At times when severe weather such as pre-harvest precipitation occurs, varietal differences in lock retention and opening of the suitable bolls before harvest are considerable (Lubbers and Chee, 2009; Raper, 2019). Carpel characteristics and relationships among these characters can be used as selection criteria to improve resistance to adverse weather such as rain and wind storms in cotton (Killi and Beycioğlu, 2020).

Seeds exposed to excessive rainfall during the pre-harvest season may have poor quality, and the most important indicator of poor quality is the free fatty acid content of the seed (Waddle and Colwick, 1961; Zaxos *et al.*, 2012). Under such conditions, the free fatty acids of seeds changed from 0.5 to 8 %, increasing the content of free fatty acids reduces germination. Therefore, cottonseeds that have a fatty-acid content above 0.75 percent should not be used as seed for sowing (Anonymous, 2021).

Boll properties and free fatty acid content in terms of the detrimental effects of precipitation were evaluated in only a few studies. Therefore, this study was conducted to investigate the varietal differences caused by pre-harvest precipitation in cotton (*Gossypium hirsutum* L.).

MATERIALS and METHODS

Cotton cultivars, Gloria, ST-373 and Flash were selected from cultivars with medium earliness. The experiment was arranged in a Randomized Complete Block Design with two factors and four replications. Planting was carried out on 13th May 2014. The first bolls on the plant that were not exposed to precipitation were considered as controls. Rainfall after the second half of September did not affect the control plots. During the harvest season, seed cotton on the plant was exposed to rain 10 times. The amount of rain was measured by using a pluviometer in a meteorology station established in the experimental area. When the amount of precipitation reached totals of 20 mm, 45 mm and 125 mm, the bolls in the respective plots were harvested. The climate of Nazilli-Aydın is a Mediterranean climate and monthly precipitation (mm) and average temperature of the experimental year and long-term are given in Figure 1. It is clearly seen that cotton bolls during the opening period were exposed to 151.8 mm of precipitation in the September-November period in 2014. The total precipitation of the long-term period was 138.1 mm (Anonymous, 2014).

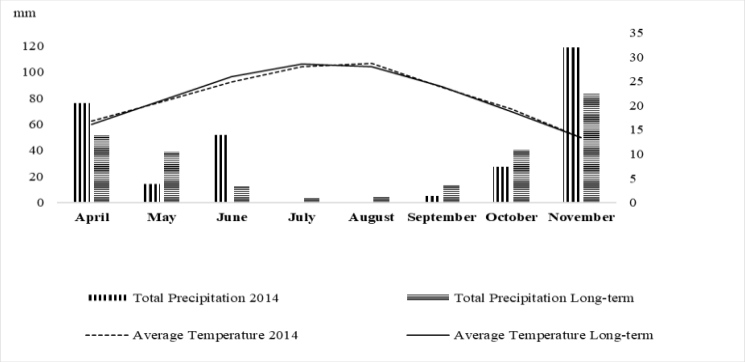

Figure 1. Temperature (ºC) and precipitation values (mm) of experimental and long-term years (Anonymous, 2014).
Şekil 1. Deneme yılı ve uzun dönem yağış (mm) ve sıcaklık (ºC) değerleri (Anonymous, 2014).

The plot size was 12 m x 2.8 m (33.6 m^2) accommodating 4 rows spaced 70 cm apart. Two central rows were used for plant sampling and measurements. The distance among the plots and blocks was 3 m. The experiment was conducted at Nazilli Cotton Research Institute (located between 37° 86' N, 28° 32' E). The soil characteristics of the field area were sandy-loamy, light alkaline (pH: 7.54), low in salt content, sufficient in nitrogen and phosphorus and high in potassium. All plots received 80 kg ha^{-1} N and 80 kg ha^{-1} P_2O_5 at sowing, and nitrogen was applied in the form of urea (220 kg ha^{-1}) before the first irrigation. The number of furrow irrigations was 4, and plots were kept free of weeds by mechanical and chemical weeding.

Ten randomly selected plants were sampled from each plot, and bolls in the first position of the first sympodial branch of these plants were measured for carpel openness, carpel depth and carpel angle (Kilickan and Coskun, 2009). Seed cotton from sampled bolls was ginned, and fifty seeds for each plot were used for the determination of free fatty acid (FFA) by the official AOCS method (Anonymous, 1993). To determine the fall out (kg ha^{-1}), seed cotton on the ground in a 5 m^2 area between the middle rows from each plot was picked and weighed. The data were analyzed using JMP® 13 statistical software program (Anonymous, 2016) in the experimental split-plot design. The differences between the means were compared by the least significant difference (LSD) at the 5% level (Steel *et al.*, 1997).

RESULTS and DISCUSSIONS

The precipitation x cultivar interaction for carpel depth, free fatty acid content and fall out were significant (Table 1). The LSD values for these traits are shown under the means of the relevant characteristics (Table 1 and Table 2). In addition, differences among cultivars and precipitation for carpel openness and cultivars for carpel angle were found to be significant whereas precipitation and cultivar did not significantly influence carpel width (Table 1). Although the effect of precipitation on carpel width was non-significant, increased rainfall and delayed harvest led to a reduction in carpel width (29.4 mm vs. 26.9 mm), and Gloria had the largest carpels among the cultivars.

The highest carpel depth was significantly recorded in the ST-373 cultivar at 125 mm precipitation followed by ST-373 at 20 and 45 mm, whereas the Gloria cultivar exhibited the lowest carpel depth for the control and all precipitation amounts (Table 1). In terms of carpel angle, the Flash cultivar with the lowest carpel angle (76.62°) was statistically different from other varieties (Table 1). It was seen that carpel openness increased in parallel with the increase in precipitation, and carpel openness was statistically higher in Gloria and ST-373 cultivars (Table 1).

The mean data in Table 2 clearly demonstrated that the increase in precipitation adversely affected the amount of fall out in all varieties. Natural (control) fall out on the ground varied from 27.8 kg ha^{-1} (ST-373) to 35.3 kg ha^{-1} (Flash). The fall out reached 146.3 kg ha^{-1}(Gloria) and 234.2 kg ha^{-1}

(ST-373) with 125 mm of precipitation. Although the ST-373 cultivar had the lowest value at the beginning, it was the cultivar most adversely affected by rain (27.8 kg ha^{-1} vs. 234.2 kg ha^{-1}). Gloria attracted attention as the least affected cultivar in all precipitation amounts, and the mean value of Gloria over precipitation amounts was the lowest value with 79.0 kg ha^{-1}.

Table 1. Carpel characteristics of cultivar x precipitation.
Çizelge 1. Çeşit x yağış interaksiyonuna ilişkin çenet özellikleri.

	Precipitation (mm) / Yağış (mm)				
Carpel width (mm) Çenet genişliği (mm)	0	20	45	125	Mean cultivar Çeşit ortalaması
Flash	28.3±0.37	28.3±0.87	28.3±0.47	27.0±0.67	28.0±0.36
Gloria	30.2±0.58	27.9±1.21	28.9±1.17	27.0±0.17	28.5±0.56
ST-373	29.8±1.06	27.4±0.70	26.9±0.41	26.6±0.38	27.7±0.50
Mean precipitation Yağış ortalaması	29.4±0.50	27.9±0.56	27.9±0.51	26.9±0.27	
Carpel depth (mm) Çenet derinliği (mm)					
Flash	10.7±0.09^{cd}	11.2±0.05^{bcd}	11.2±0.14^{bcd}	11.3±0.12^{bc}	11.1±0.09
Gloria	9.6±0.23^{d}	10.8±0.17^{cd}	11.2±0.19^{bcd}	11.2±0.18^{bcd}	10.7±0.21
ST-373	11.4±0.27^{b}	11.6±0.22^{ab}	11.6±0.07^{ab}	12.0±0.05^{a}	11.7±0.11
Mean precipitation Yağış ortalaması	10.6±0.28	11.2±0.15	11.3±0.11	11.5±0.14	
LSD $_{(0.05)}$ precipitation x cultivar = 0.50					
Carpel angle (°) Çenet açısı (°)					
Flash	76.13±1.12	76.75±2.19	77.50±1.40	76.09±1.25	76.62±0.79^{b}
Gloria	80.01±0.60	79.17±0.34	82.34±0.88	81.76±0.96	80.82±0.52^{a}
ST-373	84.60±1.88	82.15±1.84	85.90±2.07	81.94±1.32	83.65±1.02^{a}
Mean precipitation Yağış ortalaması	80.25±1.38	79.36±1.21	81.91±1.45	79.93±1.14	
LSD $_{(0.05)}$ cultivar = 2.84					
Carpel openness (mm) Çenet açıklığı (mm)					
Flash	37.5±0.86	37.8±0.73	37.9±0.82	39.3±0.36	38.1±0.41^{b}
Gloria	37.9±0.79	42.7±0.87	42.5±0.90	44.5±0.74	41.9±0.82^{a}
ST-373	40.0±0.90	42.3±1.09	42.4±0.28	44.0±0.38	42.2±0.56^{a}
Mean precipitation Yağış ortalaması	38.5±0.61^{b}	40.9±0.91^{a}	40.9±0.84^{a}	42.6±0.84^{a}	
LSD $_{(0.05)}$ precipitation = 1.92 ; LSD $_{(0.05)}$ cultivar = 1.51					

Table 2. Free fatty acid and fall out of cultivar x precipitation.
Çizelge 2. Çeşit x yağış interaksiyonuna ilişkin serbest yağ asitleri ve dökülme oranı.

	Precipitation (mm) / Yağış (mm)				
Free fatty acid content (%) Serbest yağ asidi içeriği (%)	0	20	45	125	Mean cultivar Çeşit Ortalaması
Flash	0.22±0.04^{e}	0.27±0.04^{de}	0.37±0.04^{d}	0.87±0.05^{a}	0.43±0.08
Gloria	0.22±0.01^{e}	0.22±0.01^{e}	0.32±0.01^{de}	0.63±0.03^{b}	0.35±0.05
ST-373	0.22±0.04^{e}	0.23±0.02^{e}	0.32±0.06^{de}	0.52±0.06^{c}	0.32±0.04
Mean precipitation Yağış ortalaması	0.22±0.02	0.24±0.01	0.33±0.02	0.67±0.05	
LSD $_{(0.05)}$ precipitation x cultivar = 0.11					
Fall out (kg ha^{-1}) / Dökülme (kg ha^{-1})					
Flash	35.3±0.49^{g}	44.0±1.25^{f}	100.0±2.50^{d}	160.3±1.52^{b}	84.9±14.51
Gloria	32.4±1.30^{gh}	38.9±1.82^{e}	98.3±1.66^{d}	146.3±2.60^{c}	79.0±13.50
ST-373	27.8±0.18^{h}	50.0±0.47^{f}	101.2±1.30^{d}	234.2±3.28^{a}	103.3±23.17
Mean precipitation / Yağış ortalaması	31.9±1.13	44.3±1.69	99.8±1.15	180.3±12.93	
LSD $_{(0.05)}$ precipitation x cultivar = 6.05					

In previous studies, carpel openness, depth and angle values were 30.3 mm - 40.0 mm, 19.0 mm - 23.0 mm and 41° – 57.8°, respectively (Coskun, 2002; Killi and Beycioglu, 2020). Although the results of our study for carpel openness and carpel depths were parallel to these studies, carpel angles exhibited differences. It can be said that the differences in results are likely due to cultivar differences.

The total yield losses (on ground and plant) in harvest changed from 3.69 kg ha^{-1} (Raper, 2019) to 334.5 kg ha^{-1} (Silva *et al.,* 2007). Similarly, the results of the present study demonstrated that fall-out values were between 38.9 kg ha^{-1} at 20 mm precipitation and 234.2 kg ha^{-1} at 125 mm precipitation.

Although precipitation x cultivar interaction for fall out was significant, the greatest yield losses were recorded in ST-373 with higher carpel depth, angle and openness. On the contrary, the Gloria cultivar with wide but superficial carpel had the lowest yield losses on the ground. It was clearly seen that carpel characteristics had a very important impact on reducing yield losses. The detrimental effects of high precipitation amounts were reflected in increased free fatty acid content in all cultivars. ST-373 was the least affected cultivar, whereas Flash could be defined as a susceptible cultivar to the high precipitation amount. Although there were non-significant differences among cultivars, the free fatty acids of cultivars were below 0.75% except for the Flash cultivar at 125 mm (Table 2). Therefore, it should be concluded that the exposure of the seed cotton on the plant to precipitation is not a problem for planting (Anonymous, 2021).

CONCLUSIONS

The carpel characteristics of cotton boll exhibited significant varietal differences under different precipitation conditions before harvest. It was clearly seen that carpel characteristics can be used for improving resistance to late-season precipitation in a cotton breeding program. Even if seed cotton is exposed to high rainfall before harvest, the free fatty acid of the seed was still below the critical level, which should not be a problem for seed producers.

Author Statement

Conceptualization of research: Serife Balcı & Aydin Unay. Designing of the experiments: Serife Balci & Aydin Unay. Resources of experimental materials: Serife Balci. Execution of field/lab experiments and data collection: Serife Balci. Analysis of data and interpretation: Volkan Mehmet Cinar & Aydin Unay. Preparation of the manuscript: Aydin Unay, Volkan Mehmet Cinar & Serife Balci.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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