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The Investigation of Effects of Pre-Harvest Rainfall on Lint Color Grade and Seed Germination Rate in Cotton (*Gossypium hirsutum* L.)

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ABSTRACT
Unexpected rainfall in harvest season has a detrimental effect on cotton lint color grade and germination rate and cause economic losses for farmers, seed producers and manufacturers. This study was conducted to elucidate the effects of different rainfall amounts on cotton technological characteristics and to evaluate the response of different cultivars in the harvest season of 2014 and 2015. Cotton bolls were exposed to 0 (control), 20, 35, 65, 95 and 125 mm of precipitation. The effects of rainfall were determined in GSN-24, Claudia, Gloria, ST-373, Flash, Carisma and ST-468 cotton cultivars (*Gossypium hirsutum* L.). The responses of cultivars to different cumulative rainfall were significant for lint color grade and seed germination rate. The linear curve in the decreasing direction according to the highest R^2 value was evaluated for germination rate (%), reflectance (Rd), trash count and trash area (%) whereas the polynomial curve was more likely for yellowness (+b). The effects of increased rainfall amounts on all observed characters were unfavorable. The different responses of cultivars indicated that the cultivars with the least loss for lint color grade and germination rate in seed production could be recommended in terms of being highly profitable.

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Pamukta (*Gossypium hirsutum* L.) Hasat Öncesi Yağışların Çimlenme ve Elyaf Renk Değerleri Üzerine Etkisi

ÖZET
Hasat döneminde gerçekleşen yağışlar pamukta elyaf renk derecesi ve tohum çimlenme oranını olumsuz etkilemekte ve çiftçi, tohumluk üreticisi ve tekstilci için ekonomik kayıplara neden olmaktadır. Bu çalışma hasat öncesi farklı miktarlarda oluşan yağışların pamukta lif teknolojik özelliklerine olan etkisini ve farklı çeşitlerin yağışlara olan tepkilerinin belirlenmesi amacıyla 2014 ve 2015 yıllarında yürütülmüştür. Kozalar kontrol (0 mm) ile birlikte 20, 35, 65, 95 ve 125 mm yağışa maruz bırakılmıştır. Yağışın GSN-24, Claudia, Gloria, ST-373, Flash, Carisma ve ST-468 çeşitlerine etkisi belirlenmiştir. Çeşitlerin elyaf renk değeri ve çimlenme oranı bakımından toplam yağışa olan tepkileri önemli bulunmuştur. En yüksek belirleme katsayısına (R^2) göre çimlenme oranı (%), yansıma (Rd), yabancı madde miktarı ve alanı (%) yönünden azalan düzeyde doğrusal regresyon eğrisi, buna karşın sarılık (+b) için polinomiyal eğri bulunmuştur. Çalışmanın sonucunda yüksek kazanç için lif kalite değerleri yağış miktarından olumsuz yönde daha az etkilenen ve çimlenme oranı kaybı en az olan çeşitlerin önerilebileceği sonucuna varılmıştır.

Tarla Bitkileri

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INTRODUCTION

Turkey is one of the world's important cotton producers, and cotton has a crucial role in Turkey's textile and clothing industry. Turkey ranked 6th in the production of lint cotton with a total amount of 815.000 tons in the 2019-2020 seasons in the world. One of the basic classification criteria is lint colour grade according to the Universal Cotton Standards. The color grade with fiber length, strength and fineness are critical components of the set of characteristics used to assess the overall quality of a sample of cotton, and thereby determine its value. Cotton lint color can be affected by environmental factors such as rainfall, freezes, insects, fungi, the condition of cotton storage, moisture and temperature (Xu et al., 1997; Duckett et al., 1999) and agronomical characters such as boll maturity (Heimoana and Wilson, 2017). The amount of precipitation plays an important role in cotton yield, ginning out-turn and fiber quality. Seasonal precipitation and temperature affect planting operations in early spring and also affect harvest in autumn. Adverse environmental factors on cotton fiber reduced the processing efficiency of cotton, the ability of fibers to absorb and hold dyes and finishes, and market value (Aspland and Williams, 1999). The undamaged lint of mature bolls is white and clean because of the highly reflective character of cellulose and waxy cuticle (Heimoana and Wilson, 2017). The monthly mean rainfall and the average length of wet spells in harvest season negatively affected cotton-fiber quality (Luo et al., 2016). Less than 25.4 mm of precipitation on newly opened bolls only delays the harvest without any significant damage to yield and quality. On the other hand, precipitation over 50.8 mm causes significant damage to yield and quality, decreases the color level and increases the amount of foreign matter (Hake et. al., 1992; Anonymous, 2001). Each 15 mm of precipitation causes one unit of color reduction while exposure to as little as 30 mm of rain could therefore result in significant price discounts (Grade 41 – Strict Low Middling) and exposure to about 60 mm of rain could result in severely discolored lint (Grade 61 – Strict Good Ordinary) (Anonymous, 2007). Parvin et al. (2005) found that cotton lint yield declined by 2.35 kg of lint per day and 4.09 kg of lint per centimetre of accumulated rainfall.

The short fiber content of cotton increased in fields that are harvested late due to adverse weather conditions and, length uniformity and fiber length in the gin and textile mill reduced (Hake, 1992). Fiber quality parameters, upper half mean length, uniformity index, strength and color grade components (includes Rd, +b and, to some extent, HVI trash), as measured by HVI, are reportedly most affected by delayed harvest with considerable rainfall accumulations (Bednarz et al., 2002; Columbus et al., 1990; Buxton et al., 1973; Shurley et al., 2004; Williford 1992). The reflectance and yellowness values of the fiber negatively affect if the opened bolls are exposed to long-term or heavy rain (Silvertooth 2001). Some varieties are more affected by bad weather conditions (rain, storm, etc.), while some varieties are less affected.

We arranged an experiment to evaluate the late-season precipitation on lint color grade parameters, germination, trash count and trash area in 2014 and 2015. The effects of precipitation on observed characteristics depending on the cultivars were calculated through regression analysis.

MATERIAL and METHODS

Field trials were conducted at Nazilli Cotton Research Institute (located between 37° 86' N, 28° 32' E) during the 2014 and 2015 cotton growing seasons. Cotton commercial cultivars GSN-24, Claudia, Gloria, ST-373, Flash, Carisma and ST-468 (*Gossypium hirsutum* L.) were evaluated for determining the effect of cumulative rainfall in harvest season on germination rate, yellowness, reflectance, trash count and trash area.

Soil Descriptions and Climatic Conditions

According to the soil analysis, experiment soils were sandy-loamy, light alkaline (pH: 7.54), low in salt content, total nitrogen and phosphorus and high in potassium. The climate of Nazilli-Aydin is a Mediterranean climate and monthly precipitation (mm) and average temperature of experimental years and long-term were exhibited in Figure 1. Precipitation of September, October and November when cotton was harvested varied between 5.2 mm and 119 mm and precipitation of November in 2014 and October and November in 2015 were above the long-term average. It was clearly seen that cotton bolls during the opening period were exposed to 151.8 – 183.2 mm of precipitation in the September-November period in 2014 and 2015, respectively. The total precipitation of the long term period was 138.1 mm.

Experimental Design and Management Practices

The experiments were planted on the dates 13 May 2014 and 29 April 2015 according to a split-plot design with four replications. Six different precipitation doses including control (0), 20 mm, 35 mm, 65mm, 95 mm and 125 mm were arranged as main plots. Cotton bolls were harvested when each precipitation amount targeted in the study was reached. During the harvest season, natural precipitation occurred 10 times in 2014 and 7 times in 2015. In addition, the experimental area was irrigated with sprinklers two times for ensuring the

total precipitation amount, and boll harvesting was carried out at 6 different times. The seven cotton cultivars, GSN-24, Claudia, Gloria, ST-373, Flash, Carisma and ST-468 were designed as sub-plots. Trial plots consisted of four rows of 12 m in length each with an inter-row spacing of 70 cm and inter-spacing of 20 cm. Hence, the parcel area was 33.6 m^2 for each treatment. All trials were fertilized with 400 kg ha^{-1} of composed fertilizer (20.20.0) before planting and 80 kg ha^{-1} nitrogen before first irrigation according to the long-term yield potential of the area.

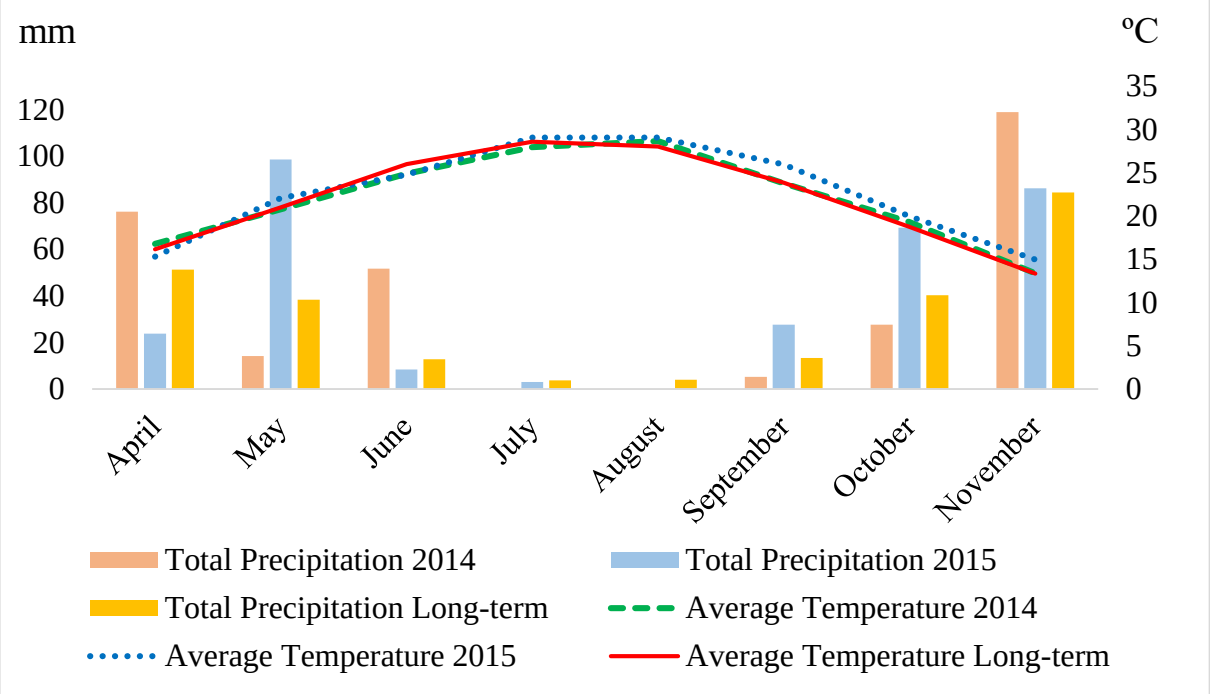


Figure 1. Temperature and precipitation values of experimental and long-term years.
Şekil 1. Deneme yılları ve uzun dönem yağış ve sıcaklık değerleri

Data Collection and Fiber Quality Analyses

At the beginning of the study, 50 bolls from the first position of the fruiting branches were picked up from 0 mm precipitation plots (not exposed to rain) and evaluated as control. The rain gauges were placed in 4 corners of the trial area, for following the precipitation during the pre-harvest period. Similarly, 50 boll samples were sampled from all target parcels when the total amount of rainfall reaches 20 mm, 35 mm, 65 mm, 95 mm and 125 mm. The samples were left to dry according to the analysis of moisture (7%) for ginning (Mayfield, 1989). The samples taken from the first boll position of each plant as 50 bolls were ginned in a roller gin machine. The reflectance (Rd), yellowness (+b), trash area (%) and trash count were determined by Uster HVI 1000 at the fiber analysis laboratory, Nazilli Cotton Research Institute. A standard germination test was used for germination rate (%). Fifty seeds from two lots for each parcel were placed in a germination cabinet at 30 °C±2°C containing moist towels. After 4 days, the wet towel was opened and healthy growing seedlings were counted and recorded. The counted seedlings were removed from the environment and the paper towels were wrapped again and left in the germination cabinet. After 8 days, the same transactions were made and the total germination was determined (Anonymous, 2005).

Statistical Analysis

The data were analyzed using JMP 14® statistical package program (SAS Institue Inc., 2018) in the experimental split-plot design. Moreover, the regression analysis due to the higher R^2 value was carried out by considering germination rate, reflectance, yellowness, trash area and trash count as dependent variables and precipitation as the independent variable in the Microsoft Excel program.

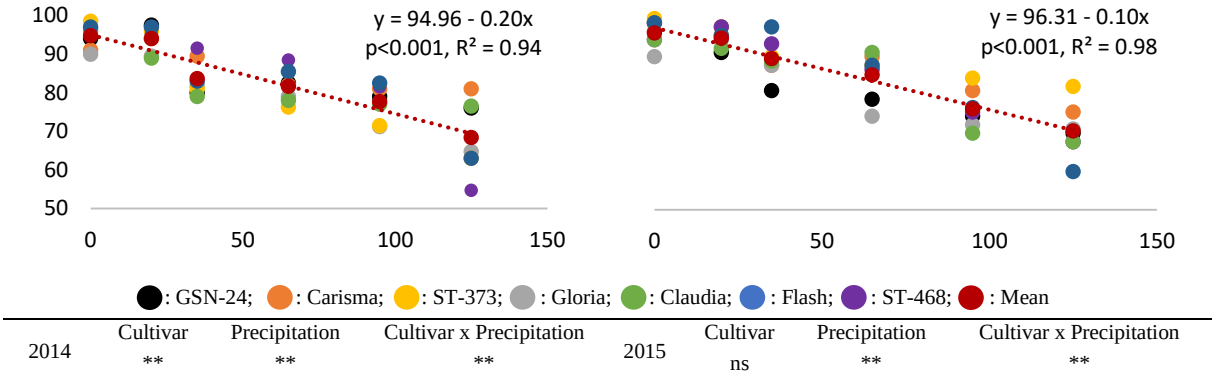
RESULTS and DISCUSSION

The significances of mean squares from variance analysis for germination rate, yellowness, reflectance, trash count and trash area were given below the figures regarding graphs of each character. The differences between the two years were significant for all observed characters according to a combined analysis of variance. Therefore, an independent analysis of variance under each level of the year was performed. Significant cultivar x precipitation interaction indicated that the differential performance of cultivars varied under different levels of precipitation.

Germination Rate

In 2014, the germination rates in the control group ranged from 98.5% (ST-373) to 90.0% (Gloria), while it varied between 97.5% (GSN-24) and 89.0% (Claudia) at 20 mm precipitation. The genotypic differences in both precipitation groups are not significant. On the other hand, the differences between the cultivars were significant at 35 mm, 65 mm and 95 mm precipitation, respectively (LSD $_{(0.05)}$ = 8.74). While the highest germination rates were obtained from the ST-468 variety in all three precipitation groups, the lowest germination rates were obtained from the Claudia variety. At 125 mm, where the heaviest precipitation is, the germination rate was 81.0% in the Carisma cultivar, 63.0% in Flash and ST-373 cultivars, and 54.75% in the ST-468 cultivar. In the Claudia cultivar, which had the lowest values in the previous rainfall amounts, the germination rate was determined as 76.5% at 125 mm rainfall (Figure 2 left).

When the germination rates of 2015 were examined, similar to 2014, the highest germination rate was found in the ST-373 variety at the beginning with 97.5%, while the lowest germination rate was found in the Gloria variety with 93.0% (LSD $_{(0.05)}$ = 7.70). It was determined that the differences between cultivars were not significant at 0 and 20 mm precipitation. The difference between Flash (96.5%) with the highest germination rate and GSN-24 (88%) with the lowest germination rate at 35 mm precipitation was significant. The least decrease in 125 mm precipitation amount was in the ST-373 variety (89.5%), whereas the germination rate was 79.5% in the Flash variety, which was significantly lower than the ST-373 variety (Figure 2 right).



2014	Cultivar	Precipitation	Cultivar x Precipitation	2015	Cultivar	Precipitation	Cultivar x Precipitation
	**	**	**		ns	**	**

Figure 2. Germination rate of precipitation x cultivar in 2014 (left) and 2015 (right)
Şekil 2. 2014(sol) ve 2015(sağ) yıllarında çeşit ve yağışlara ilişkin çimlenme oranları

In the regression analysis performed separately for both years, the R^2 values were found to be the highest for the linear equation (0.94 and 0.98, respectively). Germination rate in the first year = 94.96 - 0.20 precipitation (mm), germination rate in the second year = 96.31 - 0.10 precipitation (mm) (Figure 2). Equations indicated that the germination rate declined 0.10 - 0.20 % per milimeter of accumulated rainfall. It has been found that the amount of precipitation affects the germination rate of the seed on the seed cotton negatively depending on the years and the germination decrease rate can be estimated with the help of the equations.

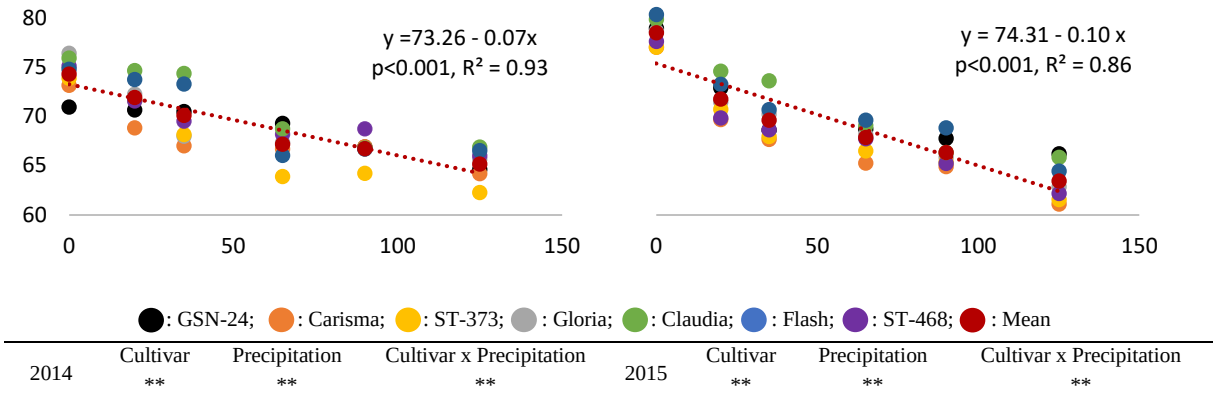
Reflectance

The reflectance values and the regression equation for both years were given in Figure 3. In 2014, Gloria (76.4), Claudia (75.9) and ST 468 (74.8) cultivars were found to have the highest reflectance values at a significant level in the control group (LSD $_{(0.05)}$ = 2.02). The lowest reflectance value was recorded in GSN-24 (71.0). It is seen that the highest reflectance values were determined in Claudia and Flash cultivars at 20 mm and 35 mm precipitation, respectively. It is noteworthy that both cultivars mentioned are the least affected by the highest rainfall. It can be seen in Figure 3 that the ST-373 variety was the most affected by the highest precipitations of 65 mm, 95 mm and 125 mm.

In 2015, the highest reflectance values were determined in Flash, Claudia, GSN-24 and Gloria in a control (non-precipitation), while Carisma, ST-468 and ST-373 varieties had the lowest reflectance values (LSD $_{(0.05)}$ = 1.67). Although all cultivars were adversely affected by an average of 8.0% in 20 mm of precipitation, the difference between cultivars did not change. The impact rate of cultivars slowed down with 35, 65 and 95 mm precipitations. GSN 24, Claudia and Flash were least affected even under the highest precipitation conditions. On the other hand, it is seen in Figure 3 that other varieties are significantly affected negatively.

R^2 values related to the linear regression curve were found to be high for both years. The regression equations were reflectance value= 73.26 – 0.07 precipitation and reflectance value= 74.31 – 0.10

precipitation in 2014 and 2015, respectively (Figure 3). Equations revealed that reflectance declined 0.07 – 0.10 per milimeter of accumulated rainfall. It was concluded that the amount of precipitation had a linear effect and, an increase in precipitation dulled the fibers.

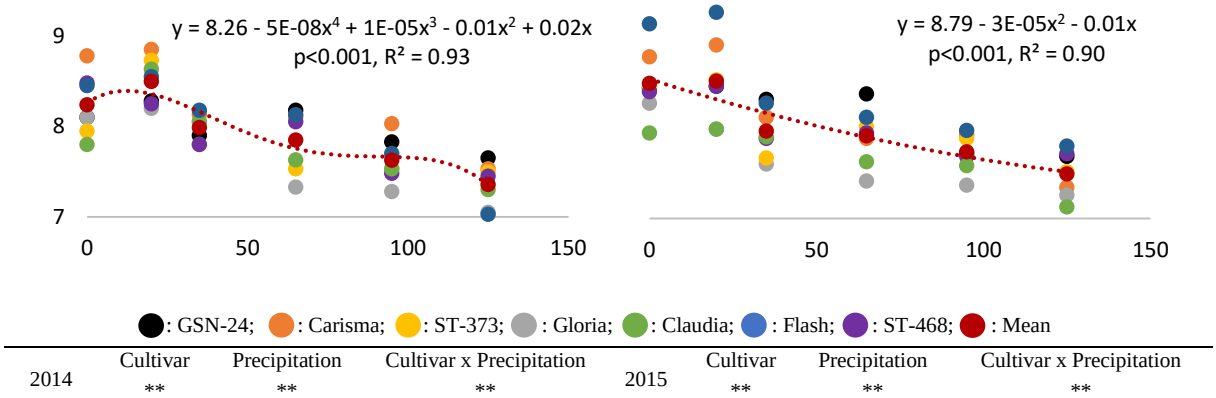


	Cultivar	Precipitation	Cultivar x Precipitation		Cultivar	Precipitation	Cultivar x Precipitation
2014	**	**	**	2015	**	**	**

Figure 3. Reflectance of precipitation x cultivar in 2014 (left) and 2015 (right)
Şekil 3. 2014(sol) ve 2015(sağ) yıllarında çeşit ve yağışlara ilişkin yansıma (Rd) değerleri

Yellowness

There were significant differences among the yellowness values of the cultivars in the control parcels (0 mm precipitation) in both years (LSD $_{(0.05)}$ = 0.21 and LSD $_{(0.05)}$ = 0.34, respectively). It is seen that Carisma (8.78) in the first year and Flash (9.5) in the second year had the highest yellowness values at the significant level. In the first year, Carisma was followed by Flash, whereas in the second year Flash was followed by Carisma. However, the Claudia variety had the lowest yellowness coefficient in both years. In the 20 mm precipitation plots, the yellowness increased, except for ST-468 in the first year and Gloria in the second year. While Carisma and ST-373 were the cultivars most affected by 20 mm precipitation in the first year, GSN 24, ST-468 and Gloria cultivars were observed to have significantly lower yellowness coefficients (Figure 4 left). In the second year, Flash and Carisma were the most affected cultivars by 20 mm rainfall, whereas Gloria and Claudia cultivars were the least affected. Significant decreases were recorded in 35 mm precipitation in both years. After this amount of precipitation, it can be said that the fluctuations depending on the yellowness of varieties have been more stable. It can be observed that the yellowness coefficient decreased significantly in 95 and 125 mm precipitation (Figure 4 right). It was determined that Flash and Gloria cultivars in the first year and Claudia, Gloria and Carisma cultivars in the second year had significantly less yellowness at 125 mm precipitation. On the other hand, it was determined that GSN-24 and Carisma varieties in the first year and, Flash and GSN-24 varieties in the second year were the varieties with the highest yellowness at the same precipitation amount. When the two-year results were evaluated together, it was noted that the Gloria cultivar had low yellowness, whereas the GSN-24 cultivar had high yellowness values.



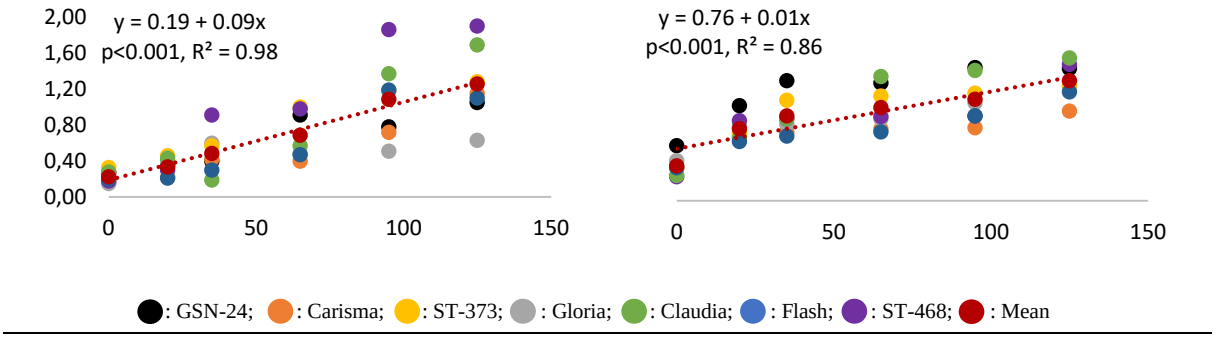
	Cultivar	Precipitation	Cultivar x Precipitation		Cultivar	Precipitation	Cultivar x Precipitation
2014	**	**	**	2015	**	**	**

Figure 4. The yellowness of precipitation x cultivar in 2014 (left) and 2015 (right).
Şekil 4. 2014(sol) ve 2015(sağ) yıllarında çeşit ve yağışlara ilişkin sarılık (+b) katsayıları

Trash Area

When the trash area values obtained in 2014 (LSD $_{(0.05)}$ = 0.17) and 2015 (LSD $_{(0.05)}$ = 0.11) were evaluated, it was seen that ST-373, Claudia and GSN-24 varieties

had significantly higher trash area values in control parcels of 2014. On the other hand, these values were significantly lower in Gloria, Carisma and ST-468 varieties. The trash area increased at 20 mm of precipitation and low values in Flash and Carisma cultivars were noted. At 35 mm, while a low trash area was observed in the Flash variety, the significant jump in the negative direction in the ST-468 variety can be observed in the same way. A significant increase in trash area was observed in ST-373 and GSN-24 varieties at 65 mm precipitation. With these two cultivars, ST-468 contains a significantly higher foreign matter area. When 95 mm and 125 mm precipitation are evaluated together, it is noteworthy that the Gloria variety was the variety that was least affected by precipitation in terms of significant foreign matter area, whereas ST 468 and Claudia varieties were the most negatively affected varieties (Figure 5 left).



2014	Cultivar	Precipitation	Cultivar x Precipitation	2015	Cultivar	Precipitation	Cultivar x Precipitation
	**	**	**		**	**	**

Figure 5. Trash area of precipitation x cultivar in 2014 (left) and 2015 (right)
Şekil 5. 2014(sol) ve 2015(sağ) yıllarında çeşit ve yağışlara ilişkin yabancı madde büyüklüğü değerleri

In 2015, at the beginning and 20 mm of precipitation, the GSN-24 cultivar had a significant trash area, whereas Claudia and Flash cultivars had the least values. In 35 and 65 mm precipitation, the GSN-24 variety had the highest foreign matter area values and it can be observed that the Claudia variety accompanied this variety. It was determined that Carisma and Flash varieties had the least values in both precipitation amounts. In 95 and 125 mm precipitation, it is seen that Claudia, GSN-24 and ST 468 varieties had significantly higher trash area values and Carisma and Flash varieties had the lowest values (Figure 5 right).

It was determined that the precipitation amount and regression equation of trash area had a linear slope in both years. Although the R^2 value was higher in the first year, trash area = 0.19 + 0.09 precipitation amount, and in the second year, trash area = 0.76 + 0.01 precipitation amount equations were obtained (Figure 5). Equations summarized that trash area increased 0.01 – 0.09 per milimeter of accumulated rainfall.

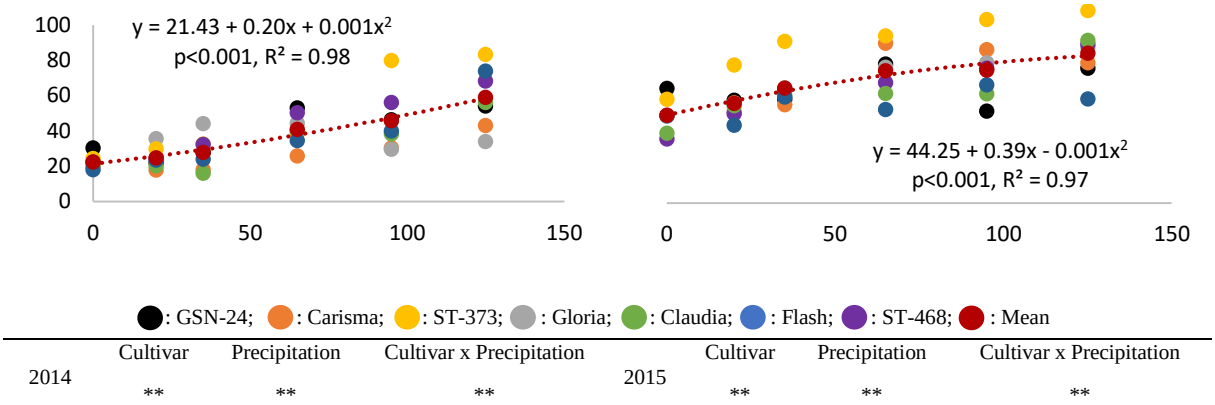
Trash Count

2014 and 2015 data in terms of trash count were given in Figure 6. When the control plots were evaluated, the GSN-24 cultivar had significantly high negative values in terms of trash count in 2014 (LSD $_{(0.05)}$ = 3.10), while other cultivars were in the same group. Similarly, in 2015 (LSD $_{(0.05)}$ = 2.38), GSN-24 and ST-373 cultivars were found to be in the highest group, while the statistical difference between other cultivars was not significant.

In both years, the polynomial regression equation between precipitation and trash count yielded the highest R^2 value (Figure 6). The equation for trash count = 21.43 + 0.20 precipitation + 0.001 precipitation^2 in the first year, trash count= 44.25 + 0.39 precipitation - 0.001 precipitation^2 in the second year was obtained. It is seen that GSN-24 and ST-373 varieties had the highest values in the control plots. Flash and Claudia in the first year and ST 468 and Claudia in the second year gave the lowest values. The response of genotypes to the increase in precipitation amounts has always been different and significant. It is noteworthy that the ST-373 variety had the worst characteristics, especially in 95 and 125 mm precipitation plots.

The results of the two-year experiment with seven cultivars and control and five precipitation amounts indicated that higher rainfall resulted in higher (unfavorable) trash count (102%) and area (311%) and resulted in a lower (unfavorable) germination rate (15.87%) and fiber reflectance (14.97%). Unlike these characters, an increase of 20 mm was observed in yellowness compared with control, and a decrease was

observed depending on the subsequent precipitation values. The linear regression curve and equation obtained for all characters except yellowness confirmed the negative increases and decreases. Previously studies revealed rainfall in the harvest season negatively affected cotton-fiber quality (Luo et al., 2016), and undamaged lint from rainfall was white and clean because of its highly reflective character (Heimoana and Wilson, 2017). Similarly, rainfall over 50.8 mm causes significant reductions in color level and increases in the foreign matter of the fiber (Hake et al., 1992; Anonymous, 2001). Also, Parvin et al. (2005) emphasized that cotton lint yield declined by 2.35 kg of lint per day and 4.09 kg of lint per centimetre of accumulated rainfall. According to Bednarz et al. (2002), HVI reflectance and yellowness decreased with weeks and light spotted color grades were recorded during the initial harvests, again corresponding to a period of significant rainfall.



	Cultivar	Precipitation	Cultivar x Precipitation		Cultivar	Precipitation	Cultivar x Precipitation
2014	**	**	**	2015	**	**	**

Figure 6. Trash count of precipitation x cultivar in 2014 (left) and 2015 (right)
Şekil 6. 2014(sol) ve 2015(sağ) yıllarında çeşit ve yağışlara ilişkin yabancı madde sayısı değerleri

Although the differences between years and the interaction of precipitation x cultivar were significant in each year, the performance of some cultivars was considerably more stable for the studied character. While the Carisma was the least affected cultivar by the increase in precipitation, significant decreases were observed in the Flash cultivar in terms of germination rate. Claudia and Flash exhibited a favorable performance for reflectance and yellowness. Gloria and Carisma for trash area; Gloria and Flash for trash count were the most suitable cultivars, whereas ST-373 performed poorly for both characters. Finally, the Flash cultivar can be recommended for minimum damage and profitable in delayed harvest conditions while seed production of the Carisma cultivar can be carried out without any problems.

CONCLUSIONS

The adverse effect of rainfall on exposed cotton boll in harvest season was clearly seen in this study. Decrease in germination rate, reflectance value and yellowness and an increase in trash count and trash area were detected with increasing precipitation amount. The different responses of cultivars to increase the precipitation amount indicated that different cultivars could be preferred in terms of seed production and lint colour grade.

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Contribution of the Authors as Summary

The authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

KAYNAKLAR

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