Performance of Some Cotton (*Gossypium hirsutum* L.) Genotypes for Agronomical and Within-Boll Yield Characters

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Abstract: Evaluating the cultivars' performance is an important step in the cotton breeding process. Therefore, we tested the yield, fiber quality and within-boll yield components of genotypes, and associations among observed characters were estimated. Ten cotton genotypes inc., Bomba, Özbek 100, Ramses, May 455, Bir 949, Fiona, Şahin 2000, Sahra, Sasha and Eva, were planted in a Randomized Complete Block Design with four replications in 2022. The highest seed cotton yield was recorded in Sasha and Bomba genotypes. Ramses performed the higher ginning out-turn (47.70%) and favorable fiber fineness (4.62 mic.). Bir 949 (32.65 mm), Ramses (31.49 mm) and Sasha (31.31 mm) for fiber length; Sasha (35.18 g tex^{-1}) and Sahra (34.08 g tex^{-1}) for fiber strength exhibited desirable performances. The highest relative leaf water content (%) as a drought indicator was recorded in Ramses (67.79), Fiona (67.45), Şahin 2000 (65.25) and Bomba (65.11). The number of fibers per seed ranged from 10.82 thousand (Özbek 100) to 13.00 thousand (Bir 949). It was concluded that it seemed difficult to associate the seed cotton yield, fiber quality and relative leaf water content. Therefore, the genotypes in which all three traits are optimized should be emphasized.

Keywords: Cotton, fiber quality, relative leaf water content, within-boll yield components, yield.

Bazı Pamuk (*Gossypium hirsutum* L.) Genotiplerinin Tarımsal ve Koza İçi Verim Özellikleri Yönünden Performanslarının Değerlendirilmesi

Öz: *Islah programlarının en önemli aşamalarından birisi genotiplerin performanslarını belirlemektir. Bu amaçla, genotiplerin verim, lif kalite özellikleri ve koza içi verim bileşenleri belirlenmiş ve incelenen özellikler arası ilişkiler değerlendirilmiştir. Bomba, Özbek 100, Ramses, May 455, Bir 949, Fiona, Şahin 2000, Sahra, Sasha ve Eva gibi 10 farklı pamuk genotipi 2022 yılında Tesadüf Blokları Deneme Deseninde 4 tekerrürlü olarak ekilmiştir. Sasha ve Bomba çeşitlerinin en yüksek kütlü pamuk verimine sahip olduğu saptanmıştır. Ramses çeşidi yüksek çırçır randımanı (%47.7) ve ince lifleri (4.62 mic.) ile dikkati çekmiştir. Lif uzunluğu yönünden Bir 949 (32.65 mm), Ramses (31.49 mm) ve Sasha (31.31 mm); lif dayanıklılığı yönünden Sasha (35.18 g tex^{-1}) ve Sahra (34.08 g tex^{-1}) yüksek performans sergilemiştir. Kuraklığa toleransın bir belirteci olan yaprak oransal su içeriği yönünden Ramses (67.79), Fiona (67.45), Şahin 2000 (65.25) ve Bomba (65.11) en iyi çeşitler olarak bulunmuştur. Tohumdaki lif sayısı değerleri 10821 (Özbek 100) ile 13002 (Bir 949) arasında değişmiştir. Çalışmada verim, lif özellikleri ve kuraklığa tolerans özelliklerinin aynı çeşitte bulunmasının güç olduğu sonucuna varılmıştır. Bu nedenle tüm özellikler yönünden optimum değerlerin bir çeşitte toplanmasının yararlı olacağı önerilmiştir.*

Anahtar kelimeler: *Lif kalitesi, koza-içi verim bileşenleri, yaprak oransal su içeriği, pamuk, verim.*

INTRODUCTION

Cotton is an important cash crop in many parts of the world. By nature, cotton (*Gossypium* spp.) is a perennial plant; however, it is commercially grown as an annual plant in many parts of the world. Cotton is a key crop in the world (Yu et al., 2012); not only are its fibers used as a source of natural textile, but also its seeds are used as a source of oil and livestock feed (Yu et al., 2012; He et al., 2013). The primary cotton-producing countries are India, China, the US, Brazil, Pakistan, Australia and Türkiye. In 2022, worldwide production was estimated at 36.4 million tons; Türkiye's share in this production was 0.83 million (ICAC, 2022). Upland cotton (*G. hirsutum* L.*)* is the dominating cultivated cotton species; it constitutes 90% of the world's cotton production. It is also the most cultivated species on irrigated lands of Türkiye's Aegean, Mediterranean and Southeast Anatolia Regions. Sanliurfa-Harran, Adana, Aydin and Izmir traditionally harvest the largest cotton areas in Türkiye. Considering the climatic conditions of these regions, cotton production consistently fluctuates based on the changing temperature and precipitation regimes over the years (Tatar, 2016). Studies have shown that climate change can negatively impact cotton farming (Baydar and Kanber, 2012; Tatar, 2016; Aydin and Sarptas, 2018), especially in fiber quality and yield. Length, fineness and strength are among the most important features in determining the quality criteria of fibers used for textile purposes (Delhom et al.,

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2018). The environmental conditions in which cotton is produced significantly impact the determination of fiber quality (Sasser and Shane, 1996) and yields (Karapinar and Erdem, 2003; Liu, 2018). During the growing season, climatic factors, such as temperature, humidity, precipitation, etc., differ for each cotton production region. Thus, each region's fiber quality characteristics, such as length, fineness, and strength, can vary (Cengiz and Goktepe, 2006; Brown, 2008; Darawsheh, 2022).

For sustainable cotton cultivation, developing new cotton genotypes with higher optimization that do not fluctuate excessively in terms of yield and fiber quality characteristics under changing climatic conditions is desirable. Yield is a trait that varies according to the genetics of the cotton genotype and environmental factors. The basis for yield formation is dry matter accumulation in the bolls through photosynthesis because of the plant's growth. This study aimed to evaluate the within-boll yield components of some cultivars that can be used as parents in breeding studies. Previous studies did not examine correlations among the yield components, drought and leaf physiological traits such as SPAD, RLWC, LAI and within-boll yield components. We hypothesized that these correlations would help determine indirect selection criteria.

MATERIAL and METHODS

We planned to conduct a trial at the Nazilli Cotton Research Institute during the 2022 cotton-growing season to evaluate the genotype performances. Bomba and Özbek 100 were selected for earliness; Eva, Şahin 2000, Sahra and Sasha for drought; Ramses, Bir 949, Fiona and May 455 for adaptation to the Aegean Region. The climate data in which the experiment was conducted showed that the average temperatures for 2022 were higher than for many years. Higher maximum temperatures were encountered in the May-August period (Figure 1).

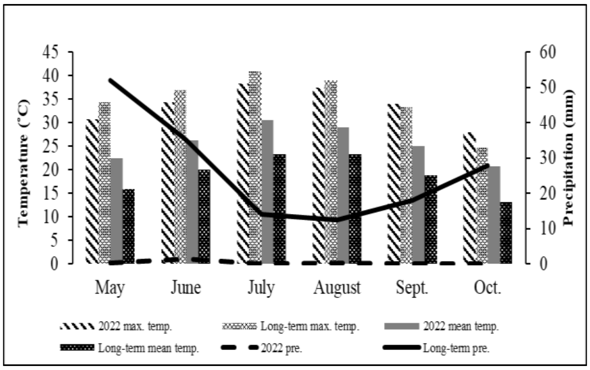

Figure 1. Monthly average and maximum air temperature and precipitation in 2022 and long-term

The trial was arranged in a Randomized Complete Block Design (RCBD) with four replications. All plots consisted of two rows with 12-m lengths. The inter-row and intra-row spaces were 70 and 25 cm, respectively. The soil characteristics of the experiment area are slightly alkaline, non-saline, very high in lime content, high in nitrogen content, medium in phosphorus, and low in potassium. Agronomical practices such as irrigation, weed control, and pesticide were performed according to recommended doses and methods for Aegean cotton growing. The trial was fertilized with 250 kg ha^{-1} of 20:20:0 NPK compound fertilizer at the time of sowing as a basal fertilizer and 250 kg ha^{-1} CAN (calcium ammonium nitrate) before the first irrigation as a top fertilizer. In addition, pesticides were sprayed four times for intensive *Empoasca* spp. damage during the growing season.

The days to first flowering (DFF) were observed in the growing period. The chlorophyll content index (CCI) was measured on the upper five fully-expanded leaves of randomly selected ten plants by "Apogee CCM-200. The first step in calculating relative leaf water content (RLWC) values was to measure fresh leaf weight (FW). After that, the saturated weight of leaves (TW) was measured after floating leaves in distilled water for 4 hours at 28˚C ± 1°C. Leaf dry weight (DW) was measured after drying the leaves in an oven at 80 °C for 48 hours (Dutta et al., 2016). The relative leaf water content was subsequently calculated with the following formula (Barrs and Weatherly, 1962):

RLWC (%) = [(FW-DW) / (TW-DW)] × 100

The leaf area index (LAI) was determined by measuring three times per plot with an AccuPAR model LP-80 ceptometer, which measures photo-synthetically active radiation and can invert these readings to give the leaf area index for plant canopy in the boll opening stage.

At harvesting time, plant height (PH; cm), number of bolls per plant (NB), boll weight (BW; g) and ginning out-turn (GOT; %) were recorded in fifty uniform plants of each replicate. Seed cotton yield (SCY; t ha^{-1}) was calculated by converting the values of fifty plants to tons ha^{-1}. The seed index (SI; g) was calculated as the weight of 100 fuzzy seeds. The fiber fineness (FF; mic.), fiber length (FL; mm), fiber strength (FS; g tex^{-1}), spinning consistency (SCI) and elongation were analyzed by Uster® High Volume Instrument (HVI) 1000 (USTER Technologies, Inc., Knoxville, TN, USA). Within-boll yield components such as lint yield /seed (LY/S; mg), number of fibers per seed (F/S), single seed volume (V/S; mm^3), specific seed weight (Wt/V; mg mm^{-3}), lint yield per boll (LY/B; g) and seed cotton per seed (SC/S; mg) were calculated according to Worley et al. (1976).

Variance analysis was run according to a randomized complete block design with four replicates in the R studio

(v. 4.1.2) using the 'agricolae' package (Mendiburu and Mendiburu, 2019; v. 1.3-5). The differences between the cultivar mean, which were statistically significant according to variance analysis, were compared by Duncan's Multiple Range Test at the 0.05 probability level (Duncan, 1955). Correlations between observed characters were calculated in R studio using the 'metan' package (Olivoto and Lucio, 2020).

RESULTS AND DISCUSSION

The differences among the genotypes were significant for days to first flowering, the number of bolls per plant, boll weight, ginning out-turn, seed index and seed cotton yield (Table 1). Many researchers have reported similar results with significant differences among the varieties for yield and yield components (Shah and Rasheed, 2019; Damtew et al., 2022). The genotypic differences resulted from genetic makeup and modification to the environment of the genotype (Dhamayanathi et al., 2010; Nikhil et al., 2018). Fourteen-day differences in the number of flowering days between the earliest genotypes (Bomba and Özbek 100) and the latest genotype (Ramses) indicated a high variation in earliness (Table 1). Earliness is a fundamental characteristic to avoid the negative consequences of late harvests in harvest (Balci et al., 2022; Balci et al., 2023). The highest boll number per plant was recorded in Bomba (32.90), followed by Sasha (27.90), Eva (27.30), Şahin 2000 (26.25) and Sahra (25.75), while Bir 949 and Eva exhibited the highest boll weight 6.53 and 6.47 g respectively. The integration of the number of bolls per plant and boll weight resulted in the highest seed cotton yield of Sasha (7.67 t ha^{-1}) and Bomba (7.00 t ha^{-1}). Fiona and Ramses considerably produced a high ginning out-turn but a low seed index.

Table 1. Agronomical traits of genotypes

Genotypes	DFF	NB	BW (g)	GOT (%)	SI (g)	SCY (t ha^{-1})
Bomba	64.00 g	32.90 a	5.39 e	44.72 b	9.63 d	7.00 b
Özbek 100	65.00 fg	14.45 d	5.89 bc	41.91 c	11.15 ab	4.09 e
Ramses	79.00 a	15.30 d	5.35 e	47.08 a	8.26 e	2.46 g
May 455	67.00 ef	19.95 c	5.98 b	44.70 b	10.75 bc	6.96 b
Bir 949	72.00 c	22.60 c	6.53 a	39.95 de	11.22 a	5.28 d
Fiona	75.00 b	14.60 d	5.60 c-e	46.83 a	8.63 e	3.46 f
Şahin 2000	68.00 e	26.25 b	5.48 de	43.83 b	9.97 d	6.27 c
Eva	70.00 d	27.30 b	6.47 a	39.27 e	11.54 a	6.16 c
Sasha	67.00 ef	27.90 b	5.76 b-d	43.65 b	9.91 d	7.67 a
Sahra	74.00 b	25.75 b	6.07 b	40.87 cd	10.54 c	6.90 b
Average	70.13±0.69	22.7±1.05	5.85±0.10	43.28±0.43	10.16±0.15	5.62±0.42
Genotype	**	**	**	**	**	**
CV (%)	1.97	9.21	3.55	1.97	3.02	1.48

*= %5; **=%1 significant probability level, respectively. Means within a column for each trait followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test. DFF; Days to first flowering, NB; The number of bolls per plant, BW; Boll weight (g), GOT; Ginning out-turn (%), SI; Seed index (g), SCY; Seed cotton yield (t ha^{-1}).

We found significant differences among genotypes for fiber quality parameters (Table 2). All cultivars except Ramses and Bir 949 in our study were classified as coarse and strong/very strong according to the fiber classification and analysis system of Uster® HVI (Anonymous, 2023). High micronaire has been one of the most important problems for the Türkiye cotton industry in recent years (Gormus, 2012). Sahra and Sasha exhibited the highest SCI values due to their superior fiber strength, whereas Bir 949 and Ramses had longer and finer fiber compared with Sahra and Sasha. The highest elongation values were recorded in Bomba and Eva cultivars.

The physiological traits, such as relative leaf water content and leaf area index, presented significant genotypic differences (Table 3). Fiona and Ramses significantly performed for RLWC, whereas Sasha and Sahra had poor performance compared to others. The significant genotypic differences for RLWC were also determined by Parida et al. (2007) and Saleem et al. (2018). Interestingly, these two genotypes produced more leaf area per unit (4.78 and 4.67 m^2, respectively). The mean chlorophyll content index of genotypes was 38.78, and this value was similar to findings by Feng et al. (2016) and Babu et al. (2019).

Table 2. Fiber traits of genotypes

Genotypes	FL (mm)	FF (mic.)	FS (g tex^{-1})	SCI	Elongation (%)
Bomba	30.35 c-e	5.06 d	32.43 c	149.75 ab	8.65 a
Özbek 100	29.00 f	5.48 a	29.85 d	132.50 c	7.73 bc
Ramses	31.49 b	4.62 f	31.63 c	150.25 ab	7.03 d
May 455	29.17 f	5.27 bc	30.18 d	138.25 bc	7.98 b
Bir 949	32.65 a	4.77 e	31.65 c	155.75 a	7.15 d
Fiona	30.62 b-d	5.26 bc	33.80 b	153.75 a	7.10 d
Şahin 2000	29.56 ef	5.05 d	29.53 d	139.00 bc	7.43 cd
Eva	30.15 de	5.02 d	29.38 d	137.25 bc	8.15 ab
Sasha	31.31 bc	5.38 ab	35.18 a	163.00 a	7.95 b
Sahra	30.89 b-d	5.14 cd	34.08 b	161.25 a	7.90 bc
Mean±SE	30.52±0.31	5.11±0.05	31.77±0.29	148.08±4.28	7.71±0.11
Genotype	**	**	**	**	**
CV (%)	2.02	1.86	1.81	5.79	2.72

** indicates significance at the 0.01 level. Means within a column for each trait followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test. FL; Fiber length, FF; Fiber fineness, FS; Fiber strength, SCI; The spinning consistency

Table 3. Physiological traits of genotypes

Genotypes	RLWC (%)	SPAD	LAI (m^2 m^{-2})
Bomba	65.11 ab	38.73	4.13 b-d
Özbek100	64.61 ab	39.00	4.17 a-d
Ramses	67.79 a	37.95	3.55 de
May455	63.41 bc	40.29	3.75 c-e
Bir949	60.55 c	38.03	4.29 a-c
Fiona	67.45 a	38.52	4.07 b-d
Şahin 2000	65.25 ab	39.26	3.44 e
Eva	61.60 bc	39.41	4.66 ab
Sasha	48.84 d	38.83	4.67 ab
Sahra	46.57 d	37.75	4.78 a
Mean±SE	61.12±1.18	38.78±0.98	4.15±0.20
Genotype	**	ns	**
CV (%)	3.86	5.08	9.58

** indicates significance at the 0.01 level. Means within a column for each trait followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test. RLWC; Relative water content, LAI; Leaf area index.

The result of variance analysis for within-boll yield components is displayed in Table 4, showing significant differences among the genotypes. Basal et al. (2009) reported the same result that there were significant differences among cultivars, which showed the presence of genetic diversity among them, while the significant genotypic difference was found only for the number of seeds by Imran et al. (2012). According to the means of within-boll yield components, the highest values were obtained in May 455 for lint yield per boll, in Bir 949 for fiber seed and the number of seeds per boll, in Eva for seed volume and number of seeds per boll, in Sahara for seed weight per volume and seeds per boll. By contrast, the lowest values were seen on Sahra for lint yield per seed, Özbek 100 for the number of fibers per seed and seed volume, Fiona for seed weight per volume and seed yield, and Şahin 2000 for lint yield per boll among the genotypes. Seed cotton yield significantly and positively correlated with seed cotton yield per seed, seed weight per volume, volume/seed, leaf area index, elongation, fiber fineness, seed index and number of bolls per plant, whereas significant and negative associations with seed cotton yield recorded in relative leaf water content, ginning out-turn and days to first flowering (Figure 2).

Table 4. Within-boll yield components of genotypes

Gen.	S/B (no.)	LY/S (mg)	F/S (no.)	V/S (mm^3)	Wt/V (mg/mm^3)	LY/B (g)	SCY/S (mg)
Bomba	30.9 b	78.0 bc	11884.7 b-d	87.5 c	110.2 cd	2.4 c	174.3 b
Özbek 100	30.8 b	80.3 b	10821.5 e	98.8 a	113.0 b-d	2.5 bc	191.8 a
Ramses	34.3 a	73.5 c	12795.4 ab	73.8 e	113.0 b-d	2.5 a-c	156.3 c
May 455	30.8 b	87.0 a	12282.0 a-c	90.6 bc	118.6 ab	2.7 a	194.5 a
Bir949	35.0 a	74.8 c	13002.0 a	96.3 ab	116.9 a-c	2.6 ab	187.0 a
Fiona	34.5 a	76.0 bc	11289.1 c-e	80.0 d	107.8 d	2.6 ab	162.3 c
Şahin 2000	30.9 b	77.8 bc	11630.8 c-e	90.0 bc	110.8 cd	2.4 c	178.0 b
Eva	34.1 a	74.8 c	11316.5 c-e	100.0 a	115.4 a-d	2.5 a-c	190.0 a
Sasha	32.8 ab	76.8 bc	11378.9 c-e	85.0 cd	116.8 a-c	2.5 bc	176.0 b
Sahra	34.1 a	73.0 c	11133.1 de	87.5 c	120.8 a	2.5 bc	178.3 b
Mean±SE	32.8±0.78	77.2±1.74	11753.4±315.9	88.9±2.13	114.3±2.38	2.5±0.05	178.8±2.97
Genotype	**	**	**	**	**	**	**
CV (%)	4.73	4.50	5.38	4.79	4.17	3.86	3.32

** indicates significance at the 0.01 level. Means within a column for each trait followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test. S/B; Seed number per boll, LY/S; Lint yield per seed, F/S; Fibers per seed, V/S; Volume of the seed, Wt/V; Seed weight per volume, LY/B; Lint yield per boll, SYC/S; Seed cotton yield/seed.

Khan et al. (2009) reported similar information: the number of bolls per plant and boll weight positively correlated with seed cotton yield. Nawaz et al. (2019) also found that seed cotton yield had a positive relationship with the number of bolls per plant, seed index, and seed per boll. Similarly, Cinar and Unay (2021) emphasized that seed cotton yield increased in the treatments where the S/B was high. These associations indicated that seed characteristics positively affected seed cotton yield compared with fiber; consequently, coarse fiber and low ginning out-turn occurred. In case of late flowering, seed cotton yield per unit area, seed cotton yield per seed, volume/seed, lint yield/seed, elongation, fiber fineness, seed index and number of bolls per plant are reduced. The boll weight, one of the essential yield components, is positively affected by seed cotton yield per seed, lint yield per boll, seed weight per volume, seed/boll, LAI and seed index. Negative associations among ginning out-turn, boll weight and boll number brought to mind that boll number and boll weight should be optimized for high ginning out-turn.

Seed/boll and fiber/seed significantly correlated positively with fiber length but negatively with fiber fineness, whereas lint yield per seed significantly correlated positively with fiber fineness but negatively with fiber length. Similarly, Brown et al. (2015) revealed a significant and positive correlation between fibers/seed and fiber length but a negative correlation between fiber/seed and fiber fineness. These findings contradict Basal (2009), who stated that fiber/seed and lint yield/seed significantly correlated negatively with fiber quality.

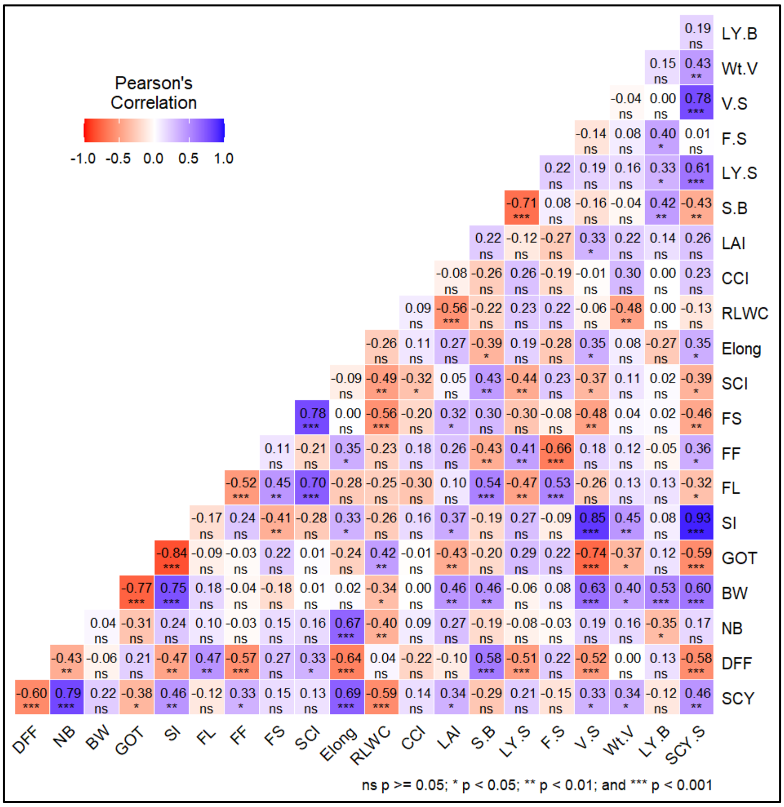

Figure 2. Correlation coefficients between observed traits

S/B; Seed number per boll, LY/S; Lint yield per seed, F/S; Fibers per seed, V/S; Volume of the seed, Wt/V; Seed weight per volume, LY/B; Lint yield per boll, SCY; Seed cotton yield, LY/S; Lint yield per seed, SCY/S: Seed cotton yield/seed, Y/B; Yield per boll, BW; Boll weight, RLWC; Relative leaf water content, FL; Fiber length, FF; Fiber fineness, FS; Fiber strength, SCI; The spinning consistency, LAI; Leaf area index, NB; Number of bolls per plant, GOT; Ginning out-turn; DFF: Days to first flowering, SI; Seed index, Elong: Elongation.

CONCLUSION

Sasha and Bomba for seed cotton yield, Ramses and Bir 949 for fiber quality, Bir 949 and Eva for within-boll yield components were superior cultivars. Bir 949 had optimum values in terms of all its properties. This research revealed that seed cotton yield was affected positively by the number of bolls per plant, seed index, and seed yield; however, it was negatively affected by days to first flowering and relative leaf water content. So, it was concluded that it seemed difficult to associate the seed cotton yield with each yield component, within-boll yield component and morphological traits.

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