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COMPARISON OF YIELD AND FIBER PROPERTIES BY CORRELATION, BIPLOT AND CLUSTER ANALYSIS IN SOME COTTON (*Gossypium hirsutum* L.) HYBRIDS

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ABSTRACT

Cotton is the most important fiber crop. Seed cotton yield, ginning outturn, lint yield, some fiber quality parameters and adaptation capability of eleven hybrid (F_{5-6}) cotton genotype were assesed in this study at Antalya/Türkiye conditions. The study was conducted in a randomized block design with three replications in 2017 and 2018. The level and significance of the relationships between genotype-traits and traits were determined by correlation, biplot and cluster analysis. Resulting, hybrid lines which 1102 for seed cotton yield and fiber yield, 1008 for seed cotton yield, ginning outturn and fiber yield, 1019 and 1103 for all the characters and Gloria cultivar for fiber paramteres were significant. In addition, hybrids which line 1115 for seed cotton yield, fiber yield, spinning consistency index and fiber maturity, lines 1005, 1006, 1101, 1102, 1105 and Sure Grow 125 cultivar were found insignificant due to their high short fiber content. The fiber yield showed significant and positive correlation with seed cotton yield, ginning outturn, fiber maturity and fiber fineness, which were not affected by the year difference. The spinning consistency index determined by the combination of a plurality of fiber properties, it has always been found to have very important and positive correlation with fiber length, fiber strength and fiber uniformity index, negligible but positive with ginning outturn, whereas short fiber index was always significantly and negatively correlated.

Keywords: Antalya, cotton yield and fiber quality, correlation, biplot analysis, cluster analysis.

INTRODUCTION

Cotton is an important fiber plant for economic and social life of Turkey. More than 90% of the world cotton production is made with *Gossypium hirsutum* L. genus varieties belonging to Malvaceae family (Zhang et al., 2007). Today, the global competition requires that new varieties which combine yield and fiber quality as well as adapting to different climatic conditions to meet different consumer demands. While producers are more concerned with yield and ginning outturn, spinners prefer fibers that are thin, long, durable, uniform and shiny. Breeders, on the other hand, try to develop varieties that combine desired traits and prevent negative correlations between both yield and fiber traits as well as some fiber traits (Ijaz et al., 2019). The researchers found a negative correlation between fiber length and fiber fineness (Shruti et al., 2020), fiber elongation and fiber maturity (Hampannavar et al., 2020), short fiber index and fiber uniformity index (Farias et al., 2016). On the other hand, in the environment where cotton is grown, it responds to a large number of biotic and abiotic stresses with its genetic makeup. At temperatures higher than 32°C, which cannot be intervened, yield decreases due to boll shedding (Unay and Basal, 2005) and carbohydrate reduction in high night transpiration (Loka and Oosterhuis, 2010).

Although it has been reported that it is difficult to develop varieties that combine yield and fiber properties (Nawaz et al., 2019), the researchers found many relationships between traits by correlation (Hampannavar et al., 2020), biplot (Mızrak et al., 2020) and clustering (Karademir et al., 2018) analysis. Correlation analysis determines the direction and importance of the relationship between characters, while

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biplot analysis determines the genotypes that best fit the good environment with the help of relationships (Yan, 2011). Clustering analysis determines genotypes with similar characteristics (Spasova et al., 2016). Resulting of different studies, seed cotton yield was positively related to fiber length and fiber fineness, but negative for fiber strength (Hussain et al., 2010) while ginning outturn, fiber length and fiber strength are also negatively related to fiber fineness. Fiber length, on the other hand, was reported to be positively correlated with ginning outturn and fiber strength (Jahan et al., 2019). In addition, there is high variation in seed cotton yield, fiber yield, fiber fineness, fiber maturity and fiber length by biplot analysis (Khalid et al., 2018), while Karademir et al. (2018), reported that genotypes cluster differently in terms of seed cotton yield, fiber yield, length, strength, fineness, uniformity index, elongation and short fiber index.

This study was conducted to determine the genetic boundaries of yield and fiber characteristics in some cotton hybrids (F_{5-6}) and define the genotypes having best yield-quality combination with the help of relationships between traits.

MATERIAL AND METHODS

The study was carried out during 2017 and 2018 cotton growing season in Antalya, Turkey conditions (36°53’48.8” N and 30°42’53.4” E). Eleven cotton hybrids (F_{5-6}) (Line 1005, Line 1006, Line 1008, Line 1013, Line 1019, Line 1101, Line 1102, Line 1103, Line 1105, Line 1109, Line 1115) and three control cultivars (Sure Grow 125, Gloria and Flash) was used in the experiment and hybrids compared with control cultivars. Because, farmers are preferred Gloria cultivar for fiber quality as preferred Sure Grow 125 and Flash cultivars due to their high yield potential. Trials were sown on May 8th, 2017 and May 16th, 2018. The experimental area is sandy-clayey, slightly alkaline, salt-free, organic matter poor (1.55%) soils. While the climatic conditions differed in 2017 and 2018, since 2018 was a hot and rainy yearand excessive rainfall caused a delay in cultivation. In addition, 25.2% (139 mm) of the total annual precipitation (549.8 mm) was seen in the May-October period in 2018. Average temperature was 3.1°C and maximum temperature 14.2°C higher than 2017 cotton season while minimum temperature was 13.3°C less in 2018 cotton growing season (Table 1a and 1b).

Genotypes were grown in a randomized block design with three replications. Planting distance was 0.70 m between rows and 0.15 m above rows and parcel length was 10 m with four rows. 150 kg ha^{-1} pure nitrogen and 60 kg ha^{-1} pure phosphorus (P_2O_5) were given to the experimental parcels. Nitrogen was given in two applications (60 kg ha^{-1} before sowing and 100 kg ha^{-1} before second irrigation) and phosphorus in once (60 kg ha^{-1} before sowing). As nitrogen and phosphorus source, compound fertilizer (20-20-0) was used before sowing and urea (46% NH_2) was used in top application. After the application of six irrigations and five hoes (two tractors, three hand hoes), harvests were done manually by hand on October 23rd, 2017 and October 17th, 2018.

In the study, seed cotton yield, fiber yield and ginning outturn were determined by parcel data, and fiber quality was determined by USTER HVI 1000 (*High Volume Instrument*) for fiber fineness, fiber lenght, fiber strenght, fiber maturity, fiber uniformity index, fiber elongation, short fiber index and spinning consistancy index. Comparison of genotypes was determined by $LSD_{(0.05)}$ (*Least significant degree*) after analysis of variance, relationship between charecters by correlation, genotype-trait interaction by biplot and genetic similarities by cluster analysis.

Table 1a. Climate data (temperature) of Antalya province for 2017 and 2018

Months	Mean temperature (^oC)		Differences	Minimum temperature (^oC)		Differences	Maximum temperature (^oC)	
	2017	2018		2017	2018		2017	2018
January	8.5	10.8	2.3	0.3	1.7	1.4	17.8	20.9
February	10.4	12.8	2.4	-1.0	3.4	4.4	21.8	21.2
March	13.1	15.0	1.9	1.7	6.8	5.1	24.4	25.8
April	16.4	18.5	2.1	4.4	6.7	2.3	31.6	35.2
Total	**48.4**	**57.1**	**8.7**	**5.4**	**18.6**	**13.2**	**95.6**	**103.1**
Average	*19.4*	*22.8*	*3.5*	*2.2*	*7.4*	*5.3*	*38.2*	*41.2*
May	20.5	23.2	2.7	12.1	11.9	-0.2	33.5	35.6
June	25.8	25.5	-0.3	15.5	16.3	0.8	44.5	38.0
July	29.4	28.5	-0.9	18.3	18.2	-0.1	44.8	43.3
August	27.9	28.0	0.1	19.0	17.2	-1.8	40.3	40.8
September	25.2	25.9	0.7	14.7	15.2	0.5	36.9	40.7
October	19.7	20.4	0.7	19.7	7.2	-12.5	19.7	35.5
Total	**148.4**	**151.5**	**3.1**	**99.3**	**86.0**	**-13.3**	**219.7**	**233.9**
Average	*24.7*	*25.2*	*0.5*	*16.6*	*14.3*	*-2.2*	*36.6*	*39.0*
November	14.4	15.7	1.3	3.1	7.2	4.1	32.2	31.5
December	12.0	11.5	-0.5	0.8	0.0	-0.8	25.9	21.6
Total of year	**223.2**	**235.7**	**12.5**	**108.6**	**111.8**	**3.2**	**373.4**	**390.1**
Average of year	*17.2*	*18.1*	*1.0*	*8.4*	*8.6*	*0.2*	*28.7*	*30.0*

Table 1b. Climate data (humidity and precipitation) of Antalya province for 2017 and 2018

Months	Humidity (%)		Differences	Precipitation (mm)		Differences
	2017	2018		2017	2018	
January	68.7	72.2	3.5	56.0	10.8	-45.2
February	62.0	83.0	21.0	5.0	91.0	86.0
March	71.5	78.9	7.4	70.0	94.0	24.0
April	69.2	68.7	-0.5	27.0	2.0	-25.0
Total	**271.4**	**302.8**	**31.3**	**158.0**	**197.8**	**39.8**
Average	*108.6*	*121.1*	*12.5*	*63.2*	*79.1*	*15.9*
May	73.0	66.2	-6.8	35.0	19.0	-16.0
June	66.4	72.8	6.4	0.0	65.0	65.0
July	62.0	65.8	3.8	0.0	18.0	18.0
August	72.3	71.2	-1.1	0.0	0.0	0.0
September	72.4	65.1	-7.3	0.0	13.0	13.0
October	64.9	67.3	2.3	29.0	24.0	-5.0
Total	**411.0**	**408.4**	**-2.6**	**64.0**	**139.0**	**75.0**
Average	*68.5*	*68.1*	*-0.4*	*10.7*	*23.2*	*12.5*
November	74.0	72.5	-1.5	48.0	57.0	9.0
December	81.8	78.0	-3.8	74.0	156.0	82.0
Total of year	**838.2**	**861.5**	**23.4**	**344.0**	**549.8**	**205.8**
Average of year	*64.5*	*66.3*	*1.8*	*26.5*	*42.3*	*15.8*

RESULTS AND DISCUSSION

Seed cotton yield

Seed cotton yield is affected by genotype potential (Karademir et al., 2015; Kıllı and Beycioğlu, 2020) and environmental conditions such as planting time, biotic and abiotic stresses (Farid et al., 2017). In the study, genotype x year interaction and differences between genotypes were found significant like result of Karademir et al. (2017), while year difference was found insignificant (Table 6). Seed cotton yield ranged from 4042.1 kg ha^{-1} (2017, Line 1008) to 2115.4 kg ha^{-1} (2017, Line 1006). While the seed cotton yield for the experimental years was 2918.7 kg ha^{-1} (2017) and 3189.6 kg ha^{-1} (2018), Line 1102 had the highest (3577.3 kg ha^{-1}) and Line 1115 had the lowest (2534.4 kg ha^{-1}) in the two-year average (Table 2).

Seed cotton yield showed positive correlation with ginning outturn (Shruti et al., 2020), fiber yield, fiber fineness (Rao and Gopinath, 2013), fiber maturity and fiber uniformity index (Hampannavar et al., 2020), whereas negative correlation with fiber strength (Khalid et al., 2018) and this situation was not affected by the year difference. On the other hand, correlation of seed cotton yield with fiber length, elongation, short fiber index and spinning consistency index was affected by the year difference (Table 5). In addition, the correlation of seed cotton yield with fiber yield and fiber fineness was always significant regardless of the year difference, and the correlation with fiber maturity was significant due to the year effect.

Ginning outturn

The ginning outturn determines the fiber ratio in the seed cotton and desired to be high. In the study, differences between genotypes, years and genotype x year interaction were found very important and results were in line with Karademir et al., (2017) (Table 6). The ginning outturn in the region varied between 46.30% (2017, Line 1103) and 37.63% (2018, Line 1005) and it was parellel with the findigs of Ehsan et al. (2008). Line 1103 had the highest (43.19%) and Line 1101 the lowest (39.29%) ginning outturn in the two-year average (Table 2). The ginning outturn of the years was 42.52% (2017), 39.35% (2018) and 40.93% in average.

Ginning outturn is positively correlated with seed cotton yield (Ehsan et al., 2008), fiber yield, fiber fineness, fiber uniformity index (Rao and Gopinath, 2013) and fiber maturity (Hampannavar et al., 2020), but negatively correlated with short fiber index, and this was not affected by the year difference (Table 5). The correlation of ginning outturn with fiber length and fiber strength was affected by the year difference. In addition, the correlation between ginning outturn and fiber yield was always significant, independent of the year difference, and the correlation with seed cotton yield and fiber properties was insignificant (Table 5).

Fiber yield

Although the fiber yields of genotypes over the years were different, the variation was low, the difference between genotypes and years was insignificant and this results were similar with findigs of Karademir et al. (2015). The regional fiber yield varied between 1858.6 kg ha^{-1} (Line 1008) and 976.1 kg ha^{-1} (Line 1101). Line 1008 had the highest fiber yield (1498.1 kg ha^{-1}) while Line 1115 had the lowest (1035.5 kg ha^{-1}) in the two-year average. In addition, the annual yields were 1244.4 kg ha^{-1} (2017) and 1256.3 kg ha^{-1} (2018), and the yearly average was 1250.4 kg ha^{-1} (Table 3).

Fiber yield was positively correlated with seed cotton yield, ginning outturn, fiber fineness (Jahan et al., 2019), fiber maturity and fiber uniformity index, but negatively correlated with fiber strength, and this was not affected by the year difference. The year difference affected the correlation of the fiber yield with elongation, short fiber index, fiber length and spinning consistency index. In addition, while fiber yield always shows significant or very significant correlations with seed cotton yield (Jahan et al., 2019), ginning outturn and fiber fineness, regardless of year difference, its correlation with fiber maturity showed significance due to year effect. Line 1102 was found to be important for the region, with its potential not affected by the year difference (Table 2, Figure 1 and 2).

Fiber fineness

Fiber fineness is one of the most important properties affecting yarn quality. In addition, the fiber fineness of the region has changed between 4.23 (2018, Line 1115) and 5.31 (2017, Flash) micronaire (Table 2). In the two-year average, Line 1105 (5.06 micronaire) and Line 1115 (4.46 micronaire) had the thickest and thinnest fibers, repectively, while the fiber fineness for years was 5.02 (2017), 4.66 (2018) and 4.99 (two years average) micronaire, so the difference between genotypes was insignificant (Table 2). Genotypes produced finer fiber in 2018 than in 2017, with the exception of Sure Grow 125. Snider et al. (2013) reported the effect of environment (63.8%) and genetic potential (9.9%) while Karademir et al. (2017) reported that the genotype difference in fiber fineness is very important.

Fiber fineness was positively correlated with seed cotton yield (Nawaz et al., 2019) ginning outturn, fiber yield, fiber maturity and uniformity index, but negatively correlated with fiber length, fiber strength, short fiber index and spinning consistency index, and this was not affected by the year difference (Table 5). The correlation of fiber fineness with the fiber elongation differed by years (Table 5). The year difference was very important (Table 6). In addition, the fiber fineness always showed significant or very significant correlation with seed cotton yield (Nawaz et al., 2019), fiber yield, fiber maturity and spinning consistency index, and a differently significant correlation with fiber length over the years.

Fiber length

The most important feature affecting the hairiness of the fabric is the fiber length. Differences between genotypes and years were highly significant, but genotype x year interaction was insignificant (Table 6). According to Karademir et al. (2010), difference between genotypes was highly significant, but year difference and genotype x year interaction were insignificant for this trait. The fiber length of the region varied from 32.13 mm (2018, Line 115) to 28.55 mm (Line 1105) (Table 4). Of the genotypes, Line 1115 (31.97 mm), Line 1103 (31.86 mm), Line 1013 (31.67 mm), Line 1019 (31.31 mm) and Gloria (31.38 mm) had the longest fibers in the two-year average, and Line 1105 had the shortest (29.24 mm) fibers. Average fiber length of the years was 30.27 mm (2017), 31.13 mm (2018) and 30.79 mm (two years average).

Fiber length was positively correlated with fiber strength, fiber uniformity index and spinning consistency index but negatively correlated with fiber fineness (Rao and Gopinath, 2013), fiber maturity and short fiber index, and the year difference did not affect this situation. The correlation of the fiber length with the elongation was affected by the year difference (Figure 5). In addition, the correlation of fiber length with short fiber index and spinning consistency index was always very important or important, and the correlation with fiber fineness, fiber strength, fiber maturity and fiber uniformity index has shown different significance level according to year effect (Table 5).

Fiber strength

Results of the study in which year difference and genotype difference are very important were similar to Karademir et al., (2010). Of the genotypes, Line 1013 (2017: 36.55 g tex^{-1}) and Gloria (2017: 37.77 g tex^{-1}) had the strongest, Line 1115 (2018: 29.73 g tex^{-1}) had the weakest fibers (Table 3). In additon, on the two-year average Gloria (36.09 g tex^{-1}) and Line 1013 (35.81 g tex^{-1}) showed the highest fiber strength, and Line 1006 had the lowest (31.24 g tex^{-1}). The fiber strength of the years was 34.25 g tex^{-1} (2017) and 31.80 g tex^{-1} (2018) (Table 4).

On the other hand, fiber strength was positively correlated with fiber length, fiber maturity, fiber uniformity index and spinning consistency index but negatively correlated with seed cotton yield (Shruti et al., 2020), fiber yield, fiber fineness (Shruti et al., 2020), fiber elongation and short fiber index. While this situation was not affected by the year difference, the correlation of the fiber strength with the ginning outturn was affected by the year difference. In addition, the correlation of fiber strength with the spinning consistency index was always very important, while the correlation with fiber length, fiber uniformity index and short fiber index was different due to the year effect (Table 5).

Fiber maturity

The fiber maturity for the years was 0.87 (2017), 0.86 (2018) and 0.87 (years average) (Table 3), Line 1115 had the least mature (0.86) fibers at the two-year average. Fiber maturity was positively correlated with seed cotton yield (Teodoro et al., 2018), ginning outturn, fiber yield, fiber fineness, fiber strength and fiber uniformity index, whereas fiber length, fiber elongation, short fiber index and spinning consistency index were negatively correlated, and this was not affected by the year difference. In addition, the correlations of fiber maturity with fiber fineness and elongation were always significant, while the correlations of seed cotton yield, fiber yield and fiber length were in different significance levels with the effect of years (Table 5). The difference between genotypes was insignificant, but the year difference was significant (Table 6).

Fiber uniformity index

The results showed that line 1103 had the highest (2017, 86.79%) and Line 1109 (2017, 83.38%) had the lowest fiber uniformity index (Table 3), while Line 1019 had the highest (86.57%) and Line 1109 (83.81%) had the lowest fiber uniformity index on the two-year average. Fiber uniformity index showed positive correlation with seed cotton yield, ginning outturn, fiber yield, fiber fineness, fiber length, fiber strength (Farias et al., 2016), fiber maturity, fiber elongation and spinning consistency index, whereas negatively correlated with short fiber index and this is not affected by the year difference. In addition, the correlation of fiber uniformity index with short fiber index and spinning consistency index was always very important, independent of the year effect, but its correlation with fiber length and fiber strength showed different significance levels due to the year effect (Table 5). The difference between genotypes was very significant (Table 6).

Fiber elongation

Line 1019 had the highest fiber elongation value in 2017 (7.91%), 2018 (7.49%) and the average of years (7.70%) while Line 1013 had the lowest (6.59%) value in average of years (Table 5). The fiber elongation for the years was 7.40% (2017), 6.98% (2018) and 7.19% (two years average) (Table 4).

Fiber elongation was positively correlated with ginning outturn (Ulloa, 2006) and fiber uniformity index, whereas fiber strength, fiber maturity and spinning consistency index (Farias et al., 2016) were negatively correlated, and this was not affected by the year difference. On the other hand, its correlation with seed cotton yield, fiber yield, fiber fineness, fiber length and short fiber index was affected by the year difference. The correlation between fiber elongation and fiber maturity was always significant or very important, independent of year effect, and correlations with other characters were insignificant (Table 5). Year difference and genotype difference were very significant (Table 6).

Short fiber index

Short cotton fiber (12.7 mm) is a problem that increases the yarn cost (Thibodeaux et al., 2008). In addition to the difference between years and genotypes, the year x genotype interaction was also important in our study. In terms of short fiber index, Line 1103 (2017: 5.82%) and Line 1019 (2018: 5.51% and yearly average: 5.96%) were found to be significant. The short fiber content of the years was 7.12% (2017), 5.82% (2018) and 6.47% (years average) in similarity with the findigs of Karademir et al. (2015).

Short fiber index was a negative correlation with ginning outturn, fiber fineness, fiber length (Ulloa, 2006), fiber strength, fiber maturity, fiber uniformity index and spinning consistency index, independent of year difference. The correlation of the trait with seed cotton yield, fiber yield and elongation was affected by the year difference. In addition, while the correlation of short fiber index with fiber length, fiber uniformity index and spinning consistency index was always important or very important and its correlation with fiber strength showed different significance levels with the effect of years (Table 5).

Spinning consistency index (SCI)

The spinning consistency index is determined by the correlation of fiber strength, fiber fineness, fiber length (UHML), fiber uniformity index, fiber brightness, and fiber yellowness (Thilagavathi and Karthik, 2016). Genotype difference and genotype x year interaction were found important in the study (Table 2). The spinning consistency index of years ranged from 161 (2018, Line 1013) to 135 (2017, Line 1005). According to the two-year averages, Gloria (161) and Line 1013 (158) gave the highest SCI value and Line 1105 (138) the lowest SCI, while Line 1008 was not affected by the year difference (2017: 148, 2018: 147) (Table 4).

The spinning consistency index was positively correlated with ginning outturn, fiber length, fiber strength and fiber maturity, whereas fiber fineness, fiber maturity, fiber elongation and short fiber index were negatively correlated, and the year difference did not affect this situation. In contrast, the correlation with seed cotton yield and fiber yield was affected by the year difference (Table 5). In addition, the correlation of spinning consistency index with fiber fineness, fiber length, fiber strength, fiber uniformity index and short fiber index has always been found to be significant or very important, independent of the year effect.

Table 2. Values of genotypes for the traits examined

Genotypes	Seed cotton yield (kg ha^{-1}) 2017	Seed cotton yield 2018	Seed cotton yield Average (Genotypes)	Ginning outturn (%) 2017	Ginning outturn 2018	Ginning outturn Average (Genotypes)	Fiber yield (kg ha^{-1}) 2017	Fiber yield 2018	Fiber yield Average (Genotypes)	Fiber fineness (micronaire) 2017	Fiber fineness 2018	Fiber fineness Average (Genotypes)
Crosses												
Line 1005	3095.1 $^{a-c}$	3485.9 $^{a-c}$	3290.5	42.37 $^{b-d}$	37.63 ^{j}	40.00 $^{f-h}$	1316.7 ^{ab}	1311.4 $^{a-c}$	1314.1	5.09	4.80	4.95
Line 1006	2115.4 ^{c}	3458.5 $^{a-c}$	2787.0	43.37 ^{bc}	40.16 $^{e-i}$	41.77 $^{b-d}$	917.3 ^{b}	1395.6 ^{ab}	1156.5	5.11	4.60	4.86
Line 1008	4042.1 ^{a}	2935.3 ^{bc}	3488.7	45.90 ^{a}	38.71 ^{ij}	42.31 ^{ab}	1858.6 ^{a}	1137.5 ^{bc}	1498.1	4.97	4.43	4.70
Line 1013	2503.5 ^{bc}	2846.0 ^{bc}	2674.8	40.38 $^{e-i}$	39.05 $^{h-j}$	39.72 ^{gh}	1009.9 ^{b}	1111.3 ^{bc}	1060.6	4.86	4.52	4.69
Line 1019	3151.9 $^{a-c}$	3519.0 ^{ab}	3335.5	43.56 ^{b}	40.22 $^{e-i}$	41.89 ^{bc}	1375.4 ^{ab}	1417.0 ^{ab}	1396.2	5.08	4.71	4.90
Line 1101	2463.4 ^{bc}	3029.1 $^{a-c}$	2746.3	39.69 $^{g-i}$	38.89 $^{h-j}$	39.29 ^{h}	976.1 ^{b}	1178.2 $^{a-c}$	1077.2	5.20	4.74	4.97
Line 1102	3450.3 $^{a-c}$	3704.3 ^{a}	3577.3	41.74 $^{c-f}$	39.58 ^{hi}	40.66 $^{d-g}$	1439.4 ^{ab}	1467.5 ^{a}	1453.5	4.97	4.53	4.75
Line 1103	3192.4 $^{a-c}$	3391.1 $^{a-c}$	3291.8	46.30 ^{a}	40.08 $^{f-i}$	43.19 ^{a}	1469.9 ^{ab}	1358.2 $^{a-c}$	1414.1	5.25	4.67	4.96
Line 1105	2255.0 ^{bc}	3476.8 $^{a-c}$	2865.9	42.90 $^{b-d}$	38.73 ^{ij}	40.82 $^{c-g}$	969.7 ^{b}	1347.5 $^{a-c}$	1158.6	5.20	4.91	5.06
Line 1109	2760.3 $^{a-c}$	2899.4 ^{bc}	2829.9	41.33 $^{d-g}$	39.55 ^{hi}	40.45 $^{e-h}$	1141.7 ^{b}	1146.7 ^{bc}	1144.2	4.98	4.62	4.80
Line 1115	2295.4 ^{bc}	2773.4 ^{c}	2534.4	42.89 $^{b-d}$	39.11 $^{h-j}$	41.00 $^{c-g}$	984.9 ^{b}	1086.1 ^{c}	1035.5	4.68	4.23	4.46
Controls												
Sure Grow 125	3203.3 $^{a-c}$	3180.7 $^{a-c}$	3192.0	40.46 $^{e-h}$	39.25 $^{h-j}$	39.86 $^{f-h}$	1296.3 ^{ab}	1247.4 $^{a-c}$	1271.9	4.85	5.21	5.03
Gloria	2742.2 $^{a-c}$	3052.2 $^{a-c}$	2897.2	42.58 $^{b-d}$	40.30 $^{e-i}$	41.44 $^{b-e}$	1167.7 ^{b}	1228.0 $^{a-c}$	1197.9	4.73	4.71	4.72
Flash	3592.1 ^{ab}	2904.0 ^{bc}	3248.1	41.87 $^{b-e}$	39.76 $^{g-i}$	40.82 $^{c-g}$	1498.5 ^{ab}	1157.1 ^{bc}	1327.8	5.31	4.63	4.97
Average (Years)	2918.7	3189.6	3054.1	42.52 ^{a}	39.35 ^{b}	40.93	1244.4	1256.3	1250.4	5.02 ^{a}	4.66 ^{b}	4.99
CV (%)	19.68	13.52	22.75	2.95	2.00	2.56	31.65	14. 25	24.91	6.28	6.97	6.62
$LSD_{(0.05)}$ Genotypes	148.2	72.38	80.50	2.10**	1.32*	1.21**	65.99	31.03	36.09	0.52	0.54	0.37
$LSD_{(0.05)}$ Years			30.43			0.46**			13.64			0.14**
$LSD_{(0.05)}$ Genotypes x Years			81.40			1.71**			51.04			0.53

*CV (%): Coefficient of Variation; LSD (0.05): Least Significant Degree; *: p>0.05; **: p>0.01; ns: non-significant; p: Probability.*

Table 3. Values of genotypes for the traits examined

Genotypes	Fiber length (mm)			Fiber strength (g tex^{-1})			Fiber maturity			Fiber uniformity index (%)		
	2017	2018	Average (Genotypes)	2017	2018	Average (Genotypes)	2017	2018	Average (Genotypes)	2017	2018	Average (Genotypes)
Crosses												
Line 1005	28.78 ^{ef}	31.42	30.10 $^{c-e}$	32.58 ^{d}	32.96 $^{a-d}$	32.77 $^{b-d}$	0.87	0.87	0.87	84.06	85.98	85.02 ^{bc}
Line 1006	29.05 $^{d-f}$	31.42	30.24 $^{c-e}$	32.73 ^{d}	29.75 ^{e}	31.24 ^{d}	0.87	0.86	0.87	84.59	86.01	85.30 ^{bc}
Line 1008	30.27 $^{b-e}$	31.21	30.74 $^{b-d}$	34.52 $^{b-d}$	31.99 $^{b-e}$	33.26 ^{bc}	0.87	0.87	0.87	84.75	84.95	84.85 $^{b-d}$
Line 1013	31.40 ^{ab}	31.93	31.67 ^{ab}	36.55 ^{ab}	35.07 ^{a}	35.81 ^{a}	0.88	0.87	0.88	84.49	85.83	85.16 ^{bc}
Line 1019	31.13 $^{a-c}$	31.49	31.31 ^{ab}	34.38 $^{b-d}$	33.41 $^{a-c}$	33.90 ^{b}	0.87	0.86	0.87	86.41	86.73	86.57 ^{a}
Line 1101	29.09 $^{d-f}$	30.09	29.59 ^{e}	33.64 ^{cd}	31.40 $^{c-e}$	32.52 $^{b-d}$	0.88	0.87	0.88	85.12	85.49	85.31 ^{bc}
Line 1102	30.79 $^{a-c}$	31.18	30.99 $^{a-c}$	32.88 ^{d}	31.88 $^{b-e}$	32.38 $^{b-d}$	0.87	0.86	0.87	84.82	84.88	84.85 $^{b-d}$
Line 1103	32.11 ^{a}	31.61	31.86 ^{a}	35.74 $^{a-c}$	30.49 ^{de}	33.12 $^{b-d}$	0.88	0.86	0.87	86.79	84.89	85.84 ^{ab}
Line 1105	28.55 ^{f}	29.92	29.24 ^{e}	33.68 ^{cd}	30.56 ^{de}	32.12 $^{b-d}$	0.88	0.87	0.88	84.62	84.65	84.64 ^{cd}
Line 1109	29.15 $^{d-f}$	30.49	29.82 ^{de}	33.72 ^{cd}	32.34 $^{b-e}$	33.03 $^{b-d}$	0.88	0.87	0.88	83.38	84.23	83.81 ^{d}
Line 1115	31.80 ^{ab}	32.13	31.97 ^{a}	33.84 ^{cd}	29.73 ^{e}	31.79 ^{cd}	0.86	0.85	0.86	85.84	84.73	85.29 ^{bc}
Controls												
Sure Grow 125	29.68 $^{c-f}$	30.67	30.18 $^{c-e}$	33.41 ^{cd}	29.96 ^{e}	31.69 ^{cd}	0.87	0.88	0.88	85.64	85.13	85.39 ^{bc}
Gloria	31.51 ^{ab}	31.25	31.38 $^{a-}$	37.77 ^{a}	34.40 ^{ab}	36.09 ^{a}	0.87	0.87	0.87	86.04	85.57	85.81 ^{ab}
Flash	30.50 $^{a-d}$	31.07	30.79 $^{b-d}$	34.07 $^{b-d}$	31.33 $^{c-e}$	32.70 $^{b-d}$	0.88	0.87	0.88	85.21	85.21	85.21 ^{bc}
Average (Years)	30.27 ^{b}	31.13 ^{a}	30.70	34.25 ^{a}	31.80 ^{b}	32.77	0.87 ^{a}	0.86 ^{b}	0.87	85.12	85.30	85.21
CV (%)	3.19	2.74	2.97	4.54	4.99	4.76	1.05	0.94	1.00	1.13	1.10	1.12
$LSD_{(0.05)}$ Genotypes	1.62**	1.43	1.06**	2.61*	2.66**	1.82**			0.0038**	1.61	1.58	1.107**
$LSD_{(0.05)}$ Years			0.14**			0.69**			0.0064			0.42
$LSD_{(0.05)}$ Genotypes x Years			1.50			2.58						1.57

*CV (%): Coefficient of Variation; LSD (0.05): Least Significant Degree; *: p>0.05; **: p>0.01; ns: non-significant; p: Probability.*

Table 4. Values of genotypes for the traits examined

Genotypes	Fiber elongation (%)			Short fiber index (%)			Spinning consistency index		
	2017	2018	Average (Genotypes)	2017	2018	Average (Genotypes)	2017	2018	Average (Genotypes)
Crosses									
Line 1005	7.70 ^{ab}	7.13 $^{a-c}$	7.42 ^{ab}	8.17 ^{a}	5.80 $^{h-j}$	6.99 ^{a}	135 ^{g}	153 $^{b-f}$	144 $^{d-g}$
Line 1006	7.53 ^{ab}	7.15 $^{a-c}$	7.34 $^{a-c}$	7.91 ^{ab}	5.81 $^{h-j}$	6.86 ^{ab}	138 ^{g}	145 $^{d-g}$	142 $^{e-g}$
Line 1008	7.54 ^{ab}	6.12 ^{f}	6.83 ^{de}	7.55 $^{a-d}$	6.05 $^{f-j}$	6.80 ^{ab}	148 $^{c-g}$	148 $^{b-g}$	148 $^{c-f}$
Line 1013	6.70 ^{c}	6.47 ^{ef}	6.59 ^{e}	7.02 $^{b-g}$	5.03 ^{j}	6.03 $^{b-e}$	155 $^{a-e}$	161 ^{ab}	158 ^{ab}
Line 1019	7.91 ^{a}	7.49 ^{a}	7.70 ^{a}	6.41 $^{e-i}$	5.51 ^{ij}	5.96 ^{e}	154 $^{a-e}$	158 $^{a-d}$	156 $^{a-c}$
Line 1101	7.54 ^{ab}	7.31 ^{a}	7.43 ^{ab}	7.30 $^{a-e}$	5.42 ^{ij}	6.36 $^{a-e}$	142 $^{e-g}$	144 $^{d-g}$	143 $^{d-g}$
Line 1102	7.54 ^{ab}	7.15 $^{a-c}$	7.35 $^{a-c}$	7.29 $^{a-e}$	6.02 $^{g-j}$	6.66 $^{a-e}$	144 $^{e-g}$	147 $^{c-g}$	146 $^{d-g}$
Line 1103	7.76 ^{ab}	7.24 ^{ab}	7.50 ^{ab}	5.82 $^{h-j}$	6.49 $^{d-i}$	6.16 $^{b-e}$	160 $^{a-c}$	142 $^{e-g}$	151 $^{b-d}$
Line 1105	7.54 ^{ab}	7.29 ^{a}	7.42 ^{ab}	7.24 $^{a-e}$	6.22 $^{e-i}$	6.73 $^{a-c}$	139 ^{fg}	136 ^{g}	138 ^{g}
Line 1109	6.76 ^{c}	6.48 ^{ef}	6.62 ^{e}	7.76 $^{a-c}$	5.96 $^{g-j}$	6.86 ^{ab}	137 ^{g}	143 $^{e-g}$	140 ^{fg}
Line 1115	7.52 ^{ab}	7.47 ^{a}	7.50 ^{ab}	6.71 $^{c-h}$	5.56 ^{ij}	6.14 $^{b-e}$	155 $^{a-e}$	144 $^{d-e}$	150 $^{b-e}$
Controls									
Sure Grow 125	7.67 ^{ab}	6.91 $^{b-d}$	7.29 ^{bc}	7.16 $^{a-f}$	5.72 $^{h-j}$	6.44 $^{a-e}$	148 $^{b-g}$	135 ^{g}	141 $^{e-g}$
Gloria	6.79 ^{c}	6.72 ^{de}	6.76 ^{de}	6.29 $^{e-i}$	5.69 $^{h-j}$	5.99 ^{de}	166 ^{a}	156 $^{a-e}$	161 ^{a}
Flash	7.21 ^{bc}	6.79 $^{c-e}$	7.00 ^{cd}	7.14 $^{a-f}$	6.29 $^{e-i}$	6.72 $^{a-d}$	145 $^{d-g}$	146 $^{d-g}$	145 $^{d-g}$
Average (Years)	7.40 ^{a}	6.98 ^{b}	7.19	7.12 ^{a}	5.82 ^{b}	6.47	148	147	148
CV (%)	5.34	3.13	4.45	9.60	9.89	9.77	5.55	5.34	5.45
$LSD_{(0.05)}$ Genotypes	0.66*	0.36**	0.37**	1.14*	0.96	0.73*	13.77**	13.20**	9.31**
$LSD_{(0.05)}$ Years			0.14**			0.28**			3.52
$LSD_{(0.05)}$ Genotypes x Years			0.52			1.04*			13.17*

*CV (%): Coefficient of Variation; LSD (0.05): Least Significant Degree; *: p>0.05; **: p>0.01; ns: non-significant; p: Probability.*

Table 5. Correlation coefficients for the examined traits

Properties	Years	Seed cotton yield	Ginning outturn	Fiber yield	Fiber fineness	Fiber length	Fiber strength	Fiber maturity	Uniformity index	Elongation	Short fiber index
Ginning outturn	2017	0.1668									
	2018	0.2321									
Fiber yield	2017	0.9874 **	0.3127 *								
	2018	0.9862 **	0.3883 *								
Fiber fineness	2017	0.4390 **	0.1292	0.4542 **							
	2018	0.3661 *	0.2116	0.3811 *							
Fiber length	2017	0.2622	0.1526	0.2768	-0.1899						
	2018	-0.2236	-0.0037	-0.2132	-0.4999 **						
Fiber strength	2017	-0.0313	-0.0111	-0.0306	-0.1874	0.5382 **					
	2018	-0.0092	0.0155	-0.0119	-0.1014	0.1905					
Fiber maturity	2017	0.4273 **	0.0171	0.4296 **	0.8979 **	-0.0733	0.0488				
	2018	0.2641	0.1938	0.2800	0.9215 **	-0.4570 **	0.1065				
Uniformity index	2017	0.2319	0.2268	0.2637	0.0926	0.5855 **	0.3497 *	0.0767			
	2018	0.1018	0.1744	0.1299	0.0775	0.2685	0.2713	0.0296			
Elongation	2017	-0.1016	0.2395	-0.0735	-0.0709	-0.1102	-0.2998	-0.4940 **	0.0951		
	2018	0.2317	0.0216	0.2260	0.0348	0.0130	-0.2897	-0.3440 *	0.2046		
Sort fiber index	2017	-0.2825	-0.1562	-0.2967	-0.0602	-0.7762 **	-0.5799 **	-0.1102	-0.7610 **	0.0054	
	2018	0.1352	-0.0383	0.1192	-0.0039	-0.3894 *	-0.2984	-0.0064	-0.5271 **	-0.0793	
Spinning consistency index	2017	0.0485	0.1089	0.0644	-0.3260 *	0.7993 **	0.8067 **	-0.1700	0.7542 **	-0.1071	-0.7949 **
	2018	-0.1260	0.0185	-0.1178	-0.4333 **	0.5346 **	0.7960 **	-0.2909	0.6265 **	-0.1072	-0.4411 **

**: p>0.05; **: p>0.01; ns: non-significant; p: Probability.*

Table 6. Analysis of variance for the examined traits over two years

Sources	Degree of freedom	Seed cotton yield (kg ha^{-1})	Ginning outturn (%)	Fiber yield (kg ha^{-1})	Fiber fineness (micronaire)	Fiber length (mm)	Fiber strength (g tex^{-1})	Fiber maturity	Uniformity index (%)	Elongation (%)	Short fiber index (%)	Spinning consistency index
Years (Y)	1	15416.49	210.70 **	30.13	2.66 **	15.59 **	125.58 **	0.0009 **	0.68	3.84 **	35.39 **	8.67
Genotypes (G)	13	84070.21 *	92.39 **	18276.57	2.15	58.89 **	156.59 **	0.0013	31.53 **	10.26 **	10.49 *	3885.53 **
Y x G	13	77110.69 *	70.63 **	16328.32	1.30	14.98	41.44	0.0008	20.10	2.28	11.60 *	1776.48 *
Replications (in years)	4	27132.69	9.53	4208.77	0.23	6.49	15.39	0.00000013	16.11	0.50	5.26	733.52
Error	54	251105.37	57.14	50570.46	5.34	43.38	128.41	0.0040	47.43	5.32	20.81	3360.70
Total	85	454835.47	440.38	89314.26	11.68	139.33	467.41	0.0070001	115.85	22.2	83.55	9764.9

**: p>0.05; **: p>0.01; ns: non-significant; p: Probability.*

Biplot Analysis

Biplot analysis is a method that graphically presents the results of principal component analysis (PCA) Gabriel (1971). Evaluating the genotype x trait interaction, the total variation (Component 1 + Component 2) was low due to low heterozygosity in the population and it was 62.5% in 2017 and 53.0% in 2018 (Figures 1 and 2). Ginning outturn and fiber elongation contributed less than fiber uniformity index, fiber length and fiber strength to the variation of 2017, much less than seed cotton yield, fiber yield, fiber fineness, fiber maturity, short fiber index and spinning consistency index (Figure 1).

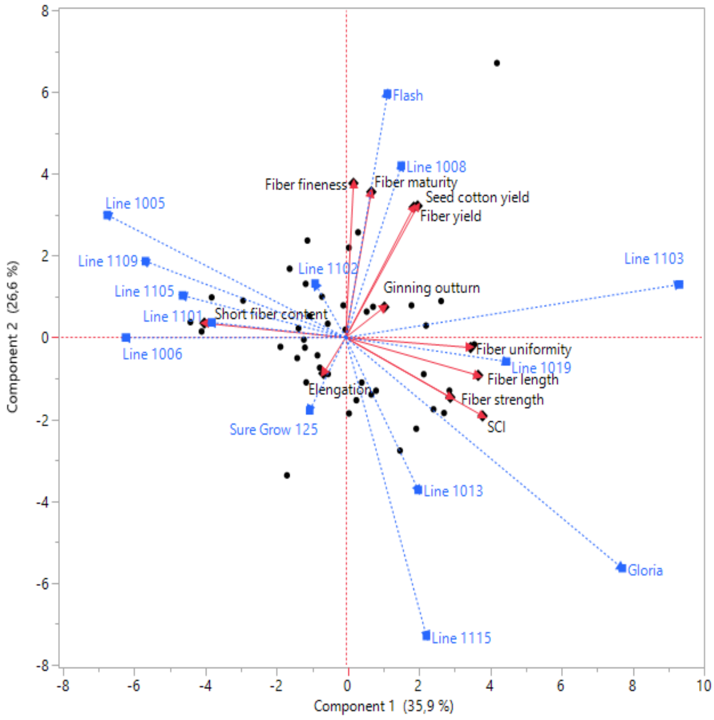

Figure 1. Biplot analysis of genotypes and traits examined in 2017

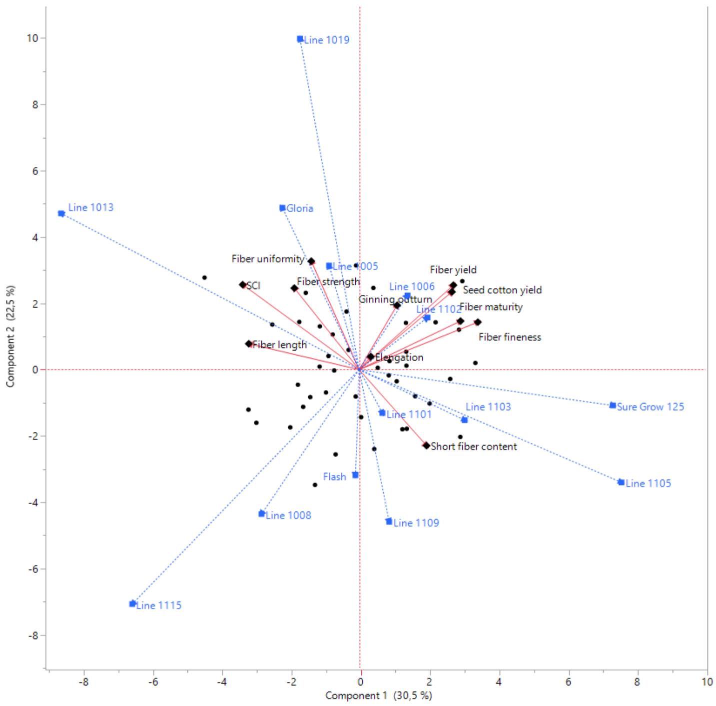

Figure 2. Biplot analysis of genotypes and traits examined in 2018

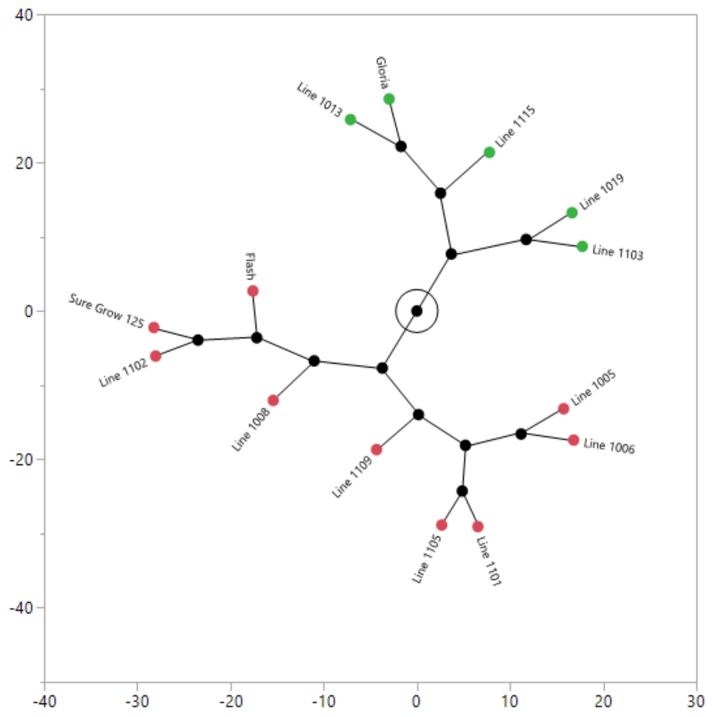

Figure 3. Cluster analysis of genotypes in 2017

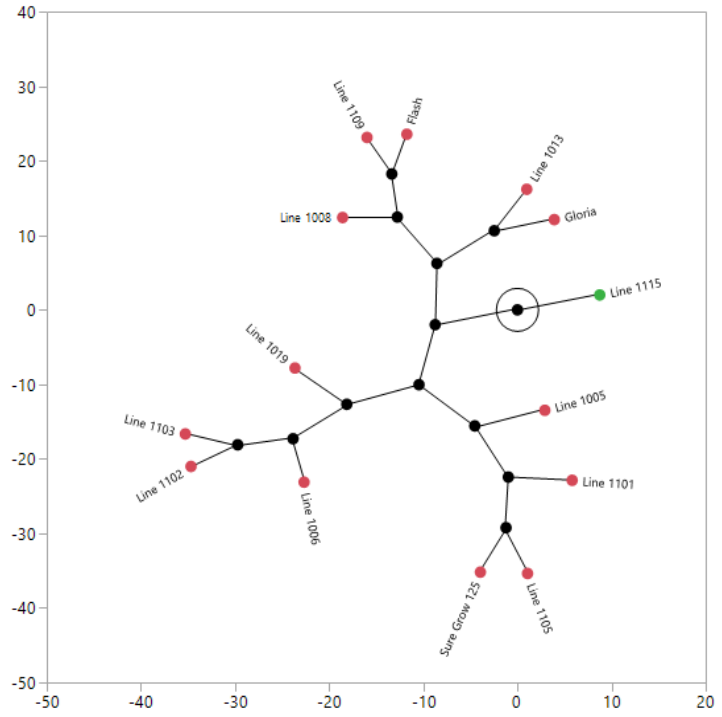

Figure 4. Cluster analysis of genotypes in 2018

Genotypes and traits were divided into four regions in 2017. Among the characteristics, seed cotton yield, fiber yield, ginning outturn, fiber fineness and fiber maturity were located in the first, fiber length, fiber strength, fiber uniformity index and SCI in the second, fiber elongation in the third, and short fiber index in the fourth, while genotypes Flash, Line 1008, Line 1103 was located in the first, Line 1013 and Line 1019 in the second, Sure Grow 125 in the third, Line 1101, Line 1105, Line 1109, Line 1005 and Line 1102 in the fourth, Line 6 in the third and fourth zones. Among the genetypes, Gloria, Flash, Line 1005, Line 1103 and Line 1115 contributed the highest to the total variation, while Sure Grow 125 and Line 1102 contributed the lowest. Similarity were found between genotypes Gloria with Line 1013, Line 1019, Line 1103 and Line 1115, Sure Grow with Line 1115, Line 1013, Line 1006, Line 1101 and Line 1105, and Flash with Line 1008, Line 1102, Line 1005 and Line 1103. On the other hand, a difference was detected between Sure Grow 125 with Line 1008, Flash with Sure Grow 125, Gloria with Line 1005 and Line 1102.

At the end of the study, Line 1008 was found to be more important than Flash, which showed similarities in terms of seed cotton yield, ginning outturn, fiber yield, fiber fineness and fiber maturity. Line 1019 was stable in terms of fiber length and fiber uniformity index, and positively differentiated from Gloria variety in terms of fiber strength and SCI with Line 1013 and Line 1115 hybrids. Line 1005, Line 1006, Line 1101, Line 1102, Line 1105 and Line 1109 hybrids have attracted attention with their high short fiber ratios.

On the other hand, the characters were divided into three regions in 2018, and the relationship between seed cotton yield, fiber yield, ginning outturn, fiber maturity and fiber fineness was also observed this year (Figure 2). In 2018, seed cotton yield, fiber yield, ginning outturn, fiber fineness, fiber elongation and fiber maturity were in the first, short fiber index was in the second, fiber length, fiber strength, fiber uniformity index and spinning consistency index were in the third region, whereas Line 1102 and Line 1006 was located in the first zone, Sure Grow 125, Line 1103, Line 1105, Line 1101 and Line 1109 in the second, Flash, Line 1008 and Line 115 in the third, Line 1013, Gloria, Line 1005 and Line 1019 in the fourth zone. In 2018, fiber elongation contributed little to the total variation, and the contribution of ginning outturn, fiber length and fiber strength were among other characters with fiber elongation. Of the hybrids, Line 1019, Line 1013 and Line 1115 contributed very high to the variation, while Line 1101 contributed very little. Line 1006 and Line 1102 in the first zone were not similar to Flash, Line 1008 and Line 1115 in the third zone as well as Line 1019, Line 1005, Gloria and Line 1013 in the second zone showed not similarity with Sure Grow 125, Line 1103, Line 1105, Line 1101 and Line 1109 in the fourth zone. This may be due to the genetic potential of the plants.

Clustering analysis

Clustering analysis is a method that enables determination of genetic distance, grouping genotypes according to characteristics and visual presentation of results in a genotype set (Spasova et al., 2016). The genotypes formed two clusters in both 2017 and 2018.

In 2017, Sure Grow 125, Flash, Line 1005, Line 1006, Line 1008, Line 1101, Line 1102, Line 1105 and Line 1109 formed the first cluster, while Gloria, Line 1013, Line 1115, Line 1019 and Line 1103 formed the second cluster (Figure 3). Values beloging to clusters were seed cotton yield, 2997.4 kg ha^{-1} and 277.71 kg ha^{-1}, ginning outturn value, 42.18% and 43.14%, fiber yield, 1268.2 and 1201.6 kg ha^{-1}, fiber fineness, 5.07 and 4.92 mic, fiber length, 29.54 and 31.59 mm, fiber strength, 33.47 and 35.66 g tex^{-1}, fiber maturity, 0.87 and 0.87, fiber uniformity index, 84.68% and 85.91%, elongation, 7.44% and 7.34%, short fiber index, 7.50% and 6.45%, and SCI, 141.88 and 158.33.

The first cluster was more important in terms of seed cotton yield and fiber yield, and the second cluster in terms of ginning outturn and fiber properties. When the difference between genotypes is examined, 1.84 between Line 1102 and Sure Grow 125 and 3.13 between Line 1102 and Flash, 1.89 between Line 1101 and Line 1105 in addition to 2.51, 2.97, 3.33, 4.19 and 5.33 between Line 1005 and Line 1006, Line 1101, Line 1109, Line 1008, Line 1013, respectively, 2.92 between Line 1019 and Line 1103, and as well as, 3.32, 4.42 and 5.08 between Line 1013 and Gloria, Line 1115 and Line 1019, respectively, and 3.71 between Line 1008 and Line 1102 were found. In 2018, Line 1115 alone constituted the first and worst cluster, and the other thirteen genotypes constituted the second cluster (Figure 4). Values of these clusters were following; seed cotton yield, 2773.4 kg ha^{-1} and 3221.7 kg ha^{-1}, ginning outturn, 39.11% and 39.37%, fiber yield, 108.61 kg ha^{-1} and 1269.4 kg ha^{-1}, fiber fineness, 4.23 and 4.70 mic, fiber length, 32.13 mm and 31.05 mm, fiber strength, 29.73 and 31.96 g tex^{-1}, fiber maturity, 0.85 and 0.87, fiber uniformity index, 84.73 and 85.35%, elongation, 7.47 and 7.44%, short fiber index, 5.56% and 5.85%, and spinning consistency index, 144.67 and 147.30. In addition, genetic differences were found between genotypes as 2.19 between Line 1109 and Flash, 2.38 between Line 1102 and Line 1103, 2.45 between Line 1008 and Line 1109, 2.57 and 3.98 between Line 1006 and Line 1102 and Line 1019, 3.84 between Line 1013 and Gloria, 3.19 between Sure Grow 125 and Line 1105, 3.43 between Line 1101 and Line 1105, 4.37, 4.74, 4.86 and 5.60 between Line 1005 and Line 1101, Line 1006, Line 1008 and Line 1115, respectively. While Line 1013 was in the same cluster with Gloria, Line 1019 and Line 1103 in two years, it attracted attention in terms of seed cotton yield and fiber quality.

CONCLUSIONS

According to the two-year results of the study, a significant and positive relationship between seed cotton yield and fiber yield, ginning outturn, fiber maturity and fiber fineness, as well as between spinning consistency index and fiber uniformity index, fiber length, and fiber strength, which do not change even if environmental conditions change. Gloria has been the most important variety in terms of fiber properties. Line 1019 and Line 1103 were found to have similar fiber quality to Gloria but more yielding than it. Line 1102 hybrid has been the most important genotype to increase the yield of the region. This hybrid showed the potential to preserve fiber quality characteristics while increasing the cotton yield of the region by 17.13% and the fiber yield by 16.24% compared to controls average over the two-years. Line 1115 did not adapt to regional conditions. In addition, the performance of the control Gloria variety in terms of fiber length, fiber strength, fiber uniformity index and SCI in both 2017 and 2018 showed that it is suitable for breeding programs.

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