RESPONSE OF COTTON (*Gossypium hirsutum* L.) HYBRİD (F_{5-6}) TO CLIMATIC DIFFERENCES IN TERM OF YIELD AND YIELD COMPONENTS

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Abstract. Cotton yield is affected by environmental conditions. This study was carried out to determine the population means response in eleven hybrids and three check cotton cultivars to climate changes in Antalya-Turkey, in 2017 and 2018. Temperature, relative humidity and precipitation in these years were found to have varied in Antalya. In the May-October period of 2018, the totals of average and maximum temperature were seen higher than in 2017 as opposed to the total of minimum temperature, but the distribution of temperature, relative humidity and precipitation varied according to months. While the genotypes affected by this situation had taller height and more fruiting branches in 2018, they created fewer vegetative branches, had a lower ginning outturn and fewer bolls. On the other hand, while the in Flash cultivar the number of bolls decreased in 2018, in Gloria the loss ratio of bolls minimized. Furthermore, in Sure Grow 125 the seed cotton yield per boll increased and the yield reduced, lower ginning outturn and boll losses were observed that affected fiber yield. As a result of the study, it has been determined that Sure Grow 125 has a high tolerance to climate change and maintains its yield potential and Gloria variety had higher yield at low temperatures, while the hybrids have the genetic potential to increase seed cotton yield in Antalya.
Keywords: *climate change, cotton, fiber yield*

Introduction

Cotton is the most important fiber plant for Turkey as well as for other countries. The rapidly increasing world population and use of natural fiber increase the importance of cotton, while the need of cotton cultivars to special environmental conditions with the global warming limited the production. Turkey ranked as the 7th country in terms of the world cotton production (Kolay, 2019) and this production involves varieties of *Gossypium hirsutum* L. However, climate change in recent years, as in other countries, affects the temperature and precipitation of Turkey. Although a solution is sought for this problem, the genetic potentials of the varieties is of great importance for the solution of possible problems.

Cotton encounters with a lot of biotic and abiotic stress throughout its life and reacts differently with its genetic heritage. These responses can be different depending on the severity of the stress and the stage of plant development. For example, the temperature stress caused by global warming, which is one of the biggest problems of today, affects germination, growth, flowering and boll formation. Moreover, if no precautions are taken, global warming will occur due to the CO_2 increase in the atmosphere by an average of 2.5 °C (1.5 - 4.5 °C) until 2100 (Aksay et al., 2005). This problem will cause melting of polar glaciers, changing day/night temperature difference and precipitation

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regime. While plants respond to this situation with field change, germination and lack of development, yield and quality losses. Researchers found that the accumulation of dry matter in cotton occurred at the peak flowering stage and day/night temperature were 30/20 °C (Reddy et al., 1991), and that air temperature, sunlight, soil and relative humidity were also important (Hake and Silvertooth, 1990). Temperatures up to 30-32 °C are effective in boll production but exceeding 32 °C are harmful because they cause a decrease in yield due to square shedding (Unay and Basal, 2005). In addition, Loka and Oosterhuis (2010) reported a decrease in the amount of carbohydrates with respiratory acceleration due to high night temperature.

On the other hand, cotton farming has also been reported to be affected by low temperatures. In particular, temperatures below 10-12 °C cause death by creating a shock effect, while the severity and duration of temperatures of more than 12 °C and less than 18 °C during the germination period, prolonging the growth, development and harvest periods of the plant, delays to pass following stage (Basra, 1999). In contrast, plants can respond to high temperature by controlling stomatal conductivity and stoma number, changing leaf area and leaf number, low temperatures by increasing earliness. Deltapine 41, Africa E5 and Campu cultivars (Gonen, 2017) as well as Melez-1 (Salman et al., 2019) were tolerant to high temperature stresses. Anjum and Khatoon (2003) had reported that *Gossypium hirsutum* L. species were more tolerant than *Gossypium arboreum* L. regarding low temperatures. On the other hand, the period, time, duration and intensity of precipitation affect the germination, growth and development of cotton. While strong and long-term rains that occur after planting reduce germination and seedling emergence, rains occurring during squaring, blooming and boll opening decrease pollination and cause shedding in bolls and contamination in fiber. On the other hand, the precipitation in May and June affects the yield positively (Cetin and Basbag, 2010).

This study was carried out in Antalya to determine the reaction of some cotton genotypes (homozygous and heterozygous, F_{5-6}) with different genetic structure to different climatic conditions.

Materials and Methods

This study was carried out in Antalya-Turkey (36° 53' 48.8" N - 30° 42' 53.4" E, altitude: 39 m) in 2017 and 2018. 11 heterozygote genotypes (Cross-1005, Cross-1006, Cross-1008, Cross-1013, Cross-1019, Cross-1101, Cross-1102, Cross-1103, Cross-1105, Cross-1109 and Cross-1115) were used as plant material with 3 homozygous control cotton (*Gossypium hirsutum* L.) namely Sure Grow 125, Gloria and Flash.

The study was carried out with three replications in randomized complete blocks design in 2017 and 2018. Genotypes were planted on May 8th, 2017 and May 10th, 2018, in 10 meters long rows of 4 in parcels. Distance between rows was 0.70 m, while 0.15 m from plant to plants in one row.

With the planting, 60 kg ha^{-1} of pure nitrogen (N) and 6 kg ha^{-1} pure phosphorus (P_2O_5) were given in the form of compound (20-20-0), and 100 kg ha^{-1} of pure nitrogen (N) was given as urea (46% N) before the second irrigation.

Harvesting was done by hand on October 23rd, 2017 and on October 17th, 2018. While seed cotton yield and fiber yield per hectare were determined from the parcels, the ginning outturn was determined with the following formula (Eq.1) below. Other characteristics were determined over 20 plants in each plot, also. Variance analyses

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were done in JMP 13 software with data collected from experiment according to split plots design in randomized complete blocks.

$$\% \text{ Ginning outturn: (Fiber yield/Seed cotton yield)*100} \qquad \text{(Eq.1)}$$

The experiment area is sandy-clay, slightly alkaline, salt-free, and is poor in organic matter (1.55%). Climate data of Antalya for 2017 and 2018 differed greatly (*Table 1*). While the first four months of 2018 were hotter, more humid, and rainier than 2017, these values differed in the cotton season (May-October) compared to the months. However, according to long term, while averages of minimum and maximum temperatures were lower in both 2017 and 2018 in the first four months, precipitation was higher. On the other hand, average temperature of 2017 was similar with long-term value.

Moreover, it is understood from *Table 1* that precipitation in the cotton season of 2018 were continued monthly, except August, and 25.2% (139 mm) of total annual precipitation (549.8 mm) fell in the cotton season. According to long term value, 2017 was very dry compared to 2018, but 2018 showed similarity with long term value in term of precipitation in the cotton growing season.

On the other hand, when the data for this period were analyzed, it was observed that the average and maximum temperatures in June and July 2018 were less than in 2017 and but similar August and high in September and October. Furthermore, in total minimum temperatures different were 13.3 ^{o}C the effects of May, July, August and October.

As a result of this study, it was determined that 2017 was drier than both 2018 and long-term averages, while the maximum temperatures for 2017 and 2018 were lower than the long-term average, whereas the minimum temperatures were higher, and 2017 was similar to the long-term value in term of average temperature. The study was analyzed according to the split plot method in a randomized block design, and population means of eleven hybrid combinations were compared with standard-control varieties. In the study, while comparison of genotypes was done with LSD $_{(0.05)}$ (Least significant degree), the yields of genotypes for years were compared with the "t-test" and the following equation (Eq.2) below.

$$\% \text{ Difference: ((Value }_{2018}\text{-Value }_{2017}\text{) / Value }_{2017}\text{) * 100} \qquad \text{(Eq.2)}$$

Results and Discussion

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

Seed cotton yields of genotypes differed over the years (*Table 2*). In the cotton season of 2018, the total average and maximum temperature was 3.1 ^{o}C and 14.2 ^{o}C more than 2017, and the minimum temperature was 13.3 ^{o}C less in total. As reported by Salman et al. (2019), heterozygous hybrids and homozygous Gloria responded positively to climate change unlike Flash cultivar while Sure Grow 125 responded negatively that was statistically non-significant. While the seed cotton yield of hybrids increased from 284.8 kg ha^{-1} (2017) to 322.9 kg ha^{-1} (2018), the average of controls decreased from 3179.2 kg ha^{-1} (2017) to 3045.6 kg ha^{-1} (2018), and the average of the region decreased from 3112.9 kg ha^{-1} (2017) to 3082.3 kg ha^{-1} (2018).

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Table 1. *Climate data of Antalya province in 2017 and 2018 with long term average*

MONTHS	Average Temperature (ºC)				Minimum Temperature (ºC)				Maximum Temperature (ºC)				Average Relative Humidity (%)			Precipitation (mm)			
	2017	**2018**	**LT**	**Dif.**	**2017**	**2018**	**LT**	**Dif.**	**2017**	**2018**	**LT**	**Dif.**	**2017**	**2018**	**Dif.**	**2017**	**2018**	**LT**	**Dif.**
January	8.5	10.8	10.0	2.3	0.3	1.7	-4.3	1.4	17.8	20.9	23.9	3.1	68.7	72.2	3.5	56.0	10.8	242.1	-45.2
February	10.4	12.8	10.6	2.4	-1.0	3.4	-4.6	4.4	21.8	21.2	26.7	-0.6	62.0	83.0	21.0	5.0	91.0	154.4	86.0
March	13.1	15.0	12.8	1.9	1.7	6.8	-1.6	5.1	24.4	25.8	28.6	1.4	71.5	78.9	7.4	70.0	94.0	97.2	24.0
April	16.4	18.5	16.3	2.1	4.4	6.7	1.4	2.3	31.6	35.2	36.4	3.6	69.2	68.7	-0.5	27.0	2.0	50.4	-25.0
Total	48.4	57.1	49.7	8.7	5.4	18.6	-9.1	13.2	95.6	103.1	115.6	7.5	271.4	302.8	31.3	158.0	197.8	544.1	39.8
Average	12.1	14.2	12.4	3.5	2.2	7.4	-2.3	5.3	38.2	41.2	28.9	3.0	108.6	121.1	12.5	63.2	79.1	136.0	15.9
May	20.5	23.2	20.5	2.7	12.1	11.9	6.7	-0.2	33.5	35.6	38.7	2.1	73.0	66.2	-6.8	35.0	19.0	32.1	-16.0
June	25.8	25.5	25.3	-0.3	15.5	16.3	11.1	0.8	44.5	38.0	44.8	-6.5	66.4	72.8	6.4	0.0	65.0	10.9	65.0
July	29.4	28.5	28.4	-0.9	18.3	18.2	14.8	-0.1	44.8	43.3	45.0	-1.5	62.0	65.8	3.8	0.0	18.0	4.5	18.0
August	27.9	28.0	28.3	0.1	19.0	17.2	13.6	-1.8	40.3	40.8	44.6	0.5	72.3	71.2	-1.1	0.0	0.0	4.6	0.0
September	25.2	25.9	25.1	0.7	14.7	15.2	10.3	0.5	36.9	40.7	42.5	3.8	72.4	65.1	-7.3	0.0	13.0	18.1	13.0
October	19.7	20.4	20.5	0.7	19.7	7.2	4.9	-12.5	19.7	35.5	38.7	15.8	64.9	67.3	2.3	29.0	24.0	72.1	-5.0
Total	148.4	151.5	148.1	3.0	99.3	86.0	61.4	-13.3	219.7	233.9	254.3	14.2	411.0	408.4	-2.6	64.0	139.0	142.3	75.0
Average	24.7	25.2	24.6	0.5	16.6	14.3	10.2	-2.2	36.6	39.0	42.4	2.4	68.5	68.1	-0.4	10.7	23.2	23.7	12.5
November	14.4	15.7	15.4	1.3	3.1	7.2	0.0	4.1	32.2	31.5	33.0	-0.7	74.0	72.5	-1.5	48.0	57.0	133.6	9.0
December	12.0	11.5	11.6	-0.5	0.8	0.0	-1.9	-0.8	25.9	21.6	25.4	-4.3	81.8	78.0	-3.8	74.0	156.0	265.3	82.0
Total (Year)	223.2	235.7	224.8	12.5	108.6	111.8	50.4	3.2	373.4	390.1	428.3	16.7	838.2	861.5	23.4	344.0	549.8	1085	205.8
Average (Year)	17.2	18.1	18.73	1.0	8.4	8.6	4.2	0.2	28.7	30.0	35.7	1.3	64.5	66.3	1.8	26.5	42.3	90.4	15.8

LT: Long term average (1930-2019), Dif: Difference (2018-2017)

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Table 2. *Analysis of variance of the parameters studied*

Sources	Degree of freedom	Seed cotton yield (kg ha^{-1})	Ginning outturn (%)	Lint yield (kg ha^{-1})	Plant height (cm)	Number of boll per plant (count)	Boll weight (g)	Number of sympodial branches (count)	Number of monopodial branches (count)
Replications	2	4752.83	0.18	935.92	382.93	10.45	1.62	0.44	1.62
Years (Y)	1	7101.67	6.70	1747.52	5809.48	36.51	0.19	28.17	0.06
Genotypes (G)	4	13498.83	10.04	1894.89	167.50	37.86	1.20	5.46	2.48
Y x G	4	10929.05	4.27	1582.84	57.65	16.38	1.03	4.27	0.59
Error	18	41818.84	8.43	6567.25	2003.91	105.61	3.50	12.57	6.15
Total	29	62097.22	57.23	10081.55	32964.48	194.23	6.79	92,48	14.61
CV (%)		15.56	1.68	15.14	9.38	15.87	10.04	5.71	17.80
$LSD_{(0.05)\ Years}$		82.68 *	1.17 *	32.77	18.10 *	4.16 *		1.43 *	
$LSD_{(0.05)\ Genotypes}$		82.68	1.17 *						

CV (%): Coefficient of Variation, $LSD_{(0.05)}$: Least Significant Degree, *: p<0.05, **: p<0.01, ns: non-significant, p: Probability

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While Gloria cultivar had positive effect on averaged controls from 2742.2 kg ha^{-1} (2017) to 3052.2 kg ha^{-1} (2018), Flash had negative contribution from 3592.1 kg ha^{-1} (2017) to 2904.0 kg ha^{-1} (2018) as Sure Grow 125 from 3203.3 kg ha^{-1} (2017) to 3180.7 kg ha^{-1} (2018). In other words, climate difference had an effect of 13.38% in hybrids, -0.67% in Sure Grow 125, 11.3% in Gloria, -19.2% in Flash, -4.18% in the control mean, and -1% in the region average. This situation may have been caused by genotype x environment dissonance.

While the effect of climate difference on the seed cotton yield was more negative (Chen et al., 2015), Sure Grow 125 was found to be important for both producers and the continuation of the breeding work with the potential to reflect the climate difference to the yield at a minimum rate, and Gloria and hybrids with potential to increase the yield of the region (*Figure 1*).

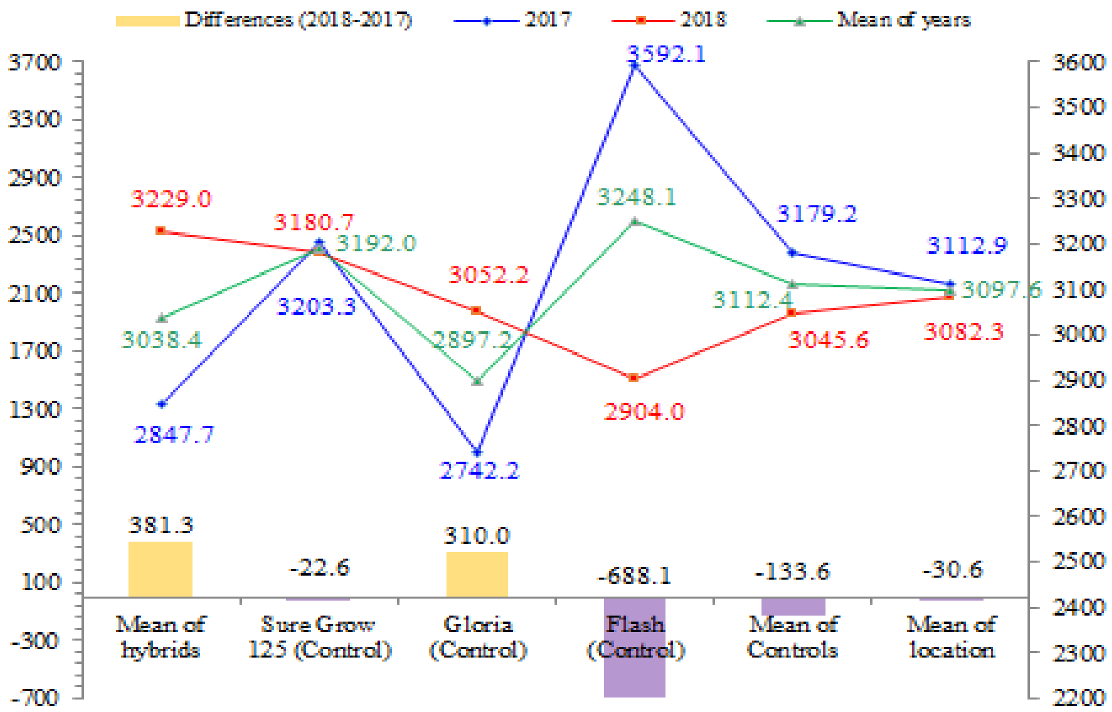

Figure 1. *Seed cotton yield (kg ha⁻¹), average and difference values of the genotypes for years*

Ginning outturn (%)

While genotypes respond to climate change between years by reducing ginning outturn, genotype difference has been found significant (*Table 2 and Figure 2*). The greatest reduction was observed in heterozygous hybrids. Ginning outturn reduced from 42.8% (2017) to 41.0% (2018) in hybrids, from 41.6% (2017) to 39.8% (2018) in the average of controls, from 41.9% (2017) to 39.7% (2018) in the region average.

While Sure Grow 125 was the least affected variety from climate difference and Gloria was the most affected (*Figure 2*), the ginning efficiency decline between years was -8.18% in hybrids, -2.96% in Sure Grow 125, -539% in Gloria, and -5.01% in Flash, -4.33% in the average of controls and -5.25% in the regional average. While climate change reduces ginning outturn in both homozygous and heterozygous

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genotypes, Sure Grow 125 has been found to be important for producers and breeding programs as the least affected variety (*Figure 2*).

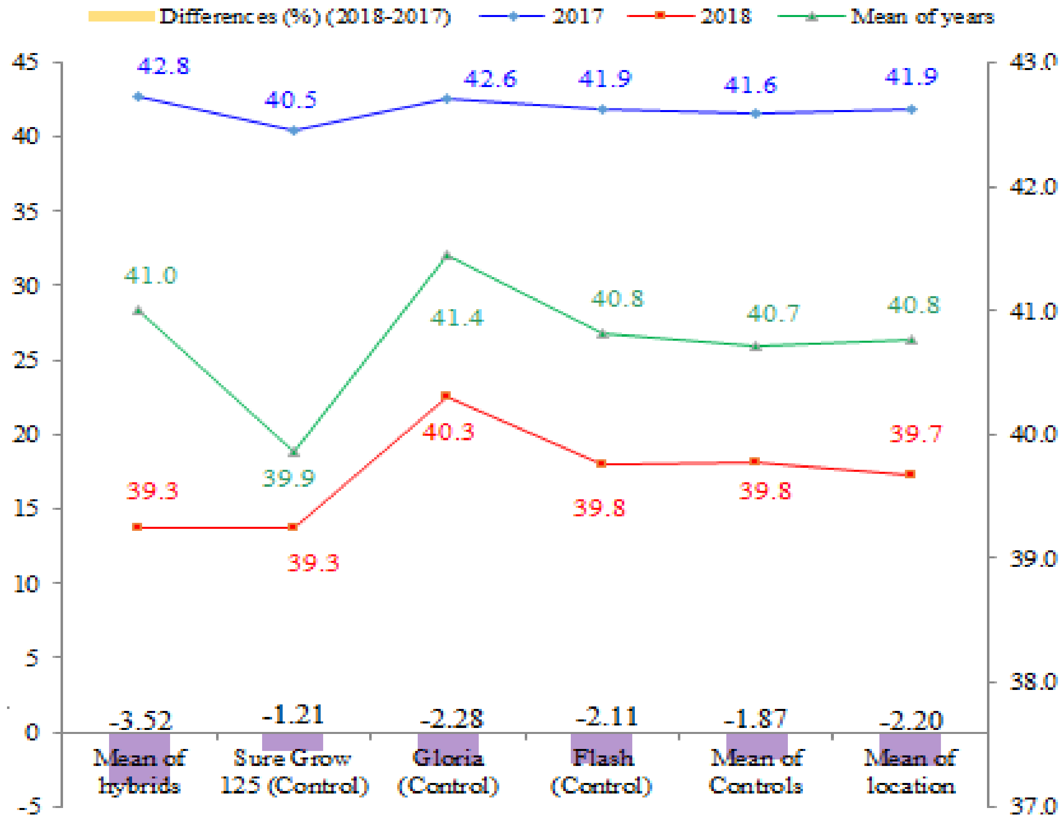

Figure 2. *Ginning outturn (%) average and difference values of the genotypes for years*

Lint yield (kg ha^{-1})

Fiber yield was positively and significantly correlated with seed cotton yield and ginning outturn. In the study where the difference in genotypes and years was significant (*Figure 3*), the fiber yield increased from 122.4 kg ha^{-1} (2017) to 126.9 kg ha^{-1} in hybrids, the average of controls decreased from 132.1 kg ha^{-1} (2017) to 121.1 kg ha^{-1} (2018), and region average decreased from 130.1 kg ha^{-1} (2017) to 122.2 kg ha^{-1} (2018).

Gloria had positive effect on average of controls (from 116.8 kg ha^{-1} (2017) to 122.8 kg ha^{-1} (2018)] while Flash [from 149.9 kg ha^{-1} (2017) to 115.7 kg ha^{-1} (2018)] and Sure Grow 125 [from 129.6 kg ha^{-1} (2017) to 124.7 kg ha^{-1} (2018)] gave negative contribution. The climate difference of the years had positive effect on fiber yield in hybrids (3.68%) and Gloria (5.14%), while Sure Grow 125 (-3.78%), Flash (-22.82%), average of controls (-8.33%) and region average (-6.07%) were negatively affected. Sure Grow 125 was the least affected by climate difference and the control with the highest fiber potential. On the other hand, hybrids had the genetic potential to increase the yield of the region, while the most sensitive variety to climate difference was Flash (*Figure 3*).

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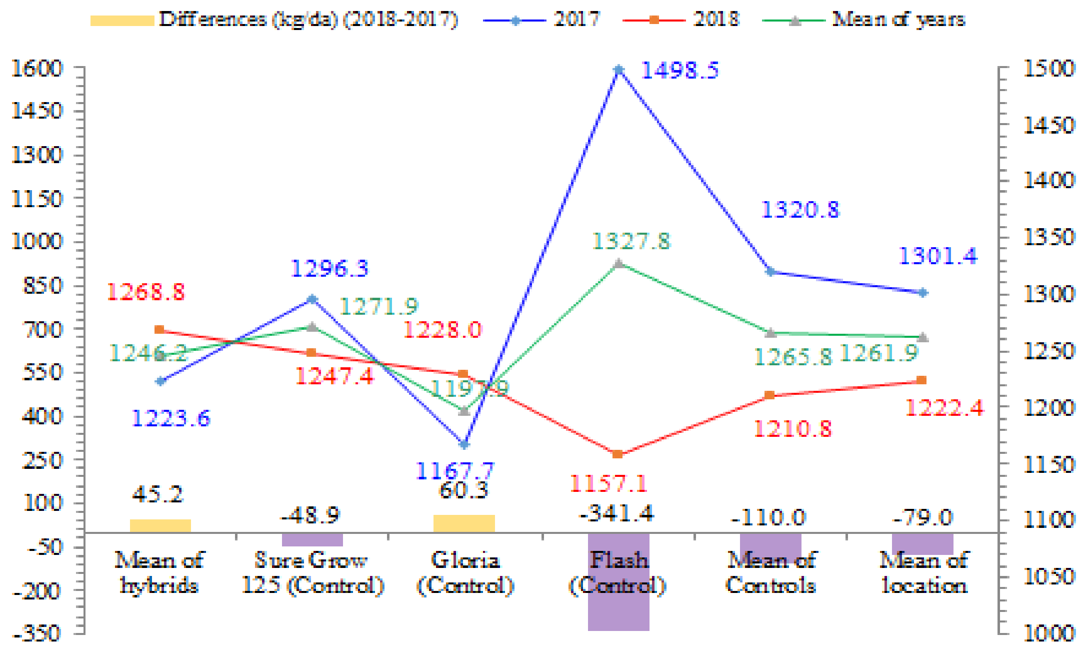

Figure 3. *Fiber yield (kg ha^{-1}) average and difference values of the genotypes for years*

Plant height (cm)

The plant height, which positively correlates with the seed and fiber cotton yields, evaluated climate differences in the direction of vegetative development (*Table 2 and Figure 4*).

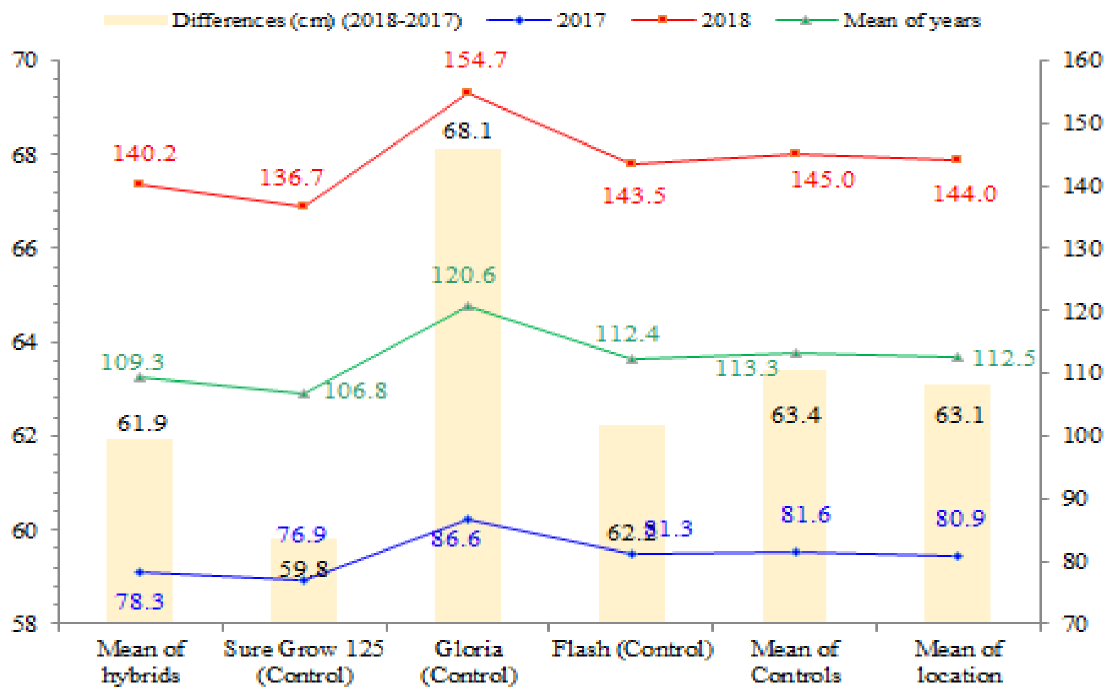

Figure 4. *Plant height (cm), average and difference values of the genotypes for years*

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83 mm precipitation, which fell in July and August 2018, increased atmospheric humidity and caused the temperatures to remain low. Vegetative branches production of plant increased because of average/minimum temperature ratios in June, July and August in 2018 that were incompatible with optimum temperature ratio (30/22 °C) of Reddy et al. (1992). Therefore, the plant height increased from 78.3 cm (2017) to 140.2 cm (2018) in hybrids, from 81.6 cm (2017) to 145 cm (2018) in the control mean and from 80.9 cm (2017) to 144 cm (2018) in the region means (*Figure 4*) but ginning outturn of the region has decreased as well as the seed and fiber cotton yield. While the highest contribution to the average of the controls was from Gloria with 68.1 cm, Sure Grow 125 gave the lowest contribution.

Number of bolls per plant

The number of bolls in a plant is the most important feature that contributes positively to the yield with its boll weight (Worley et al., 1974; Rauf et al., 2006; Srinivas et al., 2014). Since the climatic conditions of 2018 (*Table 1*) encouraged vegetative growth and delayed generative development, the number of bolls of hybrids and varieties decreased.

The number of bolls decreased from 16.1 (2017) to 14.6 (2018) in hybrids, from 16.5 (2017) to 14.0 (2018) on the average of controls, from 16.4 to 14.1 (2017) in the region average that was confirmed by Zhao et al. (2005). While Flash was the biggest contributor to this decrease, Gloria was the most tolerant variety. In other words, climate difference had an impact of -9.32% in hybrids, -11.76% in Sure Grow 125, -3.40% in Gloria, -25.39% in Flash, -15.15% in control mean, and -14.02% in region average. Gloria was found to be important for breeding programs and producers as the most tolerant variety for climate difference (*Figure 5*).

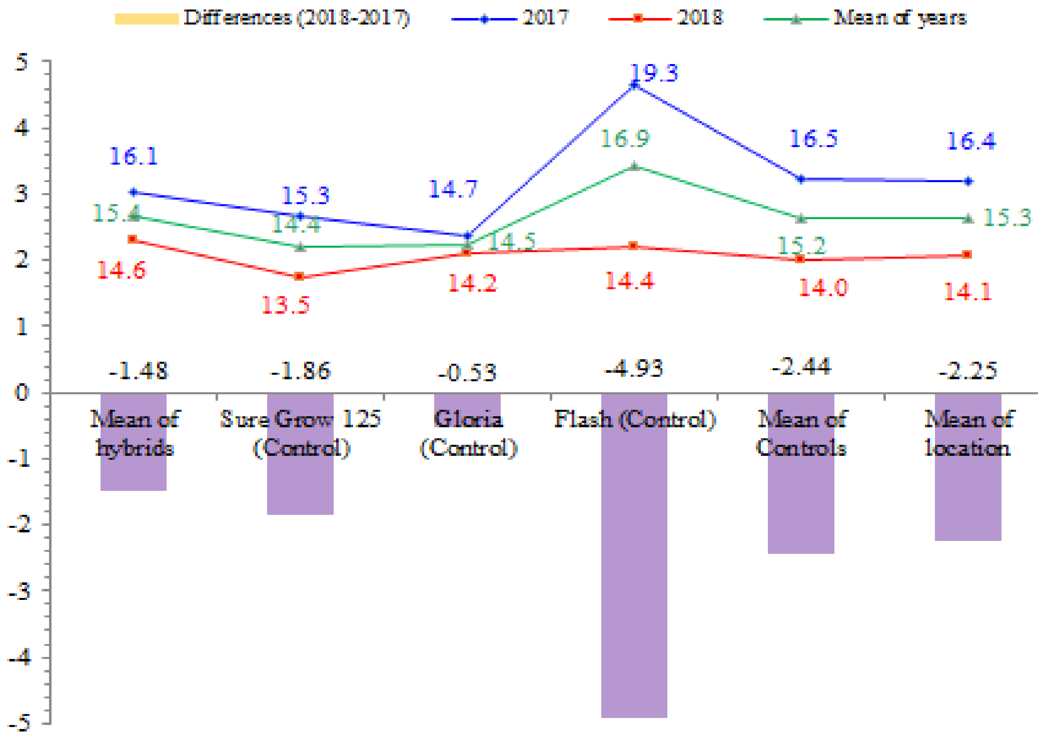

Figure 5. *Number of bolls per plant, average and difference values of the genotypes for years*

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Boll weight (g)

Seed cotton yield per boll is an important feature with a positive correlation with cotton yield (Khalid et al., 2018). The boll weights of hybrids and other controls increased in 2018, except for Sure Grow 125. This was found to be important in terms of reducing the negative impact of climate difference on number of bolls and yield. Boll weight increased from 4.06 g (2017) to 4.28 g (2018) in hybrids, from 4.41 g (2017) to 4.47 g (2018) in control averages, from 4.34 g (2017) to 4.43 g (2018) in region average. Gloria [from 4.07 g (2017) to 4.49 g (2018)] and Flash [4.32 g (2017) to 4.69 g (2018)] had positive effect on average of controls, while Sure Grow 125 [from 4.23 g (2017) to 4.84 g (2018)] had a negative contribution.

In other words, climate difference contributed to the boll weight by 5.42% in hybrids, -12.60% in Sure Grow 125, 10.32% in Gloria, 8.56% in Flash, 1.36% in controls average, and 2.07% in region average. While Sure Grow 125 is the most affected variety of climate change in terms of boll weight, Gloria has been found to be important for breeding programs and producers as the most tolerant variety (*Figure 6*).

Number of fruiting (sympodial) branches

Although the number of fruiting branches is one of the characteristics that positively affect the cotton yield, the number of fruiting branches that sheds bolls is a problem as vegetative growth.

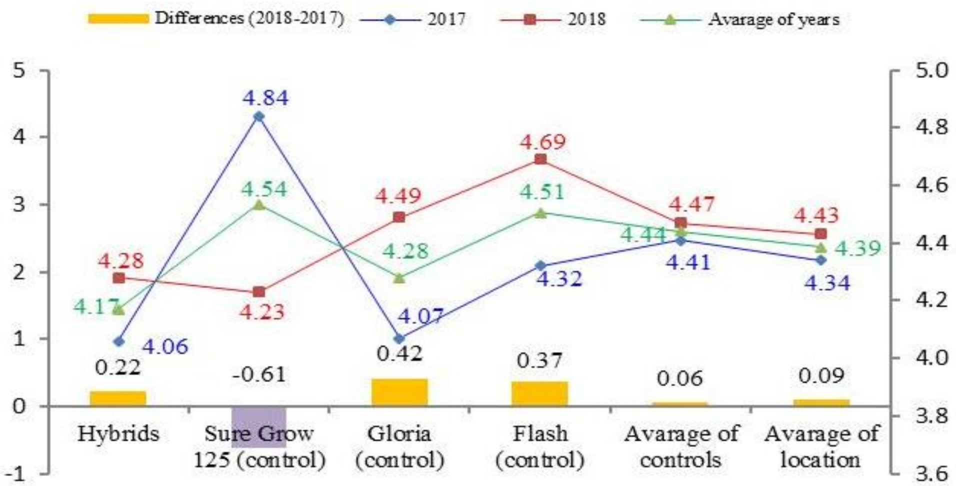

Figure 6. *Boll weight (g), average and difference values of the genotypes for years*

In the study, both homozygous (controls) and heterozygous (hybrids) genotypes increased the number of fruiting branches in 2018 (*Table 2 and Figure 7*), while Flash had the highest number of fruiting branches. Number of sympodial branches increased from 12.9 (2017) to 15.9 (2018) in hybrids, from 13.2 (2017) to 16.2 (2018) in control averages, and from 13.1 (2017) to 16.1 (2018) an average of region that is comparable with Ekinci et al. (2017). In other words, the climate difference contributed the number of fruiting branches as 23.25% in hybrids, 20.8% in Sure Grow 125, 13.98% in Gloria, 33.33% in Flash, 22.72% in the control average, and 22.90% in the region average. While climate change affects Flash variety at most in terms of number of fruiting branches, Gloria was found to be the most tolerant variety for breeding programs and producers (*Figure 7*).

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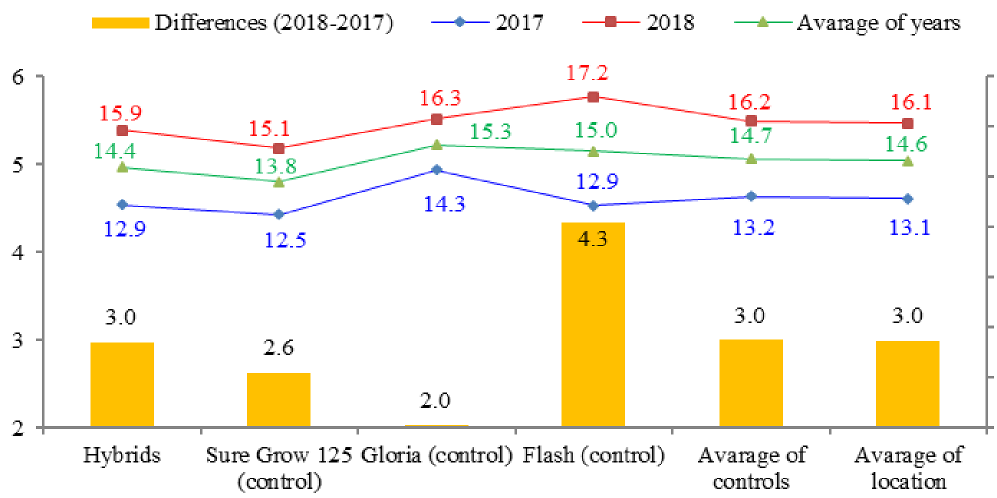

Figure 7. *Number of sympodial branches, average and difference values of the genotypes for years*

Number of vegetative (monopodial) branches

Vegetative branch having bolls affects yield positively, and the non-retainer affects negatively since it is a vegetative shoot. In the study, the number of monopodial branches of other controls and hybrids, except Gloria, decreased in 2018. The number of monopodial branches reduced from 3.77 (2017) to 3.03 (2018) in hybrids, from 3.37 (2017) to 3.14 (2018) in control averages, and from 3.45 (2017) to 3.12 (2018) in region average.

In other words, climate difference contributed to the number of vegetative branches -19.63% in hybrids, -18.73% in Sure Grow 125, 1.84% in Gloria, -5.00% in Flash, -6.83% in the control mean and -9.57% in the region average. While climate difference affects hybrids and Sure Grow 125 the most, Gloria was found to be important for breeding programs and producers as a tolerant variety (*Figure 8*).

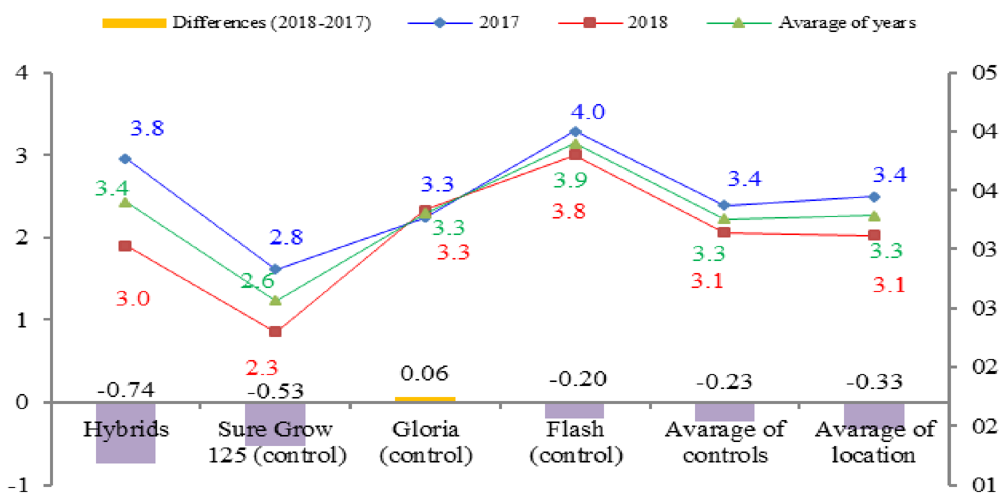

Figure 8. *Number of monopodial branches, average and difference values of the genotypes for years*

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Conclusion

Genotypes differ in terms of ginning outturn compared to the averages of 2017 and 2018. In addition, the differences between years in terms of seed cotton yield, ginning outturn, plant height, number of bolls and number of fruiting branches were also found significant. Hybrids have increased the boll weight and decreased the number of vegetative branches, reducing the potential negative impact of the number of bolls per plant and ginning outturn that are negatively affected by the climate of 2018 on the seed cotton yield and fiber yield. On the other hand, it was determined that the variation continues in hybrids in terms of seed cotton yield, ginning outturn, plant height and number of fruiting branches. Therefore, when suitable plants are selected, the yield of the region may increase. Sure Grow 125, which is one of the controls, is found to be tolerant for the year difference in terms of seed cotton yield, ginning outturn, fiber yield and number of bolls per plant, and is sensitive in terms of boll weight. On the other hand, Gloria was tolerant for fiber yield, number of bolls per plant, number of vegetative branches and had also potential for seed cotton yield, fiber yield, boll weight and number of fruiting branches. Flash was the most sensitive control type in terms of seed cotton yield, ginning outturn, fiber yield, number of bolls per plant and number of fruiting branches. At the end of the study, it has been determined that climate difference will have the least impact on Sure Grow 125, while hybrids have the potential to increase the yield of the region.

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