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Assessment of Tolerance Level of some Cotton (*Gossypium hirsutum* L.) Varieties against *Verticillium wilt* (*Verticillium dahliae* Kleb.)

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Abstract

The objective of this study was to assess the tolerance level of some cotton varieties against *Verticillium* wilt (*Verticillium dahliae* Kleb.) disease. *Verticillium wilt* is one of the major constraint diseases of cotton production worldwide and also in Turkey. The study was carried out at the Southeastern Anatolia Agricultural Research Institute's naturally infected experimental area during 2004-2006. In this study, 10 different commercial cotton varieties were used as plant material. The experimental design was a randomized complete-block with four replications. During the cotton growing season, foliar disease index (FDI), vascular disease index (VDI) and vascular disease rate (VDR) were observed in addition to seed cotton yield and some fiber quality characteristics. According to the results, it was determined that with regards to FDI, VDI and VDR, the most tolerant varieties were 'GW-Teks', 'GW-Golda' and 'Carmen', while the most sensitive varieties were 'Maraş 92', 'Sayar 314' and 'Stoneville 453'. The other varieties had moderate tolerance levels. The highest seed cotton yield and lint yield were obtained from 'DP-Deltaopal' and 'Stoneville 453'. These results showed that some sensitive varieties had high yield; the reason for this situation may be related with early or late occurrence of the disease. The result of this study indicated that 'GW-Teks', 'GW-Golda' and 'Carmen' varieties must be preferred for infected areas; on the other hand, 'DP-Deltaopal' and 'Stoneville 453' can be recommended and grown in uninfected areas. Additionally, 'Carmen', 'GW-Teks' and 'GW-Golda' varieties can be used as material for improving disease resistance in cotton breeding programs.

Keywords: disease severity, yield, fiber quality, infected area

Introduction

Verticillium wilt is one of the most important diseases of cotton (*Gossypium hirsutum* L.), which affects yield and fiber quality in cotton production, worldwide and in Turkey. *Verticillium dahliae* fungus causes diseases in many crops such as vegetables, leguminous plants, ornamentals, industrial plants, orchards and wild plants apart from cotton. The main factors affecting the epidemiology of *Verticillium wilt* of cotton are pathotypes and inoculum density of *Verticillium dahliae* Kleb. in the soil, air and soil temperature, irrigation timing and soil moisture, plant density, potassium and nitrogen nutrition of plants. These factors directly affect both, the incidence and earliness of foliar symptoms of verticillium wilt and lint yield (El-Zik, 1985; Frisbie *et al.,* 1989)

Symptoms of infection appear as necrotic areas on leaves, wilting and usually discoloration of the vascular tissue. Severely affected plants shed all their leaves and most of their young bolls. The cotyledons of infected cotton plants become yellowish and quickly dry out. Young plants with three to five true leaves suffer considerable stunting. The leaves appear darker green compared to those of a normal plant and become somewhat crinkled between the veins. The amount of stunting apparently depends on the stage of development of the plant when it becomes infected. The outstanding symptom is the chloritic areas on the leaf margins and between the main veins, which make it look mottled (Presley, 1953).

The control of disease is difficult because the causal agent is soilborne and soil sterilization is impractical and expensive (Biçici and Kurt, 1998). The use of resistant cultivars has long been considered the most practical and effective method for the control of the diseases. The new cultivars are not immune to the *Verticillium wilt* pathogen and their resistance is indicated by reduced disease incidence and reduced disease severity. The introduction and quick adoption of these new cotton cultivars has resulted in a steady reduction in disease incidence (Allen and Lonergan, 1998)

Bejarano-Alcazar *et al.* (1997) reported that the greatest yield reduction was observed in plants showing symptoms before the opening of first flowers; yield increased with delay in the development of foliar symptoms during the crop season and the effect of the wilt epidemics on yield was small or nil for plants that developed symptoms after opening of the first bolls. Marani and Yaacobi (1976) observed that good differentiation between susceptible and tolerant cultivars was obtained by observing foliar symptoms after the middle of the flowering period. Erdoğan *et*

al. (2006) screened cotton cultivar resistance to the disease and found that 'Carmen' was recommended for yield and fiber quality in infected areas. Göre *et al*. (2009) indicated that the most promising cultivars appeared to be 'Carmen' and 'ST 373'. 'Carmen' showed differential resistance: it was succeptible to the D (defoliating pathotype), but resistant to the ND (non-defoliating) pathotype. Azaddisfani and Zangi (2007) reported that 'Sahel' and 'Smooth' leaf genotypes had the highest disease rate (89.56% and 92.56%, respectively) and these genotypes had the greatest infected plants. On the other hand, the 'Sahel' cultivar had the highest and 'Q29' the lowest disease severity among test genotypes. 'Sahel', 'Smooth' leaf and 'Gokroba' had the highest disease index, 'Q29' and 'Termez14' had the lowest disease index. Bölek *et al*. (2005) determined that 'Pima S-7' and 'Acala Prema' showed the strongest resistance reactions and 'Acala 44' was the most susceptible. Moshirabadi *et al*.(2000) revealed that 'Zeta 2' was the most tolerant variety to *Verticillium wilt*, falling into the same class as 'Sahel' for tolerance and earliness.

The objective of this study was to assess the tolerance level of some commercial cotton varieties, against Verticillium wilt (*Verticillium dahliae* Kleb.) disease and to determine resistant cotton varieties.

Materials and methods

The study was conducted in the Southeast Anatolia Agricultural Research Institute's experimental area during 2004-2006 in Diyarbakır, Turkey. In this study 10 different commercial cotton varieties (*Gossypium hirsutum* L.), including two control varieties ('Carmen' as tolerant and 'Sayar 314' as succeptible) were planted in naturally infected fields to test the *Verticillium* wilt performance of varieties. The experiments were arranged as a randomized complete block design with four replications. Each plot consisted of four rows of 12 m length, between and within the rows, spacing was 70 cm and 20-25 m respectively.

The soils of the experimental area were zonal soils which are generally red-brown and included in the big soil group having a clayish nature, flat or about-to-be flat, having very small erosion and deep or medium deep. The soil is low in organic material and phosphorus, has adequate potassium, calcium and high clay content (49-67%) in the 0-150 cm profile. The *Verticillium dahliae*-infected experimental area has been planted continuously with cotton for more than 10 years and contains 16.3 CFU (ms/g) in soil. CFU (ms/g) in soil was determined according to Melouk (1992).

Sowing was made with combine cotton drilling machine. Planting was done the first year on 29th April, the second year on 27th April and the third year on 10th May; all plots were treated with 20-20-0 composite fertilizer providing 70 kg ha^{-1} N and 70 kg ha^{-1} P_2O_5. Just before flowering, 70 kg ha^{-1} N (as ammonium nitrate) was applied to the trial as an additional N source. The experiment was thinned and hoed three times by hand and four times by machine; herbicides were used only once, before sowing, in all three years. Insect controls were needed for (*Aphis gossypi*) and leaf fleahopper (*Empoasca* spp.) in 2004: 200 cc/da Thiodan were applied twice. During the other two years, insects were monitored throughout the experiment and it was decided that no insect control was necessary during the growing season. Experimental plots were irrigated for the first time five weeks after sowing, and then repeatedly eight times at ten-day intervals. Furrow irrigation was applied. The four rows of each plot were harvested to determine of fiber yield and seed cotton yield. After harvest, the samples were ginned on a laboratory roller-gin for lint percentage. Fiber samples were analyzed for fiber quality properties by High Volume Instrument (HVI Spectrum).

During the investigation, meteorological data were recorded from planting date to harvest date and are presented in Tab. 1. In the Southeastern Anatolia Region of Turkey, long-term climatic findings showed that there were 491 mm total rainfall and 15.8°C average temperature. The average maximum temperature can reach 38.3°C in July and average rainfall can reach 70.5 mm in April.

Observation of diseases were taken from the middle two rows of the plot with consecutive 30 plants on leaves at 50% boll opening stage (Barrow, 1970) and stems following the last harvesting by hand. 0-3 scale was used for observations of diseases (Erwin *et al*., 1976); besides, discoloration of the interior of the stems was taken into account and plants were marked as healthy or diseased. Disease rates were calculated and obtained data were sub-

Tab. 1. Mean temperature, maximum temperature and total rainfall during the investigation and long term

Months	Mean Temperature (°C)				Maximum Temperature (°C)				Rainfall (mm)			
	2004	2005	2006	Long Term	2004	2005	2006	Long Term	2004	2005	2006	Long Term
March	9.6	8.4	9.2	8.2	17.0	14.0	15.9	14.2	1.5	58.4	26.6	67.9
April	12.8	14.1	14.5	13.8	20.1	21.1	20.6	20.3	54.9	36.8	77.9	70.5
May	18.0	19.6	19.4	19.2	25.3	27.5	27.5	26.5	97.5	26.5	38.4	42.1
June	26.4	25.8	28.5	26.0	33.8	33.1	37.0	33.3	16.0	33.1	-	6.9
July	31.1	32.4	31.4	31.0	38.2	39.7	38.1	38.3	-	-	6.1	0.6
August	30.0	31.8	32.6	30.3	37.5	39.2	40.9	38.0	-	-	-	0.4
September	25.0	25.0	25.0	24.8	34.0	32.8	33.1	33.2	-	0.7	3.5	2.7
October	18.2	16.2	17.6	17.1	26.7	24.7	25.1	25.2	1.3	14.9	104.5	31.1

source: Turkish State Meteorological Service, Diyarbakır

jected to Arcsin for transformation (Karman, 1971). Statistical analyses were performed using JMP 5.0.1 statistical software (http://www.jmp.com) and the means were grouped by means of the LSD (0.05) test.

Results and discussion

Results from the analysis of variance of the investigated characteristics in the experiment are presented in Tab. 2. As shown in the table, the variety and year were significant for all the investigated characteristics, variety x year interactions were significant for most of the characters, however variety x year interactions were non-significant for vascular disese index, vascular disease rate, seed cotton yield and ginning percentage.

The mean values obtained for the investigated characteristics, regarding foliar disease index, vascular disease index and vascular disease rate are presented in Tab. 3; mean values of seed cotton yield, fiber yield and ginning percentage are presented in Tab. 4; mean values of fiber length, fiber fineness and fiber strength are presented in Tab. 5.

As seen in Tab. 3, data analysis indicated that differences among varieties and years for foliar disease index (FDI) were significant. FDI ranged from 0.54 to 1.21. Lower FDI were observed for 'Carmen', 'GW-Teks' and 'GW-Golda' varieties; while the highest FDI values were observed for 'Sayar 314', 'Maraş 92' and 'Stoneville 453'; the other varieties in the experiment had moderate tolerance levels. These results are in agreement with those of Kurt and Biçici (1998) who revealed the sensitivity of 'Maraş 92' and 'Sayar 314', and Erdoğan *et al.* (2006) who revealed the tolerance of the 'Carmen' variety. Variety x year interactions for this character was significant at $p<0.01$ probability level. Year differences were significant, FDI observed from the first and third year were lower than those observed from the second year. Some researchers stated that environmental conditions play an important role in the host-pathogen interaction. *Verticillium wilt* in different crops is affected by environmental conditions such as temperature and var-

Tab.2. Analysis of variance for the investigated characters and mean of sum of squares

Source of Variance	df	FDI	VDI	VDR (%)	SCY (kg ha^{-1})	FY (kg ha^{-1})	GP (%)	FL (mm)	FF (mic.)	FS (g/tex)
Replication (R)	3	0.36*	0.78**	924.72*	10947.23*	5892.81**	125.77**	0.07	0.86	6.48
Variety (V)	9	6.06**	4.29**	6383.96**	34194.93**	7969.63**	198.47**	28.70**	3.72**	725.30**
Year (Y)	2	3.91**	5.37**	4595.43**	132898.02**	16176.11**	62.58**	8.21**	6.78**	48.51**
V x Y	18	2.61**	1.71	1709.18	36196.51	10163.20*	88.41	18.29*	5.54**	76.26*
Error	87	3.68	5.62	7943.94	105477.61	27401.20	537.17	49.28	11.86	201.91
Total	119	16.62	17.80	21557.25	319714.50	67602.98	1012.42	104.56	28.79	1058.47

*and ** significant at the 0.05 and 0.01 probability level, respectively, FDI = foliar disease index, VDI = vascular disease index, VDR = vascular disease rate, SCY = seed cotton yield, FY = fiber yield, GP = ginning percentage, FL = fiber length, FF = fiber fineness, FS = fiber strength

Tab. 3. Mean values of foliar disease index, vascular disease index and vascular disease rate

Variety	Foliar disease index				Vascular disease index				Vascular disease rate			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
'GW-Teks'	0.48 LM	0.69 H-L	0.50 LM	0.55 F	0.84	0.76	0.70	0.76 EF	45.83	45.00	39.70	43.51 EF
'GW-Golda'	0.60 J-L	0.59 KL	0.73 G-L	0.64 F	0.74	0.86	0.75	0.78 D-F	43.33	43.01	44.75	43.70 EF
'Carmen'	0.25 M	0.95 E-H	0.44 LM	0.54 F	0.50	1.14	0.41	0.68 F	30.83	48.88	30.61	36.77 F
'Şahin 2000'	1.13 C-F	1.01 D-G	0.60 J-L	0.91 C-E	1.07	1.23	0.66	0.98 B-D	55.00	55.83	39.67	50.16 DE
'DP-Deltaopal'	0.74 G-L	1.13 C-F	0.58 KL	0.81 E	0.90	1.36	0.66	0.97 C-E	50.83	62.41	39.70	50.98 C-E
'Dicle 2002'	1.08 D-F	1.28 B-D	0.65 I-L	1.00 B-D	0.97	1.47	0.80	1.04 A-C	55.00	64.60	44.42	54.67 A-D
'Maraş 92'	1.19 C-E	1.36 A-C	0.93 E-I	1.16 AB	1.17	1.48	1.07	1.24 A	60.84	66.44	52.24	59.84 A
'Stv. 453'	0.86 F-K	1.58 A	0.63 J-L	1.02 BC	1.05	1.70	0.82	1.19 AB	58.33	71.66	46.20	58.73 A-C
'Sayar 314'	1.03 D-F	1.48 A	1.14 C-F	1.21 A	1.05	1.63	1.06	1.24 A	57.50	68.21	51.96	59.22 AB
'Nazilli 342'	0.89 F-J	1.07 D-F	0.61 J-L	0.85 DE	0.99	1.17	0.74	0.96 C-E	56.67	56.59	42.02	51.76 B-D
Mean	0.82 B	1.11 A	0.68 C	0.87	0.93 B	1.27 A	0.76 C	0.98	51.42 B	58.26 A	43.13 C	50.94 A
CV (%)	22.98				25.51				18.75			
LSD (0.05)												
Variety	0.158**				0.198**				7.722**			
Year	0.079**				0.099**				4.217**			
Variety x Year	0.277**				ns				ns			

*and ** significant at the 0.05 and 0.01 probability level respectively, ns= non significant, means in each column followed by the same letter are not significantly different ($p< 0.05$)

Tab. 4. Mean values of seed cotton yield, fiber yield and ginning percentage

Variety	Seed cotton yield (kg ha^{-1})				Fiber Yield (kg ha^{-1})				Ginning Percentage (%)			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
'GW-Teks'	3600.4	4166.3	3540.9	3769.2 B	1594.1 C-I	1714.5 A-F	1492.8 E-J	1600.5 A-D	44.63	41.13	42.12	42.63 A-C
"GW-Golda"	3507.4	3981.4	3816.2	3768.3 B	1572.1 D-I	1660.4 B-G	1740.1 A-E	1657.5 AB	44.40	41.71	45.58	43.89 A
'Carmen'	3748.5	4518.6	3119.0	3795.3 B	1655.4 B-G	1903.4 AB	1318.7 J	1625.8 A-C	43.71	42.09	42.30	42.70 A-C
'Şahin 2000'	3701.3	4187.1	3404.7	3764.3 B	1578.2 D-I	1599.0 C-H	1322.0 J	1499.7 C-E	42.51	38.15	38.76	39.80 D
'DP-Deltaopal'	4239.2	4758.6	3564.0	4187.2 A	1794.5 A-D	1915.5 A	1457.3 G-J	1722.4 A	42.11	40.25	40.88	41.08 CD
'Dicle 2002'	3611.6	4091.1	3442.3	3715.0 BC	1428.7 G-J	1612.9 C-H	1399.8 H-J	1480.5 DE	39.55	39.43	40.68	39.89 D
'Maraş 92'	3514.1	4308.0	3599.3	3807.1 B	1542.5 E-J	1831.5A-C	1531.1 E-J	1635.0 A-C	44.64	42.51	42.52	43.22 AB
'Stv. 453'	3571.4	4484.7	3661.9	3906.0 AB	1435.5 G-J	1864.0 AB	1534.8 E-J	1611.4 A-D	40.15	41.55	41.90	41.20 CD
'Sayar 314 '	3700.9	4351.5	3174.1	3742.1 BC	1583.1 C-I	1795.7 A-D	1349.5 IJ	1576.1 B-E	42.74	41.26	42.47	42.15 A-C
'Nazilli 342'	3454.8	3635.4	3312.5	3467.5 C	1446.9 G-J	1481.0 F-J	1414.8 G-J	1447.6 E	41.89	40.74	42.73	41.78 B-D
Mean	3664.9 B	4248.2 A	3463.5 C	3792.2	1563.1 B	1737.8 A	1456.1 C	1585.7 b	42.63 A	40.88 B	41.99 A	41.83
CV (%)		9.17				11.18				5.92		
LSD (0.05)												
Variety		281.3**				143.35*				1.99 **		
Year		154.0**				78.40**				1.10 **		
Variety x Year		ns				248.29*				ns		

*and ** significant at the 0.05 and 0.01 probability level respectively, ns= non significant, means in each column followed by the same letter are not significantly different (p< 0.05)

ious nutritional factors (Bell and Presley, 1969; Bell and Mace, 1981; Barash *et al*., 1988).

There were significant differences among varieties and years for vascular disease index (VDI), and this trait ranged from 0.68 ('Carmen') to 1.24 ('Maraş 92' and 'Sayar 314'). For thes traits, 'Carmen', 'GW-Teks' and 'GW-Golda' varieties had the lowest values, as these short sequences were the same as for FDI and Vascular Disease Rate (VDR). Year differences were significant, lower VDI was obtained for the third year, higher values were obtained for the second year. Variety x year interaction was non-significant for this character. Frishbie *et al*. (1989) indicated that vascular browning in cotton stems is a good indicator of plant infection, but it has little or no effect on lint yield. In contrast, foliar symptoms are usually less common than vascular browning but are a major determinants in

Tab. 5. Mean values of fiber length, fiber fineness and fiber strength

Variety	Fiber Length (mm)				Fineness (mic)				Fiber Strength (g/tex)			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
'GW-Teks'	29.36 AB	28.50 A-G	29.48 A	29.11 A	4.06 H-K	4.55 A-H	4.17 F-J	4.26 CD	35.23 AB	36.30 A	36.77 A	36.10 A
"GW-Golda"	28.98 A-D	28.56 A-F	26.85 J	28.13 B	4.31 D-I	4.59 A-G	4.65 A-F	4.51 A-C	32.38 C-E	33.52 BC	30.27 E-H	32.05 B
'Carmen'	28.09 C-I	27.57 F-J	28.43 A-H	28.03 B	4.01 I-K	4.83 A-C	4.06 H-K	4.30 B-D	30.50 D-G	32.30 C-E	32.55 CD	31.78 B
'Şahin 2000'	28.09 C-I	27.54 F-J	28.64 A-E	28.09 B	4.16 F-J	4.21 F-J	4.16 F-J	4.17 D	26.83 M	27.70 J-M	29.15 G-K	27.89 E
'DP-Deltaopal'	28.86 A-D	27.92 D-I	28.52 A-G	28.43 B	4.53 B-H	4.91 AB	4.33 C-I	4.59 AB	31.48 C-F	33.07 C	32.85 C	32.46 B
'Dicle 2002'	27.28 IJ	27.30 IJ	27.42 H-J	27.33 C	3.78 JK	4.75 A-E	4.27 E-J	4.26 CD	27.60 J-M	27.95 I-M	28.57 G-M	28.04 DE
'Maraş 92'	27.67 E-J	26.84 J	27.68 E-J	27.39 C	4.80 A-D	5.05 A	4.46 B-I	4.77 A	28.58 G-M	29.40 F-J	29.70 F-J	29.22 CD
'Stv. 453'	28.29 C-I	27.50 G-J	29.01 A-C	28.26 B	3.56 K	4.94 AB	4.75 A-E	4.41 B-D	28.53 G-M	27.00 LM	30.05 F-I	28.52 C-E
'Sayar 314 '	28.86 A-D	27.99 C-I	28.40 B-H	28.42 B	4.10 G-J	4.93 AB	4.28 D-J	4.43 B-D	28.28 H-M	29.02 G-L	31.52 C-F	29.60 C
'Nazilli 342'	28.34 B-J	28.18 C-I	28.55 A-G	28.35 B	4.00 I-K	4.29 D-J	4.46 B-I	4.25 CD	27.15 K-M	29.65 F-J	30.50 D-G	29.10 C-E
Mean	28.38 A	27.79 B	28.30 A	28.11	4.13 C	4.70 A	4.36 B	4.40	29.65 B	30.59 A	31.19 A	30.47 B
CV (%)		2.66				8.18				4.98		
LSD (0.05)												
Variety		0.59 **				0.29 **				1.17 **		
Year		0.31 **				0.15 **				0.67 **		
Variety x Year		1.00 *				0.55 **				2.11 *		

*and ** significant at the 0.05 and 0.01 probability level respectively, ns= non significant, means in each column followed by the same letter are not significantly different (p< 0.05)

losses caused by verticillium wilt. The result of this study showed that the values obtained for VDI were paralleled with FDI. This means that the disease observations can be taken from both, leaves and stems. Therefore, this result was inconsistent with that of Frishbie *et al.* (1989).

Variety and year were significant for vascular disease rate. VDR ranged from 36.77% to 59.84%. 'Carmen', 'GW-Teks' and 'GW-Golda' varieties had the lowest vascular disease rates, indicating tolerance to verticillium wilt, while 'Maraş 92', 'Sayar 314' and 'Stoneville 453' varieties had the highest values for this trait and shared the same statistical group. Year differences were significant for vascular disease rate and the lowest disease index (43.33%) was obtained in 2006. Variety x year interactions were not significant for vascular disease rate (Tab. 3). These results agree with those of Sağır and Aydın (2001), who detected disease percentages between 23.47% and 58%. Furthermore, the results of this study confirmed those of El-Zik (2002) who reported that modern cultivars such as the 'Acala's', released recently from California and New Mexico, as well as the 'Pima's G.' barbadense, are highly resistant to *Verticillium dahliae;* the other Upland cultivars such as 'Paymaster HS-26', 'Deltapine 5690' and 'Stoneville 495' have moderate resistance to Verticillium wilt.

Results from the analysis of variance for seed cotton yield are given in Tab. 4. As seen in the table, there were significant differences among varieties. Seed cotton yield ranged from 3467.5 to 4187.2 kg ha^{-1}. The maximum seed cotton yield was obtained from 'DP-Deltaopal' variety (4187.2 kg ha^{-1}), and followed by 'Stoneville 453' (3906.0 kg ha^{-1}) and 'Maraş 92' (3807.1 kg ha^{-1}), respectively. The lowest seed cotton yield was obtained from 'Nazilli 342' variety. Year differences were significant for seed cotton yield. Higher seed cotton yield were obtained from the second year of the experiment. Variety x year interaction was non-significant for this character.

Variety, year and variety x year interaction for fiber yield were significant. Varieties for fiber yield ranged from 1447.6 for 'Nazilli 342' to 1722.4 kg ha $^{-1}$ for 'DP-Deltaopal'. Year differences were also significant and the second year had the highest fiber yield. Variety x year interaction was significant, the highest fiber yield was obtained from 'DP-Deltaopal' variety in 2005, but the lowest fiber yield was obtained from the 'Carmen' variety in 2006.

The analysis of variance indicated significant differences among varieties for seed cotton yield and fiber yield. This study showed that some cotton varieties such as 'Stoneville 453' had the highest foliar disease index and vascular disease rate and also had the highest yield. These findings indicated that some sensitive varieties had a high yield. The reason for this situation may be related to early or late occurence of disease. This finding is consistent with a previous study reported by Pullman and DeVay (1982) who stated that plant growth and cotton lint yields were related to the period of cotton growth before foliar symptoms of Verticillium wilt appear and that growth reductions can be first observed about two weeks prior to the appearance of foliar symptoms. Higher yields were obtained in the second year of the experiment. It is estimated that year differences may be caused by climatical or cultural differences during the experiment. Previous studies revealed that Verticillium wilt is currently managed by the use of tolerant cotton cultivars, crop rotation, irrigation and fertilization practices (Schnathorst and Mathre, 1966). Verticillium wilt in different crops is affected by environmental conditions such as temperature and various nutritional factors, as reported by Bell and Mace (1981), Bell and Presley (1969), Barash *et al.* (1988).

Variety and year differences for ginning percentage were significant, but variety x year interaction was non-significant in this trait. Varieties for this trait ranged from 39.80% for 'Şahin 2000' to 43.89% for 'GW-Golda' variety. The results also indicated that these varieties had different genotypic performances. Year differences were also significant and the highest ginning percentages were obtained in 2004 followed by 2006.

Variety, year and variety x year interaction for fiber length were significant. Varieties for fiber length changed between 27.33 and 29.11 mm. 'GW-Teks' variety had the longest fiber length. Year differences were also significant; the first and third year had higher fiber length than the second year. Fiber length was also affected by variety x year interaction. The lowest fiber length value was recorded for 'Maraş 92' in 2005, while the highest fiber length value was recorded for 'GW-Teks' in 2006.

Differences among varieties for fiber fineness were significant. Variety, year and variety x year interaction were found significant. This trait ranged from 4.17 mic for 'Şahin 2000' to 4.77 mic for 'Maraş 92', but all of the micronaire values belonging to varieties were of acceptable level for the textile ındustry. Year differences were significant; the finest fiber was obtained in 2004. Variety x year interactions were significant, the highest micronaire value was obtained from 'Maraş 92' in 2005, while the lowest micronaire value was obtained from 'Stoneville 453' in 2004.

The differences between the cotton varieties in terms of fiber strength were significant. Variety, year and variety x year interactions were significant. This most important fiber quality character ranged from 27.89 g/tex for 'Şahin 2000' to 36.10 g/tex for 'GW-Teks'. The strongest fibers were obtained from 'GW-Teks', 'DP-Deltaopal', 'GW-Golda' and 'Carmen' varieties respectively, while the weakest fibers were obtained from 'Şahin 2000'. This trait was also affected by variety x year interactions, the highest value obtained from 'GW-Teks' in 2006, the lowest value obtained from 'Şahin 2000' in 2004 (Tab. 5).

The result of this study showed that 'GW-Teks' for fiber length, 'Şahin 2000' and 'GW-Teks' for fiber fineness and 'GW-Teks', 'GW-Golda', 'DP-Deltaopal' and 'Carmen' varieties had favorable values for fiber strength. Some researchers revealed that fiber length trait differs and de-

pends on many factors but genotype is considered one of the most important factors (Meredith, 1984; Braden, 2005). Kechagia and Xanthopoulos (1998) reported that fiber length was generally the least affected by wilt, as expected, because length is established about 25 days after anthesis when infection is minimal. Similar results were reported by Sağır and Başbağ (2002), who observed no significant differences between varieties in healthy and diseased plants for fiber strength.

Conclusions

In conclusion, the result of this study indicates that the varieties used in this research had different tolerance levels to the *Verticillium dahliae* Kleb. disease. The varieties showed the same sort of sequence in terms of foliar disease index, vascular disease index and vascular disease rate. Therefore, according to the results of this experiment, it can be said that if observation is made in the 50% boll opening time, either by using foliar disease index or vascular disease index, it will be enough to evaluate the severity of verticillium. The most tolerant varieties were 'GW-Teks', 'GW-Golda' and 'Carmen', while the most sensitive varieties were 'Maraş 92', 'Sayar 314' and 'Stoneville 453'; the other varieties had a moderate level of tolerance. The moderately affected variety 'DP-Deltaopal' and the sensitive variety 'Stoneville 453' had high yield. This situation showed the importance of the occurrence time of the diseases. In the light of these observations, 'Carmen', 'GW-Teks' and 'GW-Golda' had both resistance to disease and better technological characteristics, so they can be recommended for infected areas; on the other hand, 'DP-Deltaopal' and 'Stoneville 453' can be recommended and grown in the non-infected areas. Additionally, 'Carmen', 'GW-Teks' and 'GW-Golda' varieties can be used as material for improving disease resistance in cotton breeding programs.

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