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THE DETERMINATION OF RELATIONSHIP BETWEEN VERTICILLIUM WILT (*Verticillium dahliae* Kleb.) AND EARLY MATURITY IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

The present study was conducted to investigate the relationship between earliness of crop maturity and Verticillium wilt. Ten cotton genotypes were evaluated in natural infection under field conditions of Nazilli Cotton Reseach Institute in 2006 and 2007. Foliar disease index (FDI), vascular disease index (VDI), days to flowering (DF), days to boll opening (DB) and seed cotton yield (SCY) were determined. In regard to FDI and VDI, the most tolerant genotypes were Carmen (standard cotton cultivar), NGC, GSN 12 and M25-G, while the most sensitive genotype was NP Ozbek-100. NMCH-11/4, NCCH-9/2 and NCCH-8/1 were other sensitive genotypes. The performances to verticillium wilt of other standard cotton cultivars, Nazilli 84 S and Sayar 314 were non-stabile. The maturity characteristics, DF and DB, were significant negative correlated with all Verticillium severity parameters, whereas these characteristics were significant positive correlated with SCY. Carmen cultivar should be recommended for infected areas and improving diseases tolerance in cotton breeding programs.

Key words: Cotton, verticillium wilt, early maturity, disease severity, yield

INTRODUCTION

Cotton is an agricultural product serving as raw material for textile and other various industries. Turkish cotton area and production are expected to reach 410.000 hectares and 600.000 MT (2.7 million bales) in 2011. Cotton is grown in Turkey in four major regions: Southeastern Anatolia, Aegean, Çukurova and Antalya. Aegean region has an area of 74.000 hectares with the total production of 94000 tons (Sirtioglu 2011).

In the Aegean Region, cotton disease, especially Verticillium wilt is one of the major constraints affecting yield and quality. Verticillium wilt, caused by the soil-borne fungus *Verticillium dahliae* Kleb., is found in many cotton fields of the Aegean Region. In Turkey, Verticillium wilt of cotton was first defined by Karaca et al. (1971). The losses of seed cotton yield due to Verticillium wilt were estimated 12 % and 10 % for Aegean and Çukurova, and Southeastern Anatolia regions, respectively (Sağır et al., 1995). The disease was responsible for significant yield losses (approximately 1.5 million bales) in the world cotton belt (Nemli 2003). Several factors, including variety selection, plant density, pathogen aggressiveness, inoculum density (microsclerotia per gram of soil), and environmental conditions influence Verticillium wilt development. Initial infections occur early in the growing season, following the germination of microsclerotia. The fungus infects through the roots, invades the vascular system resulting in a systemic infection. Prolific growth in the xylem vessels disrupts the plants ability to transport water and nutrients.

Cotton growers have generally created favorable conditions for Verticillium wilt, İncreased vegetative growth, late maturity and reduced boll load induced by excesiive nitrogen fertilization and frequent irrigation.

Moreover, crop rotation is not used in the Aegean Region. One of the main strategies for management of Verticillium wilt of cotton involves the use of Tolerant and/or resistant cultivars.

Bowman (1999) stated that the Texas A&M programs at College Station (MAR) and Lubbock have been breeding for Verticillium resistance since the 1960s. The Texas A&M program at Lubbock released 22 influential lines that have contributed to 59 cultivars of the 260 released between 1970 and 1990 (Bowman et al.,1996). That program does not produce cultivars, but impacts Texas High Plain's cultivars through release of storm proof material with improved earliness, fiber quality, and increased resistance to Verticillium wilt. Today, private and public breeders routinely screen for Verticillium wilt resistance.

Recently, evaluation and breeding for Verticillium wilt and root-knot nematode resistance and tolerance for drought and salt stresses have also become an integral part of the breeding effort (Bajaj et al., 2008; Zhang et al., 2006, 2008). In addition, extensive effort has been made to introduce desirable genes and traits from *G. barbadense* L. into Upland cotton (Zhang and Percy 2007).

Early maturity may also help in reducing losses from diseases such as Verticillium Wilt and boll rot (Verhalen et al., 1984; Frisbie et al., 1989). Earliness in cotton is defined as shorter time flowering from sowing, faster maturation and early yield potential (Poehlman and Sleper 1995). Galanopoulu (2006) revealed that early maturing varieties were generally more susceptible to the late infestation than the early and than late varieties to the late infestation, and similar reaction was also displayed between early and late sowings. It was reported that the highest yield losses were observed in plants showing symptoms before first flowering stage, and the effects of late stage symptoms on yield was negligible (Bejarano-Alcazar et al., 1997).

The objectives of this work were to determine the Verticillium wilt tolerance of standard cotton cultivars and improved genotypes by Nazilli Cotton Research Institute and the relationships between early maturity and Verticillium wilt severity parameters.

MATERIALS AND METHODS

In the study, three cotton standard cultivars as control (CARMEN, NAZILLI 84 S and SAYAR 314) and 7 genotypes that have different days to flowering and boll opening were used as material.

Field trials were conducted in field infested with the non-defoliating pathotype in 2006 and 2007 cotton growing seasons. The inoculum density of *Verticillium dahliae* Kleb. in naturally infested field was determined 69 ms/g (Erdoğan et al., 2011). El-Zik (1985) revealed that the fungal population density required for 50 % disease is approximately 22 p/g. Also, with 60 p/g symptoms appear early, about 50-60 days after planting, compared with 90 days with 5 p/g. The Experiments were arranged in a randomized complete block design with four replications. Each plot consisted of two rows of 12 m length, with 0.7 m between rows. Initial soil analysis showed that experimental area had clay soil, slight alkaline (pH: 7.85), low salinity and rich in lime, organic matter, potassium and phosphorous. The cultural managements such as irrigations, fertilizations and crop protection applications were programmed according to recommendations for Aegean Region cotton growing.

Observations of diseases were taken from the middle two rows of each plot with all of the plants on leaves at 5-10 %, 50-60 % cotton boll opening stage and 0-3 scale (0=healty plant; 1=50% foliar symptoms on leaves; 2= 51-75 % foliar symptoms on leaves; 3= 76-100 % foliar symptoms on leaves and plant died) was used for observations of diseases (Ünal and Aydın 1980).

Disease severity was evaluated for the middle two rows of each plot with all of the plants on stems at harvesting period and 0-3 scale (0= no discoloration xylem on trunk sectional area; 1=1-33 % discoloration xylem; 2= 34-67 % discoloration xylem; 3= 68-100 % discoloration xylem) was used for observations of diseases (Buchenauer and Erwin 1976). Disease Severity Index was calculated by using the following Formula with formula; $DSI=[(ax0)+(bx1)+(cx2)+(dx3)]/M$

Where a, b, c, and d refer the plant number with degree 0, 1, 2, and 3 respectively, and M refer total plant number.

Disease rates were calculated and obtained data were subjected to Arcsin for transformation (Karman 1971). Statistical analyses were performed using JMP 5.0.1 statistical software and the means were grouped by means of the LSD (0.05) test. Besides, discoloration of the interior of the stems was taken into account and plants were marked as healthy or diseased.

The number of days from sowing to flowering (DF) and the number of from sowing to boll opening (DB) were calculated by using first white flower and first boll opening observations, respectively. Seed Cotton Yield (SCY) data were recorded from two rows of each harvested two times by hand.

RESULTS AND DISCUSSION

Variance analysis showed that genotype and year were significant for all the investigated characteristics, and genotypes were significantly different for all observed characters, while year x genotype interactions were significant for FDI (5-10 %), FDI (50-60 %) and VDI (Table 1). The year x genotype interaction for Verticillium severity parameters are consistent with previous studies reported by Kheiri and Fatahi (2010) and Karademir et al. (2010). The results of interactions demonstrated environment altered Verticillium severity and virulence of pathogen was increased by favorable climatic conditions. Disease development and symptom expression are influenced by environment, including temperature, light and soil moisture etc. and by cultural management such as planting date, plant density, fertilization and irrigation (El-Zik and Frisbie 1985; El-Zik 1985). It can be said that all were not affected in the same way by Verticillium severity.

Standard cotton cultivar of Aegean Region, CARMEN had the lowest FDI (5-10 %), FDI (50-60 %) and VDI values (Table 2). The results of many studies demonstrated that Carmen cultivar was recommended for yield and fiber quality in infected area (Erdoğan et al., 2006; Göre et al., 2009; Karademir et al., 2010). NGC, GSN 12 and M25-G genotypes had characteristics similar to that of CARMEN for Verticillium tolerance. Remarkably, NP OZBEK-100 had the highest disease severity for each of the three characters. This cultivar was followed by by NCCH-9/2, NMCH-11/4, NCCH-8/1, NAZILLI 84 S (control) and SAYAR 314 (control), respectively.

Table 1. Results of variance analysis for the investigated characters.

Source of Variance	Df	FDI (5-10)	FDI (50-60)	VDI	DF	DB	SCY
Rep.	3	0.01	0.01	0.07	0.18	0.30	9416.22
Year (Y)	1	0.30*	0.67*	0.15*	10.51*	6.05*	11367.08*
Genotype (G)	9	0.23*	0.27*	0.18*	204.67*	901.87*	5970.68*
YxG	9	0.06*	0.07*	0.02*	0.57	0.38	475.93
Error	57	0.03	0.03	0.07	0.43	0.54	665.97
Total	79	0.04	0.05	0.033	23.83	103.26	1716.40

Df: degrees of freedom; * Significant at the 0.05 probability level.
FDI = foliar disease index, VDI = vascular disease index, DF; days to flowering, DB; days to boll opening, SCY: seed cotton yield,

Table 2. Data means of FDI (5-10 %), FDI (50-60%), VDI separated by LSD

	2006			2007		
Genotypes	**FDI (5-10 %)**	**FDI (50-60 %)**	**VDI**	**FDI (5-10 %)**	**FDI (50-60 %)**	**VDI**
NGC	0.38 f	0.58 e	0.59 c	0.51 c	0.59 c	0.62 c
GSN-12	0.44 ef	0.64 e	0.60 c	0.50 c	0.61 c	0.58 cd
NAZILLI 84 S (C)	0.96 d	1.13 d	1.02 b	0.73 ab	0.85 b	0.82 b
CARMEN (C)	0.26 g	0.54 e	0.45 c	0.36 d	0.47 d	0.44 e
NP ÖZBEK-100	1.64 a	1.90 a	1.49 a	0.83 a	0.90 ab	0.89 ab
NMCH-11/4	1.16 b	1.45 b	1.12 b	0.75 ab	0.86 b	0.85 ab
NCCH-9/2	1.15 b	1.57 b	1.09 b	0.77 ab	0.96 a	0.94 a
NCCH-8/1	1.07 bc	1.29 c	1.09 b	0.68 b	0.96 a	0.91 a
SAYAR 314 (C)	0.98 cd	1.14 d	1.07 b	0.78 ab	0.94 ab	0.94 a
M25-G	0.49 e	0.66 e	0.51 c	0.47 cd	0.56 cd	0.52 de
LSD	0.096	0.137	0.251	0.114	0.096	0.088

FDI = foliar disease index, VDI = vascular disease index

Between years and genotypes were significant for the number of days from sowing to flowering (DF) and boll opening (DB) (Table 1). Earliness of crop maturity in cotton genotype did not change due to years. DF ranged from 47.3 days (NP OZBEK-100) to 62.6 days (CARMEN), while the DB values were between 97.3 days and 121.1 days for same genotypes (Table 3). Comparing genotypes that differed in maturity times, the late maturity cotton genotypes were CARMEN, M25-G, NGC and GSN 12. The minimum values for DF and DB were obtained from NP OZBEK-100, NCCH-9/2 and NMCH-11/4, respectively.

Table 3. Data means of DF (day), DB (day), SCY (kg ha^{-1}) separated by LSD

Genotype	DF (day)	DB (day)	SCY (kg ha^{-1})
CARMEN (C)	61.6 a	121.1 a	3144 ab
M25-G	60.3 b	119.5 b	3001 bc
NGC	60.1 b	120.1 b	2991 bc
GSN-12	57.6 c	120.0 b	3278 a
SAYAR 314 (C)	55.8 d	116.1 d	2951 bc
NAZİLLİ 84 S (C)	55.3 d	118.0 c	3188 ab
NCCH-8/1	51.5 e	102.2 e	2845 cd
NMCH-11/4	50.3 f	98.2 f	2636 de
NCCH-9/2	49.3 g	97.7 fg	2591 de
NP ÖZBEK-100	47.3 h	97.3 g	2455 e
LSD (0.05)	0.659	0.733	365.40

DF; days to flowering, DB; days to boll opening, SCY: seed cotton yield,

The analysis of variance indicated that there were significant differences among genotypes for seed cotton yield (SCY). The maximum SCY values were obtained from GSN-12 (3278 kg ha^{-1}), NAZILLI 84 S (3188 kg ha^{-1}) and CARMEN (3144 kgha^{-1}), and followed by M25-G (3001 kg ha^{-1}) and NGC (2991 kg ha^{-1}), respectively. The lowest seed cotton yields were obtained from the early maturity cotton genotypes, NP OZBEK-100, NCCH-9/2 and NMCH-11/4.

Three Verticillium severity parameters, FDI (5-10 %), FDI (50-60 %), and VDI, were significantly positive correlated with each other (Table 4). In other words, These three Verticillium severity seem to confirm each other. However, the maturity characteristics, DF and DB, were negatively significant correlated with all Verticillium severity parameters, whereas these characteristics were positively significant correlated with SCY. It was showed that early maturity characteristics of cotton genotypes increased the Verticillium sensitivity, and late maturity genotypes had higher SCY values than early maturity genotypes. Davis and Cano-Rios (1981) emphasized that although earliness and Verticillium wilt tolerance combined in the same variety would be doubly profitable, earlier maturing cotton genotypes are generally more susceptible to Verticillium wilt. The results of this study confirmed those of Bejarano-Alcazar et al. (1997) who reported that yield increased with delay in the development of foliar symptoms during the crop season and effect of the wilt epidemics on yield was small or nil for plants that developed symptoms after opening of the first bolls.

Table 4. The correlation coefficients between observed characteristics.

Characteristics	DB	SCY	FDI (5-10 %)	FDI (50-60 %)	VDI
DF	0.8708**	0.4934**	-0.6952**	-0.6989**	-0.6385**
DB		0.5860**	-0.7141**	-0.7131**	-0.6653**
SCY			-0.2616**	-0.1957**	-0.1591**
FDI (5-10 %)				0.9652**	0.8615**
FDI (50-60 %)					0.8712**

*. ** significant at the 0.05and 0.01probability level.
FDI = foliar disease index, VDI = vascular disease index, DF; days to flowering, DB; days to boll opening, SCY: seed cotton yield

CONCLUSION

The present study reveals that the genotypes used as material in this research had different values for Verticillium severity parameters, earliness and seed cotton yield. The most tolerant genotypes to *Verticillium dahliae* Kleb. disease were CARMEN, NGC, GSN 12 and M25-G with late maturity and high yielding capacity. Especially, CARMEN and GSN-12 varieties can be recommended for infected areas. The significant correlations among maturity characters, seed cotton yield and Verticillium tolerance parameters showed that late maturity genotypes should be recommended for infected areas and improving diseases tolerance in cotton breeding programs.

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