REACTION OF COTTON CULTIVARS TO FUSARIUM WILT AND ROOT-KNOT NEMATODES†

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Accepted: *21.I.1991*
Aceptado:

ABSTRACT

Starr, J. L., and R. D. Martyn. 1991. Reaction of cotton cultivars to Fusarium wilt and root-knot nematodes. Nematrópica 21:51–58.

Twenty-one selected cotton (*Gossypium hirsutum* L.) cultivars, representing a range of reaction types to the Fusarium wilt/root-knot nematode disease complex, were evaluated for response to the disease complex and to *Fusarium oxysporum* f. sp. *vasinfectum* and *Meloidogyne incognita* in field microplots infested with both pathogens. Resistance to the disease complex was based on plant mortality, whereas resistance to *F. oxysoprum* f. sp.. *vasinfectum* was based on vascular browning. Resistance to *M. incognita* was based on population densities of eggs and juveniles per 500 cm^3 of soil at crop maturity. In general, cultivars reacted to the disease complex as expected and those reported to be resistant to the disease complex were also more resistant to *F. oxysporum* f. sp. *vasinfectum* than those cultivars reported as susceptible. In contrast, there was little difference among cotton cultivars in reaction to *M. incognita*. Only 'Auburn 634' was highly resistant to the nematode. In fields infested with both pathogens, cultivars resistant to the disease complex may suffer yield losses due to *M. incognita*.

Key words: cotton, disease complex, *Fusarium oxysporum* f. sp. *vasinfectum, Gossypium hirsutum,* host resistance, *Meloidogyne incognita*, root-knot nematode.

RESUMEN

Starr, J. L., y R. D. Martyn. 1991. Reacción de cultivares de algodón a la marchitez causada por *Fusarium* y nematodos agalladores. Nematrópica 21:51–58.

Un total de 21 cultivares seleccionados de algodón (*Gossypium hirsutum* L.) que representan una amplia gama de reacciones al complejo de la marchitez fungosa y nematodos agalladores, fueron evaluadas para determinar su respuesta a *Fusarium oxysporum* f. sp. *vasinfectum* y *Meloidogyne incognita* bajo condiciones de microparcelas con suelo de campo infestados con ambos patógenos. La resistencia al complejo estuvo basado en la mortalidad de las plantas, mientras que la resistencia a *F. oxysporum vasinfectum* se basó en la descoloración vascular. La resistencia a *M. incognita* se basó en la densidad poblacional de huevos y juveniles en 500 cm^3 de suelo al momento de la cosecha. En general, los cultivares reaccionaron al complejo en forma esperada y aquellos materiales descritos como resistentes o tolerantes fueron también mas resistentes a *F. oxysporum vasinfectum* que aquellos cultivares descritos como susceptibles. Por lo contrario, se encontraron pocas diferencias entre los cultivares en su reacción a *M. incognita*. Sólo 'Auburn 634' fue altamente resis-

†Supported by the USDA CSRS Southern Region IPM Program, grant no. 86-CRSR-2-2883.

tente al nematodo. En campos infestados con ambos patógenos, los cultivares resistentes al complejo pueden sufrir pérdidas en rendimiento causadas por *M. incognita*.

Palabras clave: Algodón, complejo de enfermedad, *Fusarium oxysporum* f. sp. *vasinfectum*, *Gossypium hirsutum*, *Meloidogyne incognita*, nematodo de las agallas, resistencia.

INTRODUCTION

The Fusarium wilt/root-knot disease complex of cotton is caused by *Fusarium oxysporum* f. sp. *vasinfectum* (Atk) Synd. & Hans. and *Meloidogyne incognita* (Kofoid & White) Chitwood, and was first recognized by Atkinson in 1892 (3). This disease complex has been the subject of numerous studies since it was first reported (11,14) and it is widely accepted that symptoms of the wilt disease appear more rapidly and are more severe in the presence of the nematode than in its absence. Numerous reports indicate that infection by *M. incognita* enables *F. oxysporum* f. sp. *vasinfectum* to defeat resistance to the fungus in some cotton cultivars (11,14). As a result of the interaction between these two pathogens, and the reported effects of the nematode on resistance to *F. oxysporum* f. sp. *vasinfectum*, some cotton breeding programs evaluate cotton germplasm only for resistance to *F. oxysporum* f. sp. *vasinfectum* in the presence of *M. incognita*. Furthermore, resistance to the wilt disease in certain cotton genotypes during such tests also has been considered to be evidence of resistance to the root-knot nematode, even though no direct assessment of response to the nematode was made (8).

Several studies with other crop species have reported that root-knot nematodes do not enable *Fusarium* spp. to overcome resistance in all instances (2,6,7); thus, resistance to the wilt disease cannot be used to infer resistance to the nematode. Starr and Veech (17) reported that selected cotton genotypes which exhibited high levels of resistance to Fusarium wilt in soils infested with both pathogens were susceptible to the nematode.

Numerous cotton cultivars have been reported to be resistant (1) to the Fusarium wilt/root-knot complex. For many of these cultivars, data as to whether the cultivar is resistant to both *F. o. vasinfectum* and *M. incognita* are lacking. The objective of this study was to determine the reaction of selected cotton cultivars to each pathogen in the Fusarium wilt/root-knot complex and to the disease complex itself.

MATERIALS AND METHODS

All experiments were conducted in field microplots (55-cm diam, 45-cm deep) containing a loamy sand (91% sand, 2% silt, and 7% clay, < 1% organic matter, pH 7.9). Plots were fumigated each year with methyl bromide (98%) and chloropicrin (2%) at 1 kg/m^2 to eliminate existing microflora and fauna populations. Microplots were infested with *F. oxysporum* f. sp. *vasinfectum* race 1 and *M. incognita* race 3 as described previously (18). Nematodes were reared in a greenhouse on *Lycopersicon esculentum* Mill. cv. Rutgers. Infested soil and infected root fragments from greenhouse cultures were added to the upper 30 cm of soil in the microplots at the rate of 10 eggs and juveniles per 500 cm^3 soil. *Fusarium oxysporum* f. sp. *vasinfectum* was cultured on a sand-corn meal medium (18); microplots were infested by adding 25 g of infested sand-corn meal medium to each plot. Established population densities of *F. oxysporum* were determined by soil dilution plates (18) 2 weeks after infesting the microplots. *Fusarium oxysporum* f. sp. *vasinfectum* population densities were 1 800 ± 450 colony forming units (CFU)/g soil in 1987, 11 900 ± 1 900 CFU/g soil in 1988, and 5 900 ± 850 in 1990. These levels of *M. incognita* and *F. oxysporum* f. sp. *vasinfectum* were shown previously (18) to cause sufficient disease development for evaluation of resistance.

Disease reactions of 21 cotton cultivars were examined (Table 1). Cultivars were selected to represent a reported range of resistance and susceptibility to the disease complex (1). A susceptible control 'Rowden' (16) and a resistant control 'Auburn 634' (15) were included as a part of each experiment. Three treatments were imposed on each cotton cultivar in a split-plot experiment arranged in a complete-block design with four replications of each treatment. Cultivars were main plots and treatments were subplots. Treatments were uninfested soil, soil infested with *F. oxysporum* f. sp. *vasinfectum*, and soil infested with both *F. oxysporum* f. sp. *vasinfectum* and *M. incognita*. Due to space limitations and because *F. oxysporum* f. sp. *vasinfectum* does not affect the reaction of cotton to *M. incognita* (18), no nematode alone treatment was included. The lack of a nematode alone treatment was further justified because it was not the objective of these experiments to determine if an interaction occurred. Ten seeds were planted in each microplot and plants were thinned to five per microplot 2 weeks after emergence. Microplots were irrigated as needed and fertilized based on soil test results. Insecticides were applied as needed to control anthropod pests.

At crop maturity, ca. 140 days after planting, total plant mortality was assessed for each microplot and the crown region of each plant (± 5 cm from the soil line) was examined for vascular browning by removing the bark and cortex. Stem tissue samples collected from the crown region from two plants per microplot were plated out on Komoda's selected medium (10) to confirm the presence of *F. oxysporum* f. sp. *vasinfectum*. Additionally, composite soil samples consisting of eight 2.5-cm-diam cores per microplate were collected. Population densities of eggs and juveniles of *M. incognita* in nematode-infested plots were determined following elutriation of 500-cm^3 soil samples (4,5). Data were subjected to analysis of variance using the SAS GLM procedure (13).

Table 1. Mortality of cotton cultivars caused by *Fusarium oxysporum* f. sp. *vasinfectum* in the presence or absence of *Meloidogyne incognita*.[x]

1987		1988		1990	
Mean cultivar values for all treatments					
Auburn 634 (E)[y]	0.1	Auburn 634 (E)	0.7	Auburn 634 (E)	0.4
Rowden (P)	1.6	Rowden (P)	2.2	Rowden (P)	1.0
Tamcot SP21 (E)	0.0	All Tex E2 (M)	0.4	Paymaster 505 (E)	1.9
Paymaster 145 (G)	0.0	DP SR383 (M)	0.8	Tamcot CABS (E)	1.1
Paymaster 404 (G)	0.0	Paymaster HS26 (G)	1.3	Highland 34 (M)	0.9
		Dawson Co. 81 (–)	1.6	Rilcot RK-6 (M)	0.7
		Ranger BB53 (G)	2.2	Coker 320 (–)	0.4
		Rilcot RK-7 (M)	1.6	NK KC 380 (G)	0.3
		GSA 71 (P)	2.8	Ranger RV64 (G)	0.1
		Qaw Paw D (P)	2.8	McNair 220 (M)	0.1
LSD (P = 0.05)	–[z]		1.2		0.8
Treatment effects					
Uninfested	0.4		1.0		0.4
Fusarium	0.1		1.1		0.6
Fusarium + root-knot	0.9		2.8		1.2
LSD (P = 0.05)	0.4		0.6		0.4

[x]Values are mean number of plants per microplot with vascular browning in the crown region; there were 5 plants/microplot.
[y]Level of resistance to the Fusarium wilt/root-knot complex as reported in references 1, 15, and 16: E = excellent, G = good, M = moderate, P = poor, (–) = reaction unknown.
[z]Analysis not done because of zero values.

RESULTS

There were significant (P = 0.05) differences in plant mortality (Table 1) and vascular browning (Table 2) due to treatments and cultivars each year. Highest levels of mortality and vascular browning were observed in plants grown in microplots infested with both pathogens. The presence of *F. oxysporum* f. sp. *vasinfectum* in the crown tissue was confirmed by its greather than 50% recovery from samples from fungus plus nematode treatments. Recovery from samples from other treatments was significantly (P = 0.05) lower. Cultivars reported to have good to excellent resistance to the complex consistently had lower levels of mortality and vascular browning than those cultivars listed as susceptible (1). Higher levels of disease were observed in 1988 than in 1987 or 1990. This corresponded to the trend of the established population densities of *F. oxysporum* f. sp. *vasinfectum,* which were higher in 1988 than in 1987 or 1990. Vascular browning and plant mortality occasionally were observed in uninfested microplots and was probably due to cross-contamination of the microplots with *Fusarium* from splashing rain.

Table 2. Vascular browning of cotton cultivars caused by *Fusarium oxysporum* f. sp. *vasinfectum* in the presence or absence of *Meloidogyne incognita*.[y]

1987		1988		1990	
Mean cultivar values for all treatments					
Auburn 634 (E)[z]	1.2	Auburn 634 (E)	1.4	Auburn 634 (E)	1.4
Rowden (P)	2.5	Rowden (P)	2.1	Rowden (P)	2.2
Tamcot SP21 (E)	1.8	All Tex E2 (M)	3.9	Paymaster 505 (E)	2.0
Paymaster 145 (G)	2.3	DP SR383 (M)	2.5	Tamcot CABS (E)	2.0
Paymaster 404 (G)	2.6	Paymaster HS26 (G)	2.0	Highland 34 (M)	1.5
		Dawson Co. 81 (–)	2.6	Rilcot RK-6 (M)	2.2
		Ranger BB53 (G)	2.3	Coker 320 (–)	1.8
		Rilcot RK-7 (M)	3.2	NK KC (G)	2.0
		GSA 71 (P)	2.5	Ranger RV64 (G)	1.5
		Qaw Paw D (P)	2.5	McNair 220 (M)	1.2
LSD ($P = 0.05$)	0.8		1.2		0.9
Treatment effects					
Uninfested	1.2		1.1		0.7
Fusarium	2.0		2.5		1.4
Fusarium + root-knot	3.6		3.9		2.9
LSD ($P = 0.05$)	1.4		2.0		0.5

[y]Values are mean number of plants per microplot with vascular browning in the crown region; there were 5 plants/microplot.
[z]Level of resistance to the Fusarium wilt/root-knot complex as reported in references 1, 15, and 16: E = excellent, G = good, M = moderate, P = poor, (–) = reaction unknown.

Population densities of *M. incognita* increased at least 10-fold on all cultivars except Auburn 634 (Table 3). No increase in nematode population densities was observed in microplots planted to Auburn 634. No consistent relationship between reported reaction to the disease complex and host status to the nematode was evident. Plants of 'Paymaster 145' and 'Tamcot SP21' were not killed and had little vascular browning but supported the highest population densities of the nematode. Correlations between final nematode population densities and either plant mortality or vascular browning were not significant ($r < 0.25$).

DISCUSSION

In these tests, vascular browning was used as an indicator of susceptibility to *F. oxysporum* f. sp. *vasinfectum* (9) and final population densities of the nematode were used as an indicator of resistance to *M. incognita* (17). Plant mortality was used as an indicator of resistance to the disease complex. Seed cotton yield was not measured in these experiments due to constraints of the microplot system and the plasticity of cotton (16).

Table 3. Effect of cotton cultivar on final population densities of *Meloidogyne incognita* in microplots.[y]

1987		1988		1990	
Auburn 634 (E)[z]	10	Auburn 634 (E)	10	Auburn 634 (E)	10
Rowden (P)	3 300	Rowden (P)	100	Rowden (P)	620
Tamcot SP21 (E)	5 000	All Tex E2 (M)	400	Paymaster 505 (E)	140
Paymaster 145 (G)	1 200	DP SR383 (M)	3 600	Tamcot CABS (E)	460
Paymaster 404 (G)	23 800	Paymaster HS26 (G)	1 000	Highland 34 (M)	640
		Dawson Co. 81 (–)	3 600	Rilcot RK-6 (M)	100
		Ranger BB53 (G)	500	Coker 320 (–)	240
		Rilcot RK-7 (M)	2 500	NK KC 380 (G)	1 930
		GSA 71 (P)	500	Ranger RV64 (G)	2 330
		Qaw Paw D (P)	800	McNair 220 (M)	730
LSD (P = 0.05)	1 500		1 400		1 800

[y]All values are numbers of eggs and second stage juveniles per 500 cm^3 soil.
[z]Level of resistance to the Fusarium wilt/root-knot complex as reported in references 1, 15 and 16: E = excellent, G = good, M = moderate, P = poor, (–) = reaction unknown.

With the exceptions of 'Paymaster 505' and 'Ranger BB53', cultivars reported to have good to excellent resistance (1) to the disease complex had lower levels of mortality than did susceptible Rowden. No cultivar tested was completely resistant to infection by *F. oxysporum* f. sp. *vasinfectum* as determined by vascular browning and recovery of the fungus. Rowden was the most susceptible to infection of the cultivars tested and Auburn 634 the most resistant. Those cultivars reported to have good to excellent resistance to the Fusarium wilt/root-knot complex were more resistant to *F. oxysporum* f. sp. *vasinfectum* than those reported as susceptible to the complex. Auburn 634 is known to be highly resistant to *M. incognita* (15,17) and it supported little nematode reproduction in our tests. All of the other cotton cultivars supported sufficiently high population densities of the nematode to be considered susceptible. Despite the lack of a sufficient correlation, with the exceptions of Auburn 634 and 'All-Tex E2', those cotton lines which supported relatively low nematode populations also suffered the highest levels of plant mortality. Starr et al. (18) reported that as plant mortality of cotton increases due to the Fusarium wilt/root-knot complex, nematode population densities decline. Although All-Tex E2 suffered little mortality and supported a low number of nematodes, in subsequent greenhouse tests it supported reproduction of *M. incognita* similarly to Rowden (data not shown).

Shepherd (16) reported that resistance to *F. oxysporum* f. sp. *vasinfectum* can be closely linked to resistance to root-knot nematodes in that cotton genotypes resistant to the nematode usually are more resistant to the wilt pathogen than other cultivars. Shepherd (16) and Starr and Veech (17), however, demonstrated that cotton genotypes resistant to Fusarium wilt in the presence of the nematode are not necessarily resistant to the nematode. Although root-knot nematodes are known to form disease complexes with *Fusarium* spp. and to defeat resistance to the wilt diseases (11,13), several studies have shown that the nematodes are not able to overcome resistance to Fusarium wilt in all instances (2,6,7). Because root-knot nematodes are responsible for a significant portion of the cotton yield losses observed in soil infested with nematodes and *Fusarium* spp. (18), it is important that resistance to the nematode be determined directly and not based on wilt symptoms. Release of cotton cultivars reported as resistant to the Fusarium wilt/root-knot complex implies resistance to both pathogens. When this is not the case, as is apparently true for many cotton cultivars, producers may suffer unnecessary losses by assuming that those cultivars are providing protection against both pathogens.

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Received for publication: *30.VIII.1990*
Recibido para publicar: