Published November, 1979

Fusarium Wilt Resistance in Day-Neutral Selections from Primitive Races of Cotton and Crosses of Race Selections with a Commercial Cultivar[1]

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ABSTRACT

Day-neutral plants of selections from the primitive cotton (*Gossypium hirsutum* L.) race collection and from crosses of these with 'Deltapine 16' (DPL-16) were evaluated for resistance to Fusarium wilt [*Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Snyd. & Hans.]. Yield and fiber properties of advanced material from these crosses were also determined. When evaluated as race stock selections per se, or as advanced generation materials from crosses with DPL-16, Fusarium wilt resistance of materials with either an accession 69 or 88 background was high. Selections of advanced materials from crosses of DPL-16 with six other race accessions (78, 80, 87, 113, 116, and 495) were also highly resistant. Based on a 1-year evaluation at one location lint yields and fiber properties of all advanced materials (BC_2F_4) from crosses with DPL-16 were not statistically significant from those of the two check cultivars (DPL-16 and 'Stoneville 213').

Additional index words: **Host-plant resistance, *Gossypium hirsutum* L.**

PRESENTLY, about 1,200 accessions (Texas race stocks) of primitive cotton (*Gossypium hirsutum* L.) are available. Hutchinson (4) placed seven categories in this collection that he called races. The term "race" has no taxonomic standing and thus Hutchinson's names are not valid (3). We use these names merely for convenience. Scientists in the Regional Project S-77 (Preservation and Utilization of Germplasm in Cotton) are responsible for maintaining this collection (1). Most of the accessions are photoperiodic and do not flower in the U.S. Cotton Belt during the relatively long days of the summer months. However, a number of characters of value for insect and disease resistance have been found in these lines (5, 6). Therefore, a program to breed day-neutral genes into these primitive race stocks was initiated and is presently underway at Mississippi State, Miss.

The purpose of this study was to determine the Fusarium wilt resistance of some of these primitive race stocks as well as that of advanced materials from the crosses of these stocks with 'Deltapine 16' (DPL-16). Yield and fiber properties of some of the advanced materials were also studied.

MATERIALS AND METHODS

Development of Test Materials

Thirty-six accessions from the primitive race collection were used as source materials in these studies. Of these accessions, 21 were originally collected in Gutemala, 1 in El Salvador, 3 in the Mexican state of Guerrero, 8 in the state of Chiapas, and 1 each in the states of Oaxaca and Pueblo. One accession was from an unknown location. These accessions were identified into races as follows: 31 *latifolium*; 3 *punctatum*; 1 *palmeri*; 1 *richmondi*.

DPL-16 was crossed with a number of the primitive race stock accessions. These hybrids were then backcrossed to DPL-16 two times and finally self-pollinated. The original crosses were made in Iguala, Mexico, as were both backcrosses, and the first self. Seed from plants developed following the above breeding procedures were planted at Mississippi State, Miss. Plants that flowered and set a good number of bolls at this location (day-neutral) were allowed to open-pollinate for several generations. Fusarium wilt reactions of BC_2F_3 lines from these crosses and the original race stock accessions were evaluated. The BC_2F_4 lines were evaluated for yield and fiber properties.

In a second series of crosses, several of the lines were crossed to DPL-16 and self-pollinated. The F_2 seed were planted at Mississippi State, Miss., and seed from plants with open bolls were harvested. Seed from each cross were bulked until F_5 when they were tested for resistance to Fusarium wilt.

Fusarium Wilt Testing

Seed of all materials evaluated in greenhouse tests were submerged in 80 C water for 90 sec, coated with a fungicide combination containing three parts Arasan:10 parts Demosan[3], and incubated in a germinator at 31 C for 24 to 28 hours. Germinated seeds were planted in 6- × 32-mm preformed holes in soil in greenhouse benches. After seeds were planted, the soil was covered with brown paper which was kept wet until it was removed 3 to 4 days later.

About a week after planting, all rows were thinned to 10 plants spaced approximately 5 cm within the row. Rows were spaced 15.2 cm apart. Air temperatures were maintained from 24 to 29 C, although temperatures exceeded the upper limits in two tests which were conducted during the summer months. Approximately 17 days after planting, these test plots were hand cultivated and the soil was firmed around the plants. This operation raised the soil level around the plants about 2 cm.

Isolates of *Fusarium oxysporum* Schlect f. *vasinfectum* (Atk.) Snyd. & Hans. used for inoculum were increased in Czapek's solution in flasks on a waterbath shaker maintained at 27 C. After 10 days each culture was mixed in a blender. Spores were counted with the use of a hemocytometer, then cultures were adjusted to a spore concentration of 2×10^6 microconidia/ml in sterilized distilled water. Inoculum for all tests was composed of a mixture of six Fusarium-wilt isolates and was prepared by mixing equal parts (v:v) of these highly virulent isolates.

Plants in all greenhouse tests were inoculated with Fusarium 3 weeks after emergence using a needle-puncture technique similar to that described by Bugbee and Presley (2) with two inoculations per plant. Inoculations were made on opposite sides of the stem of each plant at approximately 1.7 cm above the soil line.

Thirty-five race stocks, segregates from crosses of 22 race stocks to DPL-16 and two standard checks ('Rowden,' susceptible; Auburn BR 2, resistant) were evaluated in a series of tests. The experimental design for all greenhouse tests was a ran-

[1] Contribution from the Crops Science Research Unit, USDA, SEA, AR, in cooperation with the Dep. of Agronomy and Soils, Auburn Univ. Agric. Exp. Stn., Auburn, AL 36830, and the USDA Boll Weevil Research Laboratory, SEA, AR, Mississippi State, MS 39762. Received 18 Nov. 1978.

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[3] Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the USDA nor does it imply its approval to the exclusion of other products that also may be suitable.

Table 1. Type of materials and number of entries and replications evaluated in nine tests.

Test no.	Type of materials	No. entries	No. replications
1	Race stocks	22	7
2	Race stocks	22	7
3	Race stocks	22	8
4	Race stocks	19	8
5	Race stocks	13	10
6	F_5	22	6
7	F_5	22	6
8	BC_2F_3	22	5
9	BC_2F_3	14	4

Table 2. Percentages of plants with Fusarium wilt symptoms, means relative to the resistant check, and consensus ratings of primitive race stock selections of cotton evaluated in greenhouse tests.

Texas race stock accession no.	Wilted plants					$\bar{X}$†	Consensus rating‡
	Test 1	Test 2	Test 3	Test 4	Test 5		
	%						
3			65.0	63.8	77.0	134	S
4			34.6**	39.2**	48.0	79	HR
7			19.4**		49.0	71	HR
9			27.7**			54	HR
17			60.0	59.3		110	MR
19			95.0	94.1	97.5	185	HS
21			76.0	65.7	74.7	141	S
22			69.4	74.7		133	S
25	94.3	90.0				189	HS
40			73.3	85.7		146	S
59	68.6	58.9				130	S
66	81.4	73.9			65.0	152	HS
68			29.4**	31.2**	39.9**	66	HR
69	26.0*	28.4	20.0**	63.3	50.0	74	HR
75	54.4	42.9	32.6**	61.9		92	R
78	48.7	49.2	36.2**	58.8		94	R
80	67.5	45.5				114	MR
84	58.3	65.5				127	S
85			34.2**	78.6		102	R
87	37.1	48.6				89	R
88	49.6	38.6	37.0**	36.2**		78	HR
91	33.9	27.0				62	HR
100	88.6	61.7				151	HS
106	64.9	57.2				125	S
113	64.9	37.4				102	R
155			63.6	62.0	93.2	143	S
158	74.0	79.5				158	HS
177			77.9	85.0	86.2	161	HS
188			76.5	72.9	89.3	155	HS
195	94.3	90.0				189	HS
201	82.9	77.1				164	HS
206			83.8	70.4		143	S
209	58.6	50.3				111	MR
223	57.1	48.4				105	R
495	48.6	40.6	45.3**§			90	R
Rowden (Susceptible check)	90.0	63.0	83.8	88.3	93.9	156	HS
Auburn BR 2 (Resistant check)	54.3	44.2	51.2	57.5	47.0	100	R
L.S.D.$_{0.05}$	25.9	23.4	4.4	8.6	3.6		
L.S.D.$_{0.01}$	30.2	30.8	5.7	11.3	4.7		

*,** Significantly more wilt-resistant than the resistant check at the 0.05 and 0.01 L.S.D. levels, respectively. † Average of all greenhouse tests after converting each to a percentage of the resistant check. ‡ S = susceptible, HS = highly susceptible, R = resistant, MR = moderately resistant, HR = highly resistant. § BC_2F_3 material.

domized complete block. The test number, type of materials, and number of entries and replications evaluated in a given test are shown in Table 1. All tests, except number 9 (a field test), were conducted under greenhouse conditions. Wilted plants in greenhouse tests were removed and recorded at weekly

Table 3. Percentages of plants with Fusarium wilt symptoms, means relative to the resistant check, and consensus ratings of F_5 and BC_2F_3 generations from crosses of primitive race stock selections of cotton with DPL-16.

Texas race stock accession no.	Wilted plants				$\bar{X}$‡	Consensus ratings§
	F_5 generation		BC_2F_3			
	Test 6	Test 7	Test 8	Test 9†		
	%					
3	27.4	32.1			83	R
25	34.9	38.8	30.7	21.2	95	R
59	36.9	46.0	26.7		100	R
66	31.6	33.1	29.3		86	R
69	26.5	33.8	23.5	28.8	77	HR
75	34.2	42.0	20.9*	25.8	89	R
78	18.9*	28.0	13.7**	21.2	56	HR
80			19.0*	37.2	50	HR
84	40.5	31.7	18.3*	25.8	83	R
87			17.9*	22.5	47	HR
88	19.0*	29.3	23.1	14.8	65	HR
91	41.7	44.5	8.2**	19.0	87	R
100	30.4	36.3	28.0		87	R
106	24.0	34.9	31.3		82	R
113	32.9	26.7	20.5*	18.2	74	HR
116	22.0	15.0**			52	HR
158	44.2	23.7*	22.9		84	R
195	41.5	43.2	30.7		106	R
201	48.9	34.6	23.9		99	R
209	47.8	41.0	24.1		104	R
223	33.9	37.8	35.0	22.8	97	R
495	16.7**	22.5*	18.2*	12.5	52	HR
Rowden (Susceptible check)	65.0	69.3	75.3	51.2	191	HS
Auburn BR 2 (Resistant check)	35.4	36.4	37.8	14.0	100	R
L.S.D.$_{0.05}$	13.6	12.6	16.6	19.0		
L.S.D.$_{0.01}$	17.8	18.0	21.8	22.7		

*,** Significantly more wilt-resistant than the resistant check at the 0.05 and 0.01 L.S.D. levels, respectively. † Tested in field nursery at Tallassee, Ala. ‡ Average of all greenhouse tests after converting each to a percentage of the resistant check. § R = resistant, HR = highly resistant, HR = highly susceptible.

intervals for 4 weeks after inoculation. Wilting percentages were then determined and compared to the resistant check.

Test 9 was conducted at Tallassee, Ala., during 1975 on soil heavily infested with both *F. oxysporum* f. *vas.* and root-knot nematodes (*Meloidogyne* spp.). Entries in this test were planted with a tractor-mounted cone planter which planted 200 seeds per plot at a soil depth of about 3.2 to 3.8 cm. Rows were spaced 1 m apart and plots were 9 m in length. Initial live plant counts were made and recorded. Wilted plants were removed and recorded at 72, 101, and 134 days after planting. Remaining live plants were also counted and recorded on the last day. Differences between initial and final live plant counts were attributed to wilt losses. Percent wilted plants per plot and mean wilted plants per entry were then determined.

Yield and Fiber Properties

To obtain an approximation of potential breeding problems in the yield and fiber, seed of the BC_2F_4 generation were planted in single row plots 15.2 m long and were replicated four times at Mississippi State, Miss., in 1976. A recommended insect control program was followed. Two machine harvests were made following defoliation. A 50-boll sample was picked from each plot for determination of boll size (g cottonseed per boll) and lint percentage (ratio of lint to cottonseed expressed as a percentage). Lint from these samples was sent to a commercial laboratory for analyses of fiber length (2.5 and 50% span length), strength (T_1: breaking strength of a fiber bundle measured with a 3.2-mm gage stelometer), elongation (E_1: percentage elongation of the fiber bundle before breaking), and fineness (micronaire).

Table 4. Yield and fiber data of BC_2F_4 materials from crosses of primitive race stock selections of cotton with DPL-16.

Texas race stock accession no. or cultivar	Yield			Fiber properties						
	Lint	First harvest	First harvest / Total	Lint	Boll size	Fineness (micronaire)	Strength (T_1)	Elongation (E_1)	Span length 50%	Span length 2.5%
	kg/ha		%	%	g	units	mN/tex	%	mm	
25	676	298	44.1	39.5	5.02	4.5	528.3	9.6	13.71	29.46
59	697	275	39.4	39.9	5.66	4.6	497.8	9.5	14.22	30.23
66	538	216	40.2	39.2	4.95	4.5	535.9	9.7	13.97	29.97
69	810	424	52.3	43.9	5.15	4.5	497.8	9.4	13.72	29.46
75	569	202	35.4	38.2	5.32	4.6	533.4	9.9	13.97	29.46
78	590	239	40.5	38.5	5.15	4.5	510.5	9.6	13.97	29.46
80	744	380	51.1	39.9	5.13	4.6	508.0	9.7	13.72	28.96
84	722	253	35.1	39.1	5.28	4.7	523.2	9.7	14.22	29.46
87	707	365	51.7	39.5	5.25	4.8	508.0	9.6	14.22	29.97
88	726	337	46.5	39.2	5.92	4.7	520.7	9.2	13.97	29.97
91	704	266	37.7	39.0	5.29	4.6	528.3	9.3	13.72	29.46
100	609	351	57.6	38.4	5.20	4.5	513.1	10.1	13.72	29.21
106	673	253	37.7	39.0	4.98	4.3	510.5	10.2	19.22	29.72
113	613	248	40.4	38.7	5.26	4.6	513.1	9.3	14.22	29.72
158	618	369	59.7	38.9	5.42	4.8	535.9	9.5	14.22	30.23
195	626	269	43.0	39.1	5.18	4.5	518.2	9.8	13.72	28.70
201	584	309	52.9	39.9	5.30	4.7	518.2	9.9	13.97	29.46
209	645	244	37.9	38.3	5.20	4.3	508.0	9.0	13.72	29.21
223	797	396	50.1	38.9	4.99	4.2	510.5	9.9	13.97	29.46
495	662	343	51.8	39.6	5.17	4.5	523.2	10.0	13.97	29.21
DPL-16	722	280	38.8	40.7	5.23	4.2	520.7	9.9	14.22	29.97
ST.-213	841	377	44.8	40.8	5.05	4.6	513.1	9.4	13.72	29.21
$L.S.D._{0.05}$	ns	123		ns	ns	ns	ns	ns	ns	ns

RESULTS AND DISCUSSION

Fusarium wilt resistance of seven lines (4, 7, 9, 68, 69, 88, and 91) evaluated in greenhouse tests as selections from race stocks per se was greater than that of the resistant check (Table 2). Ten other lines (17, 75, 78, 80, 85, 87, 113, 209, 223, and 495) in these tests expressed resistance similar to that of the resistant check. Eighteen race accessions evaluated under these conditions were susceptible.

Materials from the advanced generations of 11 of the race accessions crossed with DPL-16 were significantly more resistant than the resistant check in at least one test (Table 3). In addition, advanced materials from accession 78 × DPL-16 were more Fusarium wilt resistant than the resistant check in two tests while those from 495 × DPL-16 were more resistant in three tests. None of the BC_2F_3 materials evaluated under field conditions (Test 9, Table 3) expressed significantly less wilting than the resistant check but 10 of these 12 entries had significantly less wilting than the susceptible check. Unfortunately, all materials were not evaluated in all tests. Only two of the 12 advanced materials evaluated for Fusarium wilt resistance both in greenhouse and field tests (80 × DPL-16 and 69 × DPL-16) were resistant in the greenhouse tests but somewhat susceptible under field conditions. However, because soil at the site of the field test was infested with root-knot nematodes in addition to the wilt organism, this difference in reaction is not surprising. Since DPL-16 itself was not included in the tests reported, data for direct comparisons of this cultivar with the resistant check Auburn BR2 are unavailable. Data for comparisons of each of these cottons with the susceptible Rowden, however, are available. In the eight greenhouse tests and one field test reported herein (Tables 2, 3), Auburn BR2 had 58 and 27%, respectively, as many wilted plants as Rowden. In a separate series of eight greenhouse and four field tests (7), DPL-16 had 72 and 52%, respectively, as many wilted plants as Rowden. Thus, progenies from crosses of race stock accessions with DPL-16, that had significantly less wilt than Auburn BR2, also would be expected to have significantly less wilt than DPL-16.

While day-neutral selections from accession numbers 84 and 158 were susceptible as race stock selections per se (Table 2), advanced materials from crosses of DPL-16 with each of these were significantly more resistant, in at least one test, than the resistant check (Table 3). This result might possibly be due to the greater vigor and better adaptation of segregating materials than that in their individual race stock parents. However, an alternative explanation might be that genes from these race accessions interacted favorably with those from DPL-16 to produce greater resistance.

Although all materials were not evaluated in all tests, the resistant check was common across tests, and thus allowed us to determine the resistance of entries as a percentage of this check (Tables 2, 3) and to give each entry a consensus rating. Materials with either accession number 69 or 88 in their background expressed a high degree of Fusarium wilt resistance both as race stock selections per se and as crosses with DPL-16. Entries 78, 80, 87, 113, 116, and 495 were highly resistant when evaluated as advanced materials from crosses with DPL-16 but expressed resistance only equal to the resistant check when tested as race stock selections per se (except 116, which was not tested). The mean Fusarium wilt resistance of each of these advanced materials in crosses was greater than that of the resistance check. Therefore, germplasm releases of several of these resistant materials will be made.

Lint yields and fiber properties of 20 of the advanced

lines grown at Mississippi State, Miss., were evaluated in 1976 (Table 4). Yields of none of these lines were significantly different from those of the two commercial cultivars, DPL-16 and 'Stoneville 213'; however, lint yield ranged from 538 to 841 kg/ha. Since these are based on 1-year, one-location, caution should be used with these yield data. They do indicate that we should probably not expect major yield depressing genes in crosses with these lines. Fiber properties of these advanced lines also compared favorably with those of the commercial cultivars. These yield and fiber data indicate that these lines can be used readily as breeding materials to transfer and develop high yielding commercial cultivars with good fiber properties and Fusarium wilt resistance.

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