VERTICILLIUM WILT RESISTANCE IN COTTON: GERMPLASM EVALUATION AND INHERITANCE

Jinfa Zhang
W. Wang
S. Bajaj
H. Gatica
Department of Plant and Environmental Sciences, New Mexico State University
Las Cruces, NM
S. Sanogo
Department of Entomology, Plant Pathology and Weed Science, New Mexico State University
Las Cruces, NM
Robert Flynn
C. French
Artesia Agricultural Science Center, New Mexico State University
Artesia, NM
Richard Percy
College Station, TX
Mauricio Ulloa
USDA-ARS
Shafter, CA
S. E. Hughs
Southwest Cotton Ginning Lab, USDA-ARS
Mesilla Park, NM

Abstract

This is a progress report summarizing research activities at NMSU breeding for Verticillium wilt (Vw) resistance and evaluating commercial cotton cultivars and germplasm lines for Vw resistance in the greenhouse and field since 2003. Two hundred-sixty seven cultivars and germplasm lines were screened in the greenhouse, while 357 cultivars and germplasm lines were screened in the field. The results indicated that, (1) some commercial cotton cultivars developed from major cotton seed companies displayed good Vw resistance; (2) many Acala cotton had good Vw resistance, but not every Acala cotton germplasm is Vw resistant; (3) several advanced backcross inbred lines showed good Vw resistance, indicating that the Vw resistance from Pima cotton was successfully transferred into Upland cotton; (4) F_1 hybrids between resistant and susceptible lines had similar or intermediate Vw incidence to the resistant parents, indicating that Vw resistance is completely or incompletely dominant; (5) the Vw resistance in Pima cotton is heritable and 1-2 resistance genes were implicated based on the segregation of Vw resistance in two F_2 populations; and (6) Vw infection significant reduced cotton yield, lint percentage and 50% span length, but not 2.5% span length and fiber strength.

Introduction

Verticillium wilt (Vw) caused by *Verticillium dahliae* Kleb is a soil-borne fungal disease which causes annual cotton yield loss of 0.5-3.5% nationwide in the U.S. and as high as 3.5-5.0% in New Mexico (Blasingame, 2006). The fungal hyphae penetrate root tips and enter the xylem vessels in the root system, where they proliferate and move throughout the xylem system of the plant. Young cotton plants infected with the disease show yellow or/and necrotic leaves, leaf shedding, stunting growth, wilting, vascular discoloration, and often die.

Many factors including pathogen population and virulence, cultivar, plant growth, temperature, soil microorganisms, irrigation, and fertilizers can affect the symptom development of Verticillium wilt. The development and employment of Vw-resistant cultivars could minimize the disease damage to cotton. In the past 50 years, cotton breeding has made substantial progress in progressively increasing the resistant level to Vw. Some modern Acala cultivars developed in California and New Mexico are reported to be highly resistant or tolerant, while some other cultivars such as DP 51, DP Acala 90, ST 495 and HS 26 have moderate resistance. Early work showed that the resistance in the resistant Pima and Upland cottons is polygenic with additive effects and moderate heritabilities. However, the more recently data obtained in China and Australia indicated that the Vw resistance in resistant Egyptian, Acala, and Australian cottons might be conditioned by one dominant gene. The results of Vw evaluation could be complicated by temperature, inoculation method, inoculum density, and pathogen strain. The genetic information on Vw resistance in resistant

American Pima and Acala cotton is lacking. The genetic relationship between the resistances from difference sources is also unknown.

The objectives of the study were, (1) to systematically screen cotton cultivars, germplasm, and breeding lines for Verticillium wilt resistance; and (2) to identify and utilize highly resistant germplasm and lines in genetics and breeding studies.

Materials and Methods

Field Evaluations

Year 2003

In Artesia Agricultural Science Center, Artesia, NM, a field has been annually grown with Acala 1517 for more than 30 years that has sustained a relatively uniform and heavy Vw infection. This field served as a natural screening nursery for evaluating new Acala cotton breeding lines and cultivars.

The experiment was conducted to obtain data on the field infection severity of Vw on various commercial cotton cultivars and to compare the differences between healthy and infected plants in yield and fiber quality. 18 commercial cotton cultivars and five Acala 1517 cotton cultivars or strains were chosen in the test. Seeds were delinted and inoculated with VM spore suspension. The seeds were let air dry before sown on May 2003. The experiment was arranged by a randomized complete block design with three replications. Plots were 1 row and 400 ft long. In each plot, 50 consecutive plants were selected for VW evaluation based on vascular discoloration on Oct. 10, 2003. After the plants were mature, seedcotton from five healthy and five apparently heavily infected plants in each plot were bulk harvested and transported to Las Cruces Cotton Breeding Laboratory. The seedcotton was weighed for yield determination and then ginned to determine lint percentage. A sub-sample of fiber from each plot was tested for fiber length, strength, and fineness at the Fiber Testing Lab of the NM cotton breeding and genetics program.

Year 2006

Thirty-two Acala cotton cultivars and germplasm lines were planted in the same field in 2006. The experiment was arranged in a randomized complete block design with 2 replicates. The plot size was 2 rows x 30-ft long. Row spacing was 40 inches. The tests were planted on April 25 and one row was used for destructive assessment (Based on stem discoloration) of Vw infection on Oct. 5 2006. The other row was harvested for yield determination. Cultural practices followed the local recommendations. 50 individual plants in each plot were cut above the soil line to assess stem infection by Vw. The number of infected plants was divided by the total number of plants screened to calculate the percentage of infected plants

Year 2007

The same 32 Acala genotypes were re-tested in the same field with the same experimental design and plot size. Again, one row was used for destructive assessment (based on stem discoloration) of Vw infection on Oct. 6, 2007. In the same field, 146 backcross inbred lines (BIL) and 2 parental lines (SG 747 and Pima S-7) were tested in a randomized complete block design with 2 replicates. The plot size was 1 row x 30-ft long. 50 individual plants in each plot were cut above the soil surface to assess stem infection by VW. The number of infected plants is divided by the total number of plants screened to calculate percentage of infected plants.

In another field where Verticillium wilt was seen to be severe and relatively uniform, more than 100 breeding lines developed from our program were divided into 4 tests, each of which was arranged in a randomized complete block design with 3 replicates (2 rows x 20 ft long plots). 30 plants per plot were cut to assess stem infection by VW. The number of infected plants is divided by the total number of plants screened to calculate percentage of infected plants.

Greenhouse Evaluations

Year 2003

The investigation included Pima (*Gossypium barbadense* L.) and 38 Upland cotton (*G. hirsutum* L.) genotypes, 14 F_1's and four F_2 populations. The seed was planted in a 4-inch plastic pot with 4 seed/pot (2 hill/pot, 2 seed/hill) on January 18, 2003. The pots were filled with potting soil Scott 450 mixed with slow release fertilizer. Each germplasm was grown in three pots.

The pathogen, *V. dahliae* (isolate BC), was collected from field-infected plants at Plant Science Research Center, Las Cruces, NM. The isolates were grown on Czapek-Dox medium for 7 days at 22-25^{O}C for the inoculation. The density of spores was determined using a hemacytometer. Appropriate dilutions were made to give an inoculation density of 10^5 spores/ml. Thirty-five days after planting when seedlings were at 3-4 true leaf stage, root inoculation was made by pouring 200 ml of spore suspension (10^5 spores/ml) on top of soil in each pot to provide 2.0 x 10^7 spores per pot in Experiment-1.

After the disease symptom was first noticed 18 day after inoculation (DAI), evaluation was made three times (31, 40 and 78 DAI) for Vw resistance based on total numbers of leaves, healthy, yellowish, necrotic and abscised leaves for individual plants. A rating system on a scale from 0 to 5 was also established to evaluate the plants for overall response to Vw. A healthy plant with no symptom was scored as 0, and 5 was given for plants with complete defoliation and death. Less degrees of the disease severity (defoliation, chlorosis or necrosis) were rated from 1 to 4, as follows:

0	No symptom
1	<25% chlorotic/necrotic leaves
2	25-50% chlorotic/necrotic leaves
3	50-75% chlorotic/necrotic leaves
4	>75% chlorotic/necrotic leaves
5	Complete defoliation or plant death

Year 2007

The same 146 backcross inbred lines (BILs) tested in the field in 2007, together with the two parental lines were also evaluated in the greenhouse in batches due to the high number of genotypes and limited greenhouse space. In Batch 1, the lines tested were planted on July 2, 3 and 5, and arranged in a randomized complete block design with three replicates with 3 pots per replicate per line. Seedlings were thinned to 1 plant/pot and Vw inoculation was made on July 12 and 26 based on the method used in 2003. To facilitate infection, the root system in each plant was wounded by pushing a 12" stainless steel or plastic ruler through the soil in the pots immediately after inoculation. The inoculated plants were evaluated for Vw resistance based on the aforementioned scoring system on Aug. 26 and 27.

In Batch 2, the test was planted on July 2 and 3 and arranged in a randomized complete block design with two replicates with 3 pots per replicate per line. Seedlings were thinned to 1 plant/pot and inoculated with Vw on Aug. 28. Immediately after inoculation, the root system in each plant was wounded by pushing a 12" stainless steel or plastic ruler through the soil in the pots. Evaluation for Vw resistance was made on Sept. 30.

In Batch 3, the test was planted on Sept. 9 and arranged in a randomized complete block design with two replicates with 3 pots per replicate per line. Seedlings were thinned to 4 plants per pot and inoculated with Vw on Sept. 24. Immediately after inoculation, the root system in each plant was wounded by pushing a 12" stainless steel or plastic ruler through the soil in the pots. The plants were screened for Vw resistance on Oct. 27. Plant fresh weight per plot was weighed on Nov. 19.

The 32 Acala genotypes and other 42 commercial cotton cultivars were also tested in the greenhouse. The test was planted on Sept. 9 and arranged in a randomized complete block design with two replicates with 3 pots per replicate per line. Seedlings were thinned to 4 plants per pot and inoculated with Vw on Sept. 24. Immediately after inoculation, the root system in each plant was wounded by pushing a 12" stainless steel or plastic ruler through the soil in the pots and screened for Vw resistance on Oct. 27. Plant fresh weight per plot was weighed on Nov. 19. A modified scoring system for Vw resistance was adopted, as following,

1	Healthy plants with no symptoms on leaves
2	1 yellowish cotyledon
3	2 yellowish cotyledon
4	1 cotyledon abscised
5	2 cotyledon abscised
6	2 cotyledon abscised and symptomatic true leaves
7	Complete defoliation
8	Dead plant

Data Analysis

The data was subjected to the analysis of variance. The least significant difference (LSD) was used to compare the difference between the cultivars or genotypes. The variances for the F_2 populations were calculated to compare with these from their parents in order to estimate broad-sense heritability for Vw resistance. The minimum number of resistance genes was also estimated.

Results

Commercial Cotton Cultivars

Greenhouse evaluations: The disease rating results from the second date (40 DAI) were significantly and positively correlated with the percentage of the disease infected plants from the first (31 DAI) and the disease ratings from the third (78 DAI) dates with coefficients of correlation ranging from 0.33 to 0.73. However, the data between 31 DAI and 78 DAI were not significantly correlated. Here, we will focus on the results from the third evaluation date (78 DAI) because the disease symptoms were progressing well in that almost all the plants evaluated showed symptoms and genotypes could be better differentiated.

In contrast to Upland cotton, Pima cotton generally showed similar early symptoms such as yellowish or necrotic cotyledons or leaves, followed by vascular discoloration in later plant growth stages; however, there were much fewer completely defoliated or dead plants observed, indicating a good Vw tolerance in the Pima germplasm (Table 1). In comparison with 57-4, a double haploid selection from Pima S-1 released in 1951, the current Pima cultivars have improved Vw resistance. The severity ratings for Pima S-7, PHY 57 and DP HTO were significant lower. The average rating for Pima was 2.16.

There was a significant genetic variation in Vw resistance within the commercial Upland cotton cultivars, of which some commercial cultivars exhibited a desirable Vw resistance. In comparison with the susceptible standard, TM-1, cultivars SG 125, SG 215 BR, DPL 0513 BR, and DP 449 BR from Delta and Pine Land Seed Co. showed significant lower disease ratings (Table 1). ST 5599 BR, ST 4892 BR and ST 4793 R from Stoneville Pedigreed Seed Co. also had significant Vw resistance. The grand mean rating was 2.31 for DP and 2.96 for ST.

Interestingly, ST 4892 BR and ST 4793 R, which were sister cultivars derived from the same genetic background ST 474, showed similar Vw resistance. However, ST 474 is highly susceptible to Vw. BXN 49 B also had ST 474 background, but it showed more tolerance than the latter. Similar results were obtained from the FiberMax cultivars. Cultivars from FiberMax (now Bayer Plant Science) were developed from Australia and possibly contained Acala background. FM 989 and its transgenic stack version FM 989 BR had a good Vw resistance (average rating was 2.04); however, FM 989 R was susceptible (Table 1). Unintentional selection in the process of developing the transgenic cultivars could result in random fixation of Vw resistance gene(s). GC 546 BR and HS 26 were confirmed to be moderately resistant to Vw.

The Acala cotton cultivars or breeding lines tested had lower Vw ratings than TM-1, with most ranging from 2 to 2.5, but only PHY 72 had significant Vw resistance (Table 1). New Acala cotton (1517-99, NM 970123, 970513, and W1218) developed in New Mexico after 1995 had better Vw resistance than Acala 1517-95. Acala PHY 78 and Acala 1517-95 had similar Vw severity ratings as TM-1, showing high Vw susceptibility. Therefore, not all the Acala cultivars are resistant to Vw. The same is true for the Pima cotton cultivars. The results demonstrated that if no selection is made for Vw resistance in a breeding program, Vw resistant gene(s) could be lost during the process. The average rating for Phytogen, New Mexico Acala and CPCSD was 2.42, 2.73 and 2.16, respectively.

Inoculation by mechanical root wounding (33 DAI)

In 2007, seedlings from the commercial cotton cultivars tested in the Official Variety Trial in New Mexico were inoculated with Vw right after emergence and roots were mechanically wounded immediately after inoculation. Mechanical wounding roots accelerated Vw infection in that, at 33 DAI, 24.4-84.0% (with an average of 55.8%) plants in Upland cotton showed symptoms, while almost all the plants (99.2%) in Pima cotton showed symptoms (Table 2). The difference in Vw severity between Upland (with ratings ranging from 1.54 to 5.17) and Pima cotton (ratings from 4.58 to 6.04) was similar in that Pima cotton had much higher average rating than Upland cotton (5.1 vs. 3.1). The results clearly indicate that the Vw resistance in Pima was lost when roots were mechanically wounded at seedling emergence.

Genotypic variation in Vw resistance was also noted (Table 2). Cultivars from FM and PH continued to show better Vw resistance with average ratings of 2.89 and 2.46, respectively, while cultivars from All-Tex had higher disease incidence (72.5%) and severity (3.71). Cultivars from DP and ST had similar disease incidence and severity (57.1 vs. 53.6%; 3.26 vs. 3.09). Most PH cultivars displayed better Vw resistance, and Phy 725 RF and Phy 745 WRF had the highest Vw resistance among the cultivars tested. DP 161 B2RF, DP 143 B2RF, and DP 164 B2RF from DP, ST 4498B2RF, ST 5458 B2RF and ST 4596 B2RF from ST and FM 1840 B2F also showed better Vw resistance.

Field evaluations

No significant genotypic difference was detected for VW infection since the F value of ANOVA was insignificant (Table 3). However, FM 991 and NX 2429 had the lowest VW percentage; GC 546 RR, PHY 72, PHY 78, STX 0003, DP 449 BR, DP 555 BR, NM 970513 and NM 970123 also had lower VW infection. However, ST 4892 BR, ST 457, and W 1218 had the highest Vw percentage.

Vw Resistance for Acala Cotton Germplasm

Acala Young, 1517-E2, Acala 5, Acala SJ-3 and Acala SJ-4 displayed good field resistance in both 2006 and 2007 (Table 4). Acala 1517-99, Acala Tex, Acala 1517-77BR in 2006 and Acala 1517-75, 1517-88, 1517-91, 1517-95, 1517-SR2 and Acala 29 in 2007 also showed good Vw resistance (Table 4).

However, in the greenhouse when roots were mechanically wounded immediately after inoculation at seedling emergence, Acala 1517-88 and 1517-70 had the lowest ratings, and 1517-77BR, 1517C, Acala Young, Acala SJ-2 and Acala 2 also showed better Vw resistance (Table 4). The grand mean of ratings for Acala was 2.89, similar to that for FM. Again, Acala germplasm and cultivars from New Mexico and California contain Vw resistance, but no all of them are Vw resistant.

Breeding Lines Derived from Advanced Backcrossing Using Pima Cotton as the Donor Parents

To broaden the Acala cotton genetic base and to introduce genes for fiber quality and other desirable traits into Acala 1517, hybridization between Upland and Pima or Egyptian Giza cotton and backcrosses were made for two generations using Upland cotton as the recurrent parent. The resulting BC_2F_1 were selfed three times to develop BC_2F_4 backcross inbred lines (BIL). 146 BIL lines, together with their parental lines were tested in both the greenhouse and field (Table 5) and breeding lines from further pedigree selections were also tested in the field (Table 6).

The correlations between different greenhouse tests and field test of the 146 lines and the two parents were positive as expected, but not highly consistent. Greenhouse Test 1 and 3 were significantly correlated with the field test in percentage of diseased plants ($r = 0.175$-0.252, $r_{0.05}=0.161$) and severity ratings ($r = 0.186$-0.264). However, results from Test 2 in the greenhouse did not correlate with these from Test 1 and 3, but correlated with the results from the field ($r = 0.131$-0.145).

Compared with the resistant parent Pima S-7, three BIL lines, i.e., NMHT-15, NMHT-65 and NMHT-135 showed consistently better Vw resistance in all the above four tests. 7 BIL lines in three tests and more than 35 BIL lines in two tests showed better resistance (Table 5).

In the field 2007, 64 breeding lines derived from selections from the BIL populations were tested for Vw resistance. In comparison with the commercial Acala cotton cultivar 1517-99W, two lines had 45-50% reduction in Vw incidence and 9 other lines had >20% reduction in Vw % (Table 6). This indicates that the resistance of Vw from Pima has been successfully transferred into Upland cotton.

Effects of Vw on Yield and Fiber Quality

On average, Vw infection significantly decreased yield by 31.4% (16.1 g/plant vs. 23.4 g/plant). Compared with the healthy plants, the infected plants also had significantly lower lint percentage (41% vs. 42%), shorter 50% fiber span length (0.52 inch vs. 0.54 inch) and lower micronaire (3.71 vs. 4.59). Surprisingly, 2.5% fiber span length and fiber strength were not affected by Vw infection in the test (Table 7a and 7b).

Inheritance of VW Resistance

Resistance of F_1 generations: The F_1's between the resistant and susceptible upland cotton genotypes showed a similar level of resistance to their resistant parents (Table 8, Figure 1). The ratings for the five resistant parents (Maxxa, HS 26, SG 125, NemX and M315) ranged from 1.50 to 2.22 with an average of 1.91, while the four susceptible parents had average rating of 3.50 ranging from 2.83 to 4.56. The average rating for the 11 F_1's between the resistant and susceptible parents was 2.28 with a range from 1.58 to 3.67. The results indicate that the Vw resistance is incompletely dominant.

Segregation of Vw resistance: Two F2's between 33B and Pima cotton were evaluated for segregation analysis of Vw resistance (Table 9). Plants with disease severity ratings 0, 1 and 2 were considered as resistant, while rating 3, 4 and 5 susceptible. For the cross of 33B x Giza 70, the segregation in F2 did not follow a typical 3 resistant (R) to 1 susceptible (S) ratio, but more like a 9R:7S ratio, indicating that two dominant R genes are possibly required (Table 9). For the cross of 33B x Pima DP 744, the segregating ratio followed a 3R: 1S ratio, indicating a major resistance gene involved in Vw resistance (Table 9).

Eight F_2 populations between PM 1560, DP 428B, Zhong A and D as the susceptible parents and HS 26 and Maxxa as the resistant parents were also inoculated in the greenhouse with data to be collected. The broad-sense heritability and minimum number of genes for Vw resistance were estimated for the interspecific crosses. It showed that the Vw resistance has low to moderate heritability and at least one gene is involved.

Table 1. Greenhouse evaluation of Verticillium wilt resistance in commercial cotton cultivars and lines, Las Cruces, NM, 2003

Germplasm	Type/Source	Vw%-DAI 31	Vw%-DAI 40	Vw%-DAI 78	Rating-DAI 78
TM-1 (CK)	Delta and Pine Land	71.43	100.00	100.00	3.89
33B	Delta and Pine Land	30.43	79.41	100.00	2.99
DP 458B/RR	Delta and Pine Land	41.67	75.00	100.00	2.08
DP 449 BR	Delta and Pine Land	16.67	91.67	100.00	2.00
DP 491	Delta and Pine Land	16.67	91.67	100.00	2.83
DP 555 BR	Delta and Pine Land	8.33	66.67	100.00	2.83
SG 215 BR	Delta and Pine Land	15.38	75.00	75.00	2.03
DPLX 00513 BR	Delta and Pine Land	8.33	75.00	100.00	1.33
SG 747	Delta and Pine Land	27.27	75.00	100.00	2.89
PM 1560 BG	Delta and Pine Land	0.00	72.72	100.00	2.83
SG 125	Delta and Pine Land	16.67	33.33	91.67	1.50
M315 (DP 60)	Delta and Pine Land	0.00	66.67	100.00	1.67
HS 26	Delta and Pine Land	8.33	83.33	100.00	2.08
STX 5599 BR	Stoneville Pedigreed	8.33	100.00	100.00	1.67
STX 0003	Stoneville Pedigreed	16.67	91.67	100.00	2.28
ST 4793 R	Stoneville Pedigreed	41.67	91.67	100.00	2.00
ST 580	Stoneville Pedigreed	36.36	81.82	100.00	3.89
ST 457	Stoneville Pedigreed	16.67	90.91	90.91	4.11
BXN 49B	Stoneville Pedigreed	16.67	90.91	100.00	2.89
ST 4892 BR	Stoneville Pedigreed	16.67	81.82	90.91	1.92
ST 474	Stoneville Pedigreed	0.00	20.00	100.00	4.56
NX 2429	Unknown	41.67	100.00	100.00	3.33
FM 991 R	FiberMax	25.00	70.00	100.00	3.00
FM 989 BR	FiberMax	66.67	77.78	100.00	1.31
FM 989	FiberMax	25.00	91.67	91.67	1.25
FM 989 R	FiberMax	58.33	91.67	91.67	2.61
All-Tex Altas	All-Tex	58.33	100.00	100.00	2.83
Acala Phy 78	Phytogen/Acala	27.27	90.91	100.00	3.08
Acala Phy 72	Phytogen/Acala	50.00	83.33	100.00	1.25
PH 88M-2983	Phytogen	63.64	90.91	100.00	3.33
GC 546 RR	Phytogen	58.33	100.00	100.00	2.00
NM W1218	New Mexico Acala	91.67	100.00	100.00	2.67
Acala 1517-99	New Mexico Acala	41.67	100.00	100.00	2.33
Acala 1517-95	New Mexico Acala	58.33	100.00	100.00	3.67
NM 970123	New Mexico Acala	66.67	100.00	100.00	2.33
NM 970513	New Mexico Acala	66.67	100.00	100.00	2.67
Maxxa	CPCSD/Acala	0.00	22.22	100.00	2.22
Nem-X	CPCSD/Acala	0.00	11.11	77.78	2.06
57-4	Pima	25.00	43.75	100.00	3.83
Pima S-6	Pima	41.67	91.67	100.00	1.50
Pima S-7	Pima	50.00	100.00	100.00	2.08
Phytogen 76	Pima	25.00	87.50	87.50	3.03
Phytogen 57	Pima	72.73	81.80	100.00	1.64
DP HTO	Pima	33.33	75.00	100.00	1.71
DP 340	Pima	41.67	91.67	100.00	2.04
DP 744	Pima	81.82	100.00	100.00	2.86
CH007	Pima	83.33	100.00	100.00	2.42
LSD(0.05)					1.84

Table 2. Greenhouse evaluation of Verticillium wilt resistance in commercial cotton cultivars and lines, Las Cruces, NM, 2007

Germplasm	Type/Source	Vw%	Rating
DP455 BR	Delta and Pine Land	79.17	3.50
DP174 RF	Delta and Pine Land	50.00	2.75
DP141 B2RF	Delta and Pine Land	75.00	5.17
DP161 B2RF	Delta and Pine Land	41.67	2.29
DP143 B2RF	Delta and Pine Land	54.17	2.58
DP164 B2RF	Delta and Pine Land	37.50	2.42
PM3535 BR	Delta and Pine Land	62.50	4.08
ST 4554B2RF	Stoneville Pedigreed	66.67	3.00
ST 4427B2RF	Stoneville Pedigreed	62.50	2.75
ST 5327B2RF	Stoneville Pedigreed	70.83	3.92
ST 4357B2RF	Stoneville Pedigreed	66.67	4.08
ST4498B2RF	Stoneville Pedigreed	24.36	2.04
ST 4596B2RF	Stoneville Pedigreed	33.33	2.46
ST 4678B2RF	Stoneville Pedigreed	79.17	4.50
ST 5458B2RF	Stoneville Pedigreed	37.50	2.08
ST 6351B2RF	Stoneville Pedigreed	41.67	2.96
FM 1880 B2F	FiberMax	41.67	3.21
FM 1840 B2F	FiberMax	27.24	2.56
APEX B2/RF	All-Tex	79.17	3.50
SUMMIT B2/RF	All-Tex	50.00	3.38
65219 B2/RF	All-Tex	79.17	4.46
65352 B2/RF	All-Tex	71.79	3.84
65016 RF	All-Tex	83.97	4.04
65027 RF	All-Tex	70.83	3.04
PHY 485 WRF	Phytogen	58.33	3.04
PHY 745 WRF	Phytogen	41.67	1.92
PHY 725 RF	Phytogen	25.00	1.54
PHY 710 R	Phytogen	62.50	2.50
PHY 375	Phytogen	54.17	2.50
PHY 315	Phytogen	41.67	2.75
PHY 755 WRF	Phytogen	54.17	2.96
Acala 1517-99W	Acala	83.33	3.29
PHY 800	Pima	100.00	5.33
DP 744	Pima	100.00	4.92
DP353	Pima	100.00	4.58
Colbalt	Pima	91.67	5.04
PS-7	Pima	100.00	5.07
DP340	Pima	100.00	5.21
DP353	Pima	100.00	5.29
06E1012	Pima	100.00	4.79
06E2032	Pima	100.00	6.04
06E1061	Pima	100.00	4.88

Table 3. Field evaluation of Verticillium wilt resistance in commercial cotton cultivars and lines, Artesia, NM, 2003

Genotype	Type/Source	VW%
DP 458 B/RR	Delta and Pine Land	26.67
DP 555 BR	Delta and Pine Land	23.33
DP 449 BR	Delta and Pine Land	24.00
SG 215 BR	Delta and Pine Land	32.67
ST 4892 BR	Delta and Pine Land	40.67
ST 457	Stoneville Pedigreed	49.33
ST 580	Stoneville Pedigreed	31.33
BXN 49B	Stoneville Pedigreed	30.67
STX 0003	Stoneville Pedigreed	22.67
STX 5599 BR	Stoneville Pedigreed	26.00
FM 989	Stoneville Pedigreed	26.00
FM 989 BR	Stoneville Pedigreed	33.33
FM 991	Stoneville Pedigreed	18.67
Atlas	Stoneville Pedigreed	22.67
GC 546 RR	Stoneville Pedigreed	21.33
PHY 72	Phytogen/Acala	26.67
PHY 78	Phytogen/Acala	22.00
NM W1218	Acala	38.67
Acala 1517-95	Acala	30.00
Acala 1517-99	Acala	29.00
NM 970513	Acala	21.33
NM 970123	Acala	27.33
NX 2429	Unknown	15.33
F value		1.78
LSD0.05		4.88

Table 4. Greenhouse and field evaluation of Verticillium wilt resistance in Acala cotton cultivars and lines

Germplasm	Vw%-06	Vw%-07	Vw%-Gh 07	Rating-GH 07
Acala Young	38.00	8.00	60.12	2.37
Acala 1064	51.00	23.00	66.67	2.58
Acala 1517	50.00	29.00	62.50	2.63
Acala 1517 C	55.00	18.00	50.00	2.13
Acala 1517 D	43.00	22.00	70.83	3.88
Acala 1517 BR2	71.96	20.00	75.00	2.79
Acala 1517-70	57.85	19.00	33.33	1.67
Acala 1517-75	46.00	13.00	87.50	3.67
Acala 1517-E2	39.00	11.00	70.83	3.38
Acala 1517-77 BR	30.00	22.00	37.50	2.04
Acala 1517 SR2	46.00	16.00	54.17	2.67
Acala 1517-88	49.50	16.00	29.17	1.42
Acala 1517-SR3	40.00	36.00	75.00	3.08
Acala 1517-91	62.38	16.00	75.00	2.79
Acala 1517-95	40.00	2.00	66.67	2.92
Acala 1517-99	31.00	38.00	83.33	2.96
Acala Mesilla Valley	58.21	19.00	83.33	3.28
Acala 4-42	70.06	27.00	58.33	2.58
Acala 44 WR	49.08	35.00	71.79	3.32
Acala 5	39.13	11.00	66.67	2.88
Acala 2	46.11	37.00	79.17	2.54
Acala 29	61.11	13.00	95.83	4.29
Acala 51	65.00	36.00	66.67	2.71
Acala 40 (50-5)	59.50	22.00	75.00	3.42
Acala SJ-3	36.00	10.00	66.67	2.92
Acala SJ-4	35.77	9.00	70.83	3.33
Acala SJ-2	65.00	27.00	44.32	2.46
Acala Shafter Station	63.00	27.00	83.33	3.17
Acala Wilt	64.00	22.00	45.83	2.67
Acal Original	69.48	41.00	83.97	3.81
Acala 8	49.00	20.00	66.67	2.79
Acala Tex	36.00	22.00	79.17	3.21
F-value	1.44	1.54	1.82	1.62

Table 5. Greenhouse and field evaluation of a BIL population for Verticillium wilt resistance

BIL line	GH Test 1		GH Test 2		GH Test 3		Field
	Rating	Vw%	Rating	Vw%	Rating	Vw%	Vw%
NMHT-01	0.44	11.11	2.83	100.00	2.58	66.67	37.00
NMHT-02	0.67	22.00	2.67	66.67	1.83	41.67	24.67
NMHT-03	0.00	0.00	0.67	50.00	2.58	66.67	27.00
NMHT-04	1.67	44.44	2.17	50.00	3.75	83.33	51.63
NMHT-05	0.78	33.00	3.17	66.67	2.83	66.67	12.00
NMHT-06	0.67	22.00	2.50	66.67	3.33	83.33	10.14
NMHT-07	0.89	33.00	2.17	83.33	2.33	66.67	40.00
NMHT-08	1.11	22.00	1.67	33.33	2.75	83.33	25.00
NMHT-09	0.56	11.00	4.17	83.33	2.17	41.67	15.00
NMHT-10	1.22	33.00	2.67	66.67	4.00	91.67	25.71
NMHT-11	0.56	11.00	3.83	83.00	2.67	91.67	27.50
NMHT-12	0.67	22.00	3.33	67.00	2.08	33.33	33.00
NMHT-13	0.56	11.00	1.83	50.00	3.33	58.33	34.00
NMHT-14	0.00	0.00	3.17	83.00	2.33	50.00	35.00
NMHT-15	0.00	0.00	1.83	50.00	2.17	58.33	7.00
NMHT-16	1.00	22.00	2.50	67.00	3.42	91.67	37.47
NMHT-17	0.89	22.00	3.50	83.00	3.67	75.00	40.00
NMHT-18	0.56	0.00	3.17	67.00	2.50	66.67	53.00
NMHT-19	0.78	22.00	3.67	83.00	3.42	91.67	25.00
NMHT-20	1.11	22.00	2.17	67.00	3.42	83.33	24.00
NMHT-21	2.11	44.00	3.17	100.00	2.50	66.67	26.00
NMHT-22	1.11	22.00	3.00	67.00	3.25	91.67	24.00
NMHT-23	0.56	11.00	0.67	16.00	3.77	92.31	14.14
NMHT-24	0.00	0.00	3.00	83.00	1.58	16.67	23.00
NMHT-25	1.67	33.00	3.00	83.00	4.75	100.00	37.00
NMHT-26	0.33	11.00	1.33	33.00	3.33	83.33	20.00
NMHT-27	1.22	33.00	2.67	83.00	1.83	50.00	30.00
NMHT-28	0.67	22.00	3.83	100.00	5.00	83.33	27.00
NMHT-29	1.11	22.00	2.50	50.00	3.17	83.33	45.19
NMHT-30	0.56	11.00	3.50	100.00	2.92	66.67	9.00
NMHT-31	1.56	33.00	0.83	13.00	2.75	75.00	23.55
NMHT-32	1.11	22.00	3.67	83.00	2.33	50.00	34.00
NMHT-33	0.11	11.00	5.00	100.00	2.67	83.33	17.00
NMHT-34	1.33	33.00	1.67	50.00	2.25	66.67	40.00
NMHT-35	1.00	22.00	1.67	33.00	3.25	83.33	52.43
NMHT-36	1.11	22.00	3.00	67.00	4.50	100.00	34.00
NMHT-37	0.44	11.00	0.83	13.00	2.17	58.33	17.00
NMHT-38	1.11	33.00	2.00	50.00	3.33	83.33	54.19
NMHT-39	0.56	11.00	2.67	67.00	3.83	66.67	41.00
NMHT-40	1.22	33.00	1.17	83.00	4.43	92.86	33.65
NMHT-41	0.78	22.00	3.50	83.00	2.25	66.67	29.65
NMHT-42	0.56	11.00	3.17	67.00	1.00	0.00	16.00
NMHT-43	0.78	22.00	1.50	50.00	2.75	83.33	18.45
NMHT-44	1.67	44.00	1.17	50.00	2.33	66.67	11.00
NMHT-45	0.11	11.00	4.00	83.00	2.58	66.67	24.78
NMHT-46	0.67	22.00	3.33	67.00	2.83	83.33	18.00
NMHT-47	1.44	44.00	0.83	16.00	2.42	75.00	20.00
NMHT-48	1.33	44.00	3.33	67.00	1.92	50.00	43.00

NMHT-49	2.00	44.00	2.83	67.00	5.42	83.33	13.00
NMHT-50	1.44	33.00	1.67	50.00	3.83	91.67	25.00
NMHT-51	0.44	22.00	1.33	50.00	3.58	100.00	11.00
NMHT-52	1.67	33.00	2.17	67.00	2.50	75.00	42.00
NMHT-53	1.11	22.00	1.33	33.00	3.42	83.33	15.00
NMHT-54	0.56	11.00	3.83	83.00	1.75	25.00	20.00
NMHT-55	1.11	22.00	0.33	16.00	3.42	83.33	15.00
NMHT-56	1.56	33.00	3.00	67.00	2.92	83.33	24.00
NMHT-57	0.67	22.00	3.00	83.00	1.75	41.67	37.63
NMHT-58	1.00	33.00	3.17	83.00	2.92	83.33	25.00
NMHT-59	0.22	11.00	1.50	33.00	3.92	91.67	18.00
NMHT-60	0.78	22.00	3.33	67.00	3.42	83.33	17.00
NMHT-61	0.56	11.00	1.83	50.00	2.25	66.67	25.35
NMHT-62	1.67	33.00	1.67	33.00	2.50	75.00	33.00
NMHT-63	1.11	22.00	2.67	67.00	3.42	83.33	27.00
NMHT-64	0.56	11.00	3.50	100.00	2.58	66.67	28.00
NMHT-65	0.00	0.00	0.50	16.00	1.58	33.33	13.00
NMHT-66	1.11	22.00	2.33	50.00	2.50	66.67	41.00
NMHT-67	0.56	11.00	1.00	33.00	4.33	83.33	14.00
NMHT-68	0.56	22.00	1.67	50.00	2.42	66.67	44.41
NMHT-69	0.11	11.00	1.50	50.00	3.25	83.33	36.00
NMHT-70	1.00	22.00	2.17	67.00	3.25	75.00	18.00
NMHT-71	0.33	33.00	1.50	33.00	3.83	91.67	27.00
NMHT-72	0.56	11.00	2.67	67.00	3.92	83.33	29.53
NMHT-73	0.78	33.00	3.33	67.00	1.83	41.67	16.00
NMHT-74	0.67	22.00	2.33	67.00	4.92	100.00	27.23
NMHT-75	1.78	44.00	2.83	67.00	3.67	75.00	20.00
NMHT-76	0.56	11.00	1.83	50.00	2.75	66.67	27.67
NMHT-77	1.00	44.00	2.17	50.00	2.92	75.00	16.43
NMHT-78	1.00	22.00	2.67	67.00	3.75	83.33	21.00
NMHT-79	1.11	22.00	2.17	50.00	2.08	58.33	15.00
NMHT-80	0.56	11.00	3.67	100.00	4.75	75.00	6.00
NMHT-81	0.56	11.00	3.33	83.00	3.25	75.00	21.00
NMHT-82	0.56	22.00	1.50	33.00	3.08	83.33	32.00
NMHT-83	0.89	22.00	0.83	16.00	2.92	75.00	16.73
NMHT-84	1.67	33.00	2.50	50.00	3.33	66.67	37.00
NMHT-85	2.11	44.00	3.17	67.00	3.08	75.00	4.13
NMHT-86	0.00	0.00	0.33	33.00	3.25	66.67	18.69
NMHT-87	1.11	22.00	2.67	67.00	2.67	83.33	29.00
NMHT-88	1.11	22.00	3.33	67.00	2.75	75.00	32.97
NMHT-89	1.56	33.00	1.33	67.00	3.83	91.67	21.00
NMHT-90	1.11	22.00	1.00	33.00	2.75	66.67	19.00
NMHT-91	1.00	22.00	0.83	16.00	3.33	83.33	27.00
NMHT-92	1.00	22.00	4.17	100.00	3.15	84.62	11.27
NMHT-93	1.67	33.00	2.50	67.00	3.42	100.00	13.00
NMHT-94	0.11	11.00	4.67	100.00	2.58	83.33	21.00
NMHT-95	0.56	11.00	2.83	83.00	2.69	76.92	49.00
NMHT-96	0.56	11.00	3.17	83.00	2.25	50.00	17.56
NMHT-97	0.44	22.00	4.00	83.00	2.25	50.00	30.00
NMHT-98	1.11	22.00	2.50	67.00	3.75	100.00	28.00
NMHT-99	1.78	55.00	1.50	33.00	2.08	66.67	26.00

NMHT-100	2.11	44.00	2.50	50.00	2.08	50.00	20.00
NMHT-101	1.44	44.00	1.17	33.00	5.46	92.31	33.00
NMHT-102	1.56	33.00	1.17	50.00	3.33	83.33	16.49
NMHT-103	0.00	0.00	3.50	83.00	2.42	50.00	31.40
NMHT-104	0.56	11.00	0.33	33.00	2.75	66.67	27.70
NMHT-105	0.33	11.00	1.83	67.00	2.50	58.33	32.00
NMHT-106	1.11	22.00	3.33	67.00	2.67	83.33	18.00
NMHT-107	1.22	33.00	2.50	67.00	3.33	91.67	39.05
NMHT-108	1.00	22.00	3.17	67.00	1.83	41.67	40.00
NMHT-109	1.11	22.00	1.17	33.00	2.92	41.67	35.00
NMHT-110	0.00	0.00	3.67	83.00	2.50	75.00	32.00
NMHT-111	0.89	22.00	3.83	83.00	4.92	100.00	27.00
NMHT-112	2.11	55.00	1.67	33.00	5.58	91.67	42.00
NMHT-113	1.11	22.00	3.83	100.00	2.58	75.00	30.00
NMHT-114	1.33	44.00	3.33	67.00	2.15	53.85	46.00
NMHT-115	0.67	22.00	1.17	33.00	5.25	100.00	47.00
NMHT-116	2.22	33.00	3.17	67.00	5.25	100.00	50.00
NMHT-117	1.22	44.00	1.83	50.00	3.42	100.00	33.00
NMHT-118	0.00	0.00	1.00	33.00	1.33	25.00	24.00
NMHT-119	2.22	44.00	4.83	100.00	4.31	100.00	43.00
NMHT-120	1.11	22.00	3.00	67.00	3.25	83.33	32.00
NMHT-121	1.33	33.00	4.17	100.00	3.31	69.23	41.00
NMHT-122	2.11	44.00	3.50	83.00	2.33	66.67	33.82
NMHT-123	1.11	22.00	2.83	67.00	3.33	83.33	17.00
NMHT-124	1.11	33.00	0.00	0.00	2.08	33.33	26.00
NMHT-125	1.44	33.00	2.33	50.00	2.25	58.33	27.00
NMHT-126	0.56	22.00	1.33	33.00	3.17	75.00	26.00
NMHT-127	0.00	0.00	1.67	33.00	2.42	58.33	14.78
NMHT-128	1.78	44.00	1.67	33.00	3.83	83.33	12.00
NMHT-129	0.67	22.00	3.33	83.00	3.42	83.33	20.00
NMHT-130	0.56	11.00	2.17	50.00	1.92	25.00	20.00
NMHT-131	0.89	33.00	2.50	67.00	1.67	33.33	40.00
NMHT-132	1.11	22.00	4.50	100.00	5.67	100.00	17.00
NMHT-133	1.56	44.00	3.00	67.00	3.00	66.67	26.00
NMHT-134	0.67	22.00	2.83	83.00	2.17	58.33	36.09
NMHT-135	0.00	0.00	0.17	17.00	2.58	66.67	12.00
NMHT-136	0.56	11.00	2.50	83.00	2.92	83.33	22.00
NMHT-137	1.22	33.00	4.17	83.00	5.75	91.67	39.00
NMHT-138	1.11	22.00	3.33	67.00	3.25	58.33	29.00
NMHT-139	1.67	44.00	1.83	50.00	2.75	91.67	36.00
NMHT-140	1.00	22.00	1.17	33.00	2.83	83.33	33.00
NMHT-141	0.56	11.00	2.00	50.00	2.08	41.67	20.00
NMHT-142	1.22	22.00	1.67	50.00	3.42	91.67	19.00
NMHT-143	0.00	0.00	4.17	83.00	3.42	100.00	50.00
NMHT-144	1.67	33.00	3.67	100.00	3.42	100.00	38.00
NMHT-145	1.67	33.00	2.83	67.00	3.33	83.33	48.00
NMHT-146	0.56	11.00	1.67	33.00	3.00	83.33	16.00
SG 747	1.22	33.00	3.00	67.00	2.92	91.67	32.00
Pima S-7	0.33	11.00	2.50	83.00	5.00	100.00	14.00

Table 6. Vw resistance in advanced backcross breeding lines

Field ID	Vw%	CK%	Field ID	Vw%	CK%	Field ID	Vw%	CK%
Field test 1			**Field test 2**			**Field test 3**		
05D1007	33.33	107.15	05N1049	62.22	186.69	05C1060	30.00	79.41
05D1008	33.33	107.15	05N1054	68.89	206.69	05C2119	46.67	123.52
05D1010	35.56	114.29	05N1059	43.33	130.01	05C1120	27.78	73.53
05D1014	33.33	107.15	05N1061	58.89	176.68	05C2065	38.89	102.94
05D1030	53.33	171.43	05N1063	46.67	140.01	05C1109	41.11	108.82
D051031	47.22	151.78	05N1072	42.22	126.68	05C2007	36.67	97.05
05D1038	35.56	114.29	05N1073	68.89	206.69	05C1138	34.44	91.17
05D1043	44.44	142.86	05N1089	70.00	210.02	05C2105	45.56	120.58
05D1068	31.11	100.00	05N1090	55.56	166.68	05C1135	32.22	85.29
05D1070	36.67	117.86	05N1100	72.22	216.69	05C2130	32.22	85.29
05D1083	37.78	121.43	05N1101	63.33	190.02	05C2003	35.56	94.11
05D1099	40.00	128.58	05N1104	37.78	113.34	05C1100	27.78	73.53
05D1101	52.22	167.86	05N1107	45.56	136.68	05C2103	21.11	55.88
05D1129	38.89	125.00	05N1119	56.67	170.02	05C1126	40.00	105.88
05D1135	38.89	125.00	05N1150	54.44	163.35	05C2059	33.33	88.23
05D2021	47.78	153.58	05N1156	46.67	140.01	05C1102	20.00	52.94
05D2030	38.89	125.00	05N1159	43.33	130.01	05C2036	36.67	97.05
05D2039	34.44	110.72	05N1166	38.89	116.68	05C1077	37.78	99.99
05D2054	32.22	103.58	05N1186	28.89	86.68	05C1048	25.56	67.64
05D2074	56.67	182.15	05N1197	64.44	193.35	05C2089	40.00	105.88
05D2075	26.67	85.72	05N1213	58.89	176.68	05C1131	42.22	111.76
05D2078	26.67	85.72	05N1217	60.00	180.02	05C2068	33.33	88.23
05D2084	44.44	142.86	05N1226	32.22	96.68	05C1008	37.78	99.99
05D2086	33.33	107.15	05N1227	57.78	173.35	05C2126	27.78	73.53
04N1130	62.22	200.01	05N1245	57.22	171.68	05C2010	27.78	73.53
05N1002	46.67	150.01	05N1255	51.11	153.35	05C2072	30.00	79.41
04N1125	55.56	178.58	05N1259	62.22	186.69	05C1140	30.00	79.41
05N1006	44.44	142.86	05N1273	53.33	160.02	05C2133	36.67	97.05
05N1008	65.56	210.72	05N1277	50.00	150.02	05C2108	40.00	105.88
05N1025	31.11	100.00	05N1286	51.11	153.35	05C2093	30.00	79.41
05N1044	50.00	160.72	05N1297	56.67	170.02	05C1114	37.78	99.99
1517-99W	31.11	100.00	1517-99W	33.33	100.01	1517-99 W	37.78	100.00

Table 7a. Effects of Verticillium wilt infection on yield and fiber quality, Artesia, 2003

Genotype	Lint yield (g/plant)		Lint percentage (%)		2.5% SL (in)	
	H	I	H	I	H	I
W1218	22.47	14.30	0.40	0.39	1.14	1.20
DP 458 B/RR	26.87	22.25	0.40	0.41	1.19	1.13
ATLAS	27.91	19.29	0.42	0.40	1.15	1.10
ST 4892 BR	21.05	13.11	0.40	0.40	1.09	1.13
Acala 1517-95	22.65	15.90	0.40	0.39	1.15	1.12
Acala 1517-99	24.21	16.62	0.41	0.41	1.18	1.12
NM 970513	26.64	16.44	0.41	0.39	1.13	1.13
NM 970123	24.16	13.07	0.42	0.39	1.17	1.18
PHY 72	21.97	14.47	0.40	0.38	1.17	1.17
FM 989	23.52	12.30	0.38	0.41	1.15	1.19
DP 555 BR	22.54	17.53	0.42	0.39	1.17	1.13
DP 449 BR	25.72	16.93	0.40	0.40	1.14	1.15
SG 215 BR	20.50	12.08	0.40	0.40	1.10	1.10
FM 989 BR	27.11	15.72	0.41	0.40	1.13	1.11
FM 991	24.36	19.83	0.41	0.40	1.16	1.13
ST 457	17.12	20.00	0.41	0.40	1.16	1.17
ST 580	25.10	14.13	0.41	0.39	1.10	1.11
BXN 49B	24.04	14.01	0.39	0.40	1.21	1.16
STX 0003	21.94	16.14	0.41	0.40	1.08	1.08
STX 5599 BR	18.57	14.11	0.43	0.41	1.11	1.11
PHY 78	21.13	15.29	0.40	0.39	1.14	1.08
NX 2429	26.03	17.77	0.41	0.41	1.11	1.08
GC 546 RR	22.29	17.91	0.40	0.40	1.13	1.11
Avg	23.39	16.05	0.41	0.40	1.14	1.13

Table 7b. Effects of Verticillium wilt infection on yield and fiber quality, Artesia, 2003

Genotype	50% SL (in)		Strength (g/tex)		Elongation (%)		Micronaire (unit)	
	H	I	H	I	H	I	H	I
W1218	0.53	0.52	22.86	22.84	8.67	8.33	4.61	3.33
DP 458 B/RR	0.55	0.49	22.27	22.51	9.67	9.33	4.53	3.65
ATLAS	0.55	0.50	21.25	22.37	9.00	9.33	4.67	3.83
ST 4892 BR	0.52	0.53	19.38	20.73	9.33	10.67	4.79	3.62
Acala 1517-95	0.55	0.51	22.25	21.89	9.67	10.00	4.85	4.03
Acala 1517-99	0.54	0.52	21.91	20.96	8.50	9.00	4.43	4.03
NM 970513	0.52	0.53	21.93	22.96	8.83	9.33	4.56	3.77
NM 970123	0.56	0.57	23.25	24.62	9.00	9.33	4.53	3.36
PHY 72	0.54	0.53	24.34	25.17	9.00	9.67	4.73	3.65
FM 989	0.59	0.55	25.04	23.22	8.00	9.00	4.73	3.85
DP 555 BR	0.57	0.51	20.90	22.83	9.33	9.67	4.53	3.48
DP 449 BR	0.52	0.55	21.30	20.68	9.00	9.67	4.15	3.27
SG 215 BR	0.53	0.51	21.49	21.50	9.67	9.00	4.85	3.91
FM 989 BR	0.52	0.49	22.33	22.01	9.00	9.00	4.70	3.04
FM 991	0.55	0.52	22.42	22.81	10.00	10.00	4.56	3.97
ST 457	0.54	0.53	22.39	21.07	9.00	10.67	4.61	3.83
ST 580	0.53	0.52	20.69	21.02	9.33	10.00	4.47	4.20
BXN 49B	0.57	0.53	21.75	22.51	9.33	8.67	4.26	3.59
STX 0003	0.53	0.49	21.97	22.94	9.33	9.00	4.70	3.53
STX 5599 BR	0.50	0.49	21.55	21.90	8.33	8.67	4.47	3.53
PHY 78	0.55	0.50	21.94	21.68	10.33	11.17	4.47	3.83
NX 2429	0.55	0.51	21.32	20.68	10.17	10.33	4.85	3.82
GC 546 RR	0.53	0.51	23.73	23.45	9.33	8.67	4.61	4.18
Avg	0.54	0.52	22.10	22.28	9.21	9.50	4.59	3.71

Table 8. Greenhouse evaluation of Verticillium wilt resistance in F1's and their parents, Las Cruces, NM, 2003

Germplasm	Vw%-DAI 31	Vw%-DAI 40	Vw%-DAI 78	Rating-DAI 31*	Rating-DAI 40	Rating-DAI 78
ST 474	0.00	20.00	100.00		0.20	4.56
SG 747	27.27	75.00	100.00		0.75	2.89
PM 1560 BG	0.00	72.72	100.00		1.00	2.83
SG 125	16.67	33.33	91.67		0.67	1.50
HS 26	8.33	83.33	100.00		1.08	2.08
Maxxa	0.00	22.22	100.00		0.22	2.22
Nem-X	0.00	11.11	77.78		0.33	2.06
ST474 X Nem-X F1	11.11	33.33	88.89		1.00	2.03
SG747 x Nem-X F1	41.67	83.33	91.67		0.83	1.58
PM 1560BG X Nem-X F1	63.64	81.82	90.91		1.27	1.92
SG 125 X Nem-X F1	16.67	63.64	90.91		0.73	2.03
33B x Maxxa F1	8.33	33.33	91.67		0.50	2.58
ST 474 x Maxxa F1	10.00	60.00	100.00		0.80	2.25
SG 747 X Maxxa F1	8.33	33.33	83.33		0.58	1.92
PM 1560 BG x Maxxa F1	8.33	8.33	75.00		0.42	1.75
33B X HS 26 F1	25.00	36.36	90.91		0.82	3.17
ST 474 X HS 26 F1	16.67	50.00	100.00		0.92	2.00
SG 747 x HS 26 F1	16.67	41.67	100.00		0.58	3.67
PM 1560 BG X HS 26 F1	16.67	66.67	100.00		0.83	2.17
SG 125 X HS 26 F1	8.33	91.67	100.00		1.42	3.00
HS 26 X Maxxa F1	0.00	43.75	100.00		0.50	2.67
LSD (0.05)						1.84

* Plants were not scored due to low infections.

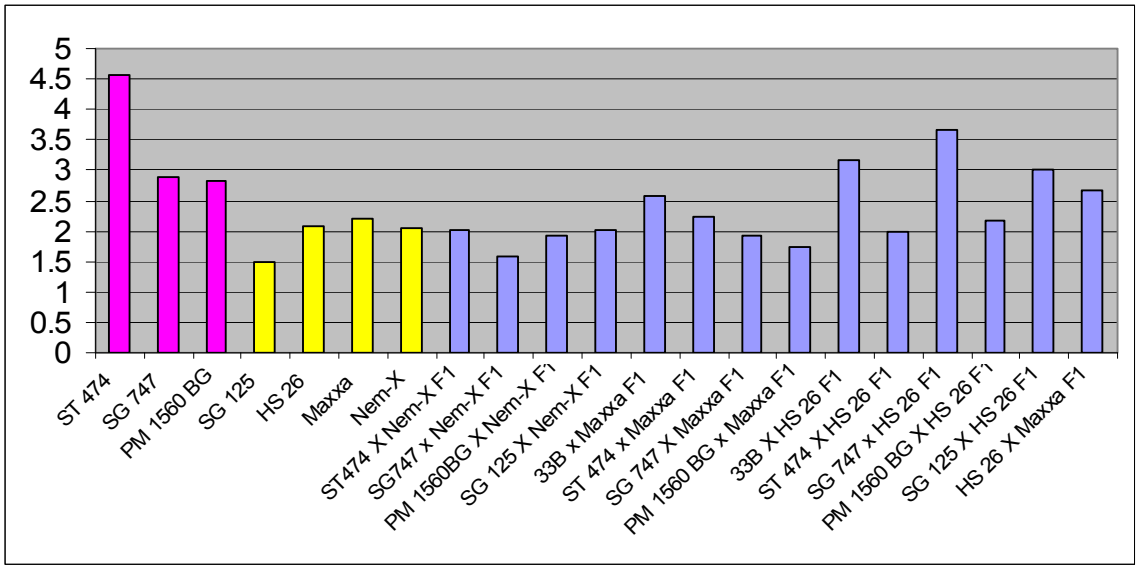

Figure 1. Resistance in F1 between resistant and susceptible Upland cotton.

Table 9. Segregation in Vw resistance: F_2 populations

F2 population	No. plants	No. resistant plants	No. susceptible plant	Chi (3:1)
33B x Giza70	106	56	50	27.8
33B x Pima DP744	126	91	35	0.51