BREEDING FOR RESISTANCE TO WILT DISEASES IN TAMCOT CULTIVARS

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Abstract

Verticillium and Fusarium wilt diseases are a serious problem is many areas of the cottonbelt. Methods, including the multi-adversity resistance (MAR) cotton system, used in breeding for resistance to Verticillium and Fusarium wilts, genetics of resistance, screening for resistance, and progress in developing new MAR germplasm resistant to both wilts are discussed. Progressive improvements in resistance to wilt pathogens and nematodes are being made in the MAR germplasm even though no direct selection for these pathogens is practiced.

Introduction

Genetic resistance to pathogens causing diseases, insects and abiotic stresses is of critical importance in cotton production and growers profitability. Losses due to pests and stresses cause significant reduction in yield and fiber quality, and increase production costs. Methods to improve crops genetically for resistance to pests depend on host diversity and sources of resistance, pest variability, genetic stability, environment and injury level of pests.

Cotton breeding programs have made progress in the last 20 years in developing current cultivars with higher yield and fiber quality, and improved levels of resistance to pests. The multi-adversity resistance (MAR) genetic improvement program has been very successful in developing cotton germplasm with higher levels of resistance to insects, pathogens, and environmental stresses, while improving their agronomic characteristics, yield, fiber and seed quality (El-Zik and Thaxton, 1989, 1992; Thaxton et al., 1991; Thaxton and El-Zik, 1994, 1996). This paper discusses the methods used in breeding for resistance to Verticillium and Fusarium wilts, genetics of resistance, screening for resistance, and progress in developing new MAR germplasm resistant to both wilts.

Breeding Methods

Several breeding methods are used to develop resistance to wilt diseases of cotton. These are: pedigree, pure-line, backcross and the MAR system. Most breeding methods depend on having large genetically variable populations.

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The pedigree method is the most widely utilized in cotton breeding programs. Parental lines with high levels of resistance to the wilt pathogens are identified and crossed with agronomically desirable lines. Selections are evaluated in the F_2, F_3 and F_4 progeny rows. After several generations of selecting resistant lines, a few plants are increased as a new cultivar with wilt resistance.

Pure-line breeding involves planting progeny rows within the most wilt resistant lines with the desirable agronomic traits such as high yield and fiber quality. This method is repeated for several years before plants from one or several rows are increased as a new cultivar.

Occasionally, back-crossing is used to combine resistance to Verticillium wilt into a line with other desirable agronomic traits. This procedure is not used extensively because resistance to the wilts is controlled by multiple genes.

The multi-adversity resistance (MAR) cotton improvement system uses a short-cycle recurrent selection method for multiple pest resistance in cotton. This approach enhances plant and crop health throughout the growing season.

Multi-Adversity Resistance (MAR) Selection Procedures

The main objective of the multi-adversity resistance (MAR) program is to breed, develop and release superior MAR cotton germplasm and cultivars for Texas and the Southwest cottonbelt. In addition to having improved yield potential, fiber and seed quality, the germplasm must have improved genetic levels of resistance to pests and abiotic stresses (El-Zik and Thaxton, 1989).

MAR is a system of direct selection for few traits and indirect genetic gains for genes and traits that provide broad resistance to adversities in cotton production. The MAR concepts and procedures evolved from basic research on seed-seedling cold resistance, preservation of seed quality, and high resistance to races of the bacterial blight pathogen, and their interrelationships with resistance to several other pathogens, earliness and yield (Bird, 1982). Earlier research by Bird (1972) has shown a strong association between resistance to bacterial blight and Fusarium wilt/root-knot nematode complex, and a lesser but significant association between bacterial blight and resistance to Verticillium wilt.

Direct selection in the laboratory and greenhouse of F_2 field selections is practiced for the following traits: (1) seed coat resistance to mold, (2) slow radicle elongation after 8 days at 13.3C, (3) cotyledon resistance to a mixture of four races of the bacterial blight pathogen (*Xanthomonas campestris* pv. *malvacearum*), and (4) absence of disease lesions at the base of the hypocotyl. Direct selection for these four traits indirectly provides genetic gains for resistance to the major pathogens, insects and abiotic stresses, along with higher yield potential and earliness.

Genetics and Sources of Resistance to the Wilt Pathogens

Maintaining genetic diversity and variability is essential for cotton improvement. The MAR program started with and continues to have a diverse gene pool, and has used several sources for resistance to Verticillium and Fusarium wilts. Most studies indicate that resistance to Verticillium and Fusarium wilts in *Gossypium hirsutum* is multigenic or quantitatively inherited, and can be explained by additive and dominant gene effects (Bell, 1992; Hillocks, 1992). For Verticillium wilt, transgressive segregation also has been reported (Verhalen et al., 1971). In a few cases, resistance appeared to be due to a single dominant gene as reported in the Acala 9519 line from New Mexico (Barrow, 1973).

Since resistance to wilts is quantitatively inherited, large segregating populations are needed for screening to identify individuals with the desirable combinations of resistance and agronomic traits. Crosses have been made between elite MAR lines and the Acala germplasm including Acala 1517. An important source for Verticillium wilt resistance in Texas are Paymaster 147, Paymaster 303, and Paymaster 266. The Tashkent cultivars from the former Soviet Union have high levels of resistance; however, they did not combine well with the MAR germplasm. Crosses have also been made for Verticillium Wilt resistance to material released from W. Sappenfield from Missouri and S. Wilhelm in California. For improving levels of Fusarium Wilt resistance, the MAR germplasm was crossed with material released from the programs of A. Kappelman, W. Sappenfield, R. Shephard, and A. Smith.

This parental material is added to transfer and intensify genes for improving disease resistance to both wilts. Parental material is screened using the MAR procedures and must meet minimum criteria for the four direct MAR selection traits. New selected parental strains are crossed to the most advanced MAR germplasm. After crossing, selected strains become part of the main MAR gene pool. The MAR breeding scheme and procedures have been discussed in previous publications (Bird, 1982; El-Zik and Thaxton, 1989).

Screening Methods

Resistance to pests and abiotic stresses must be identified and fixed in the advanced MAR strains (F_5), in addition to productivity and improved fiber quality. Success in producing selections that are resistant to Verticillium and Fusarium wilts depends on the effectiveness of the inoculation techniques and the grading scale used to evaluate the response (Bell, 1992; Hillocks, 1992). There are several techniques used for screening for resistance to both wilts. These are: root-dip technique, stem-puncture technique and field-screening under natural infestation. The root-dip technique involves growing seedlings in sterile soil, up-rooting the seedlings and washing and dipping the root in inoculum. This method is very time consuming and root damage may occur. The stem puncture technique is very effective since it requires little inoculum and can be used in the greenhouse or field which prevents escapes. A conidial suspension of 2-3 x 10^6 conidia ml^{-1} is delivered from the syringe, to form a bead at the tip of the needle. The needle is then inserted into the stem of four-week old plants for Fusarium, and six to eight week old plants for Verticillium wilt (Bell, 1992; Hillocks, 1992). The MAR program uses field screening for identifying and selecting germplasm for resistance.

Field Screening in the MAR Program

In conducting field tests, the inoculum density and disease severity in the field, pathogen strain present, environmental conditions and cultural practices need to be known. Generally, the level of resistance increases with increased inoculum density, the virulence of the pathogen strain(s), and for Verticillium wilt, number of days with soil temperature below 30C at 25 cm deep during boll development (Bell, 1992). Excess nitrogen and irrigation will increase Verticillium wilt symptoms.

Extensive evaluations for resistance to root pathogens are made each year to the most advanced MAR germplasm (F_5 to F_6) in the disease nurseries. In addition, the percentage of number of plants showing disease symptoms is calculated for each plot, performance ratings are made, and yield and fiber data are obtained. Each of the tests include resistant and susceptible checks. Resistance to Verticillium wilt is field tested at Chillicothe in the Texas Rolling Plains and at Halfway on the Texas High Plains. Resistance to Fusarium wilt is tested at the National Fusarium Wilt nursery in Tallassee, Alabama. Data is collected on nematode populations and resistance in Weslaco for reniform nematodes, and at College Station for root-knot nematodes.

In identifying resistance levels of cotton germplasm under field conditions, the time at which counts of plants with symptoms is made is very critical. The best time for evaluation will vary from year to year based on the progress of the crop and soil temperature, but usually between mid-August to September 30, after bolls have set. Counts should be made every two weeks but not at harvest since there is a poor correlation between wilt severity at harvest and yield losses. In the MAR program, due to the distance to the nurseries, counts are made two to four times, usually three times during mid-August into September.

New Wilt Resistant MAR Germplasm

The MAR-7 gene pool germplasm has higher resistance levels to pathogens causing seed-seedling disease, Verticillium and Fusarium wilts, Phymatotrichum root rot, leaf spots and root-knot and reniform nematodes than previously released MAR germplasm. All new MAR germplasm is highly resistant to the US races of the bacterial blight pathogen.

Table 1 shows the variability found in the MAR germplasm for resistance to Verticillium wilt. Strains were evaluated at the Halfway nursery in 1996, and the data presented is abstracted from the strains test that included 102 genotypes and commercial cultivar checks. The percent of plants showing foliar Verticillium wilt symptoms ranged from 25% for PD23CD3HGS-1-93 to 89% for the MAR strain CQPICDGP6H-1-95, and the resistant check Paymaster 330 with 36%. Four MAR strains had levels of resistance similar to Paymaster 330. The four strains are PD23CD3HGS-1-93, OSIKRHQWIH-2-94 (okra-shaped leaf type), CUBQHGRPIS-1-92, and PD22CUBQWS-1-95.

Resistance to Fusarium wilt in earlier released Tamcot cultivars, Tamcot SP21S, Tamcot SP37H and Tamcot CAMD-E, has been reported (Kappelman and Bird, 1981). Based on three years of data, the Tamcot cultivars developed by the indirect MAR selection procedure had resistance levels equal to that of the resistant cultivar McNair 511, and were significantly less susceptible than Rowden. The development of resistance in these cultivars indicated that the MAR system was effective for improvement of resistance to the Fusarium wilt/ root-knot nematode complex (Kappelman and Bird, 1981).

High levels of resistance to the Fusarium wilt pathogen is being maintained or increased in some of the MAR germplasm. Eight elite MAR lines were evaluated in the National Fusarium nursery at Tallassee, AL test which included the resistant check M-315 and the susceptible check Rowden (Table 2). Four strains had high levels of resistance to the Fusarium wilt and root-knot nematode complex, and three showed intermediate levels. Two strains, HQCULHQPIH-1-95 and LGQWILBCGS-1-95, had similar resistance levels as the M-315 check. Even though field resistance to the Fusarium wilt root-knot nematode complex exist at Tallassee, AL results are limited due to only a relatively small number of entries that are evaluated each year and the environmental effects on symptom expression.

Table 3 shows the results of evaluating cotton lines for resistance to reniform nematodes conducted by C. Cook at Weslaco, TX. Lint yield was measured in reniform infested soil and Telone II treated soil. Mean lint yield over genotypes was 632 lb/a in the untreated-reniform soil and 730 lb/a for the Telone II treated soil (Table 3). The MAR strain LGQWILBCGS-1-95 produced high and similar yield in the Reniform and Telone treated plots, and was the third highest yielding strain in the test with 788 lbs/acre lint, followed by the MAR strain PD22CUBQWS-1-95. These two MAR strains are the same ones with similar levels of resistance to Fusarium wilt/root-knot nematodes complex as the resistant check M-315 in the Tallassee test (Table 2).

Conclusion

Progressive improvements in resistance to wilt pathogens and nematodes are being made in the MAR germplasm even though no direct selection for these pathogens is practiced. However, the rate of genetic gain in resistance to these pests is slower than the rate for the four traits for which direct selection is practiced. High levels of resistance can be attained using the MAR system if genetic variability for resistance to the pathogens is present in the initial populations. Due to the variability in screening germplasm under field conditions, resistance should be measured over several years. The MAR selection techniques has increased levels of resistance to pathogens and insects while increasing both yield and fiber quality.

References

Barrow, J. R. 1973. Genetics of *Verticillium* tolerance in cotton. *In* Verticillium Wilt of Cotton. p. 89-97. U.S. Dep. of Agric. Publ. ARS-S-19, Washington, DC.

Bell, A. A. 1992. Verticillium wilt. p. 87-126. *In* R. J. Hillocks (ed). Cotton Diseases. C.A.B. International, London, UK.

Bird, L. S. 1972. Interrelationships of resistance and escape from multi-diseases and other adversities. Proc. Beltwide Cotton Prod. Res. Conf., Cotton Disease. Council 32:92-97.

Bird, L. S. 1982. Multi-adversity (disease, insects, and stresses) resistance (MAR) in cotton. Plant Dis. 66:173-176.

El-Zik, K. M., and P. M. Thaxton. 1989. Genetic improvement for resistance to pests and stresses in cotton. p. 191-224. *In* R. E. Frisbie, K. M. El-Zik, and L. T. Wilson, (eds.), Integrated Pest Management Systems and Cotton Production. John Wiley & Sons, New York, N.Y.

El-Zik, K. M., and P. M. Thaxton. 1992. Simultaneous improvement of yield, fiber quality traits, and resistance to pests in MAR cottons. Proc. Beltwide Cotton Prod. Res. Conf., Cotton Improv. Conf. 44:560-563.

Hillocks, R. J. 1992. Fusarium wilt. p. 127-160. *In* R. J. Hillocks (ed). Cotton Diseases. C.A.B. International, London, UK.

Kappelman, A. J, and L. S. Bird. 1981. Indirect selection for resistance to the fusarium wilt/root-knot nematode complex in cotton. Crop Sci. 21:66-68.

Thaxton, P. M, K. M. El-Zik, and R. K. Kirkpatrick. 1991. Genetic gains in resistance to pests in the MAR Germplasm. I.. Pathogens. Proc. Beltwide Cotton Prod. Res. Conf., Cotton Disease. Council. 51:151-155.

Thaxton, P.M. and K.M. El-Zik. 1994. Genetic enhancement of MAR cottons for resistance to insects and pathogens, yield and fiber quality. Proc. Beltwide Cotton Prod. Res. Conf., Cotton Improv. Conf. 46:658-661.

Thaxton, P. M. and K. M. El-Zik. 1996. Genetic advance in new multi-adversity resistance (MAR) cotton germplasm. Proc. Beltwide Cotton Prod. Res. Conf., Cotton Improv. Conf. 48:601-611.

Verhalen, L. M.., Brinkerhoff, L.A.., Fun, K.-C. and Morrison, W.C. 1971. A quantitative genetic study of Verticillium wilt resistance among selected lines of Upland cotton. Crop Sci. 11:407-412.

Table 1. Percentage of plants having Verticillium wilt symptom in 1997 at Halfway, TX.

Strain/cultivar	Percent Foliar Wilt August 30	Percent Foliar Wilt September 24
	%	%
PD23CD3HGS-1-93	12	25
OSIKRHQWIH-2-94	13	32
CUBQHGRPIS-1-92	23	32
Paymaster 330 (ck)	12	36
PD22CUBQWS-1-95	14	37
:	:	:
Tamcot Sphinx (ck)	20	51
All-Tex Topick (ck)	18	53
Deltapine 50 (ck)	19	53
:	:	:
Stoneville 887 (ck)	10	65
:	:	:
CQPICDGP6H-1-95	22	89
Test Mean	20	49

Table 2. Percent of plants with Fusarium wilt symptoms in the 1997 National Fusarium Nursery, Tallassee, AL.

Strain/cultivar	Percent Wilt
	%
M-315 (Resistant ck)	21
HQCULHQPIH-1-95	24
LGQWILBCGS-1-95	31
SPNXHQBPIS-1-94	39
SPNXCHGLBH-1-94	40
HGPIHQBPIH-2-94	48
CABCSV506S-1-94	57
SPNXCDUG8H-1-95	58
CIQUBCHGBS-1-95	71
Rowden (Susceptible ck)	89
Mean	47.5

Table 3. Lint yield of cotton strains and cultivars in the reniform nematode evaluation test in 1997 at Weslaco.

Strain/cultivar	Lint Yield Reniform	Lint Yield Telone II	Mean over Treatments
	←	lb/acre	→
X2113-27	769	884	827
X2118-32	755	829	792
MAR-LGQWILBCGS-1-95	788	787	788
MAR-PD22CUBQWS-1-95	700	858	779
C429-93	721	829	775
C95483	691	854	772
C953109	726	816	771
X2140-8	734	808	771
C118-2-93	709	772	741
X2130-26	675	798	737
C95259	624	806	715
C952103	655	735	695
Stoneville 132	649	732	691
MAR-CABCSV506S-1-94	645	712	678
C95296	627	722	674
C95220	576	719	647
Deltapine 5409	499	724	611
Tamcot Sphinx	581	596	587
Stoneville 474	572	577	574
93WB57	560	574	567
93WA126ne	593	526	560
93WD116	425	549	537
C489-1-93	476	579	527
Stoneville LA 887	409	632	520
Mean	632	730	681
LSD (*P*=0.05)†	179	209	137

†Least significant difference between two means within a column.