EVALUATION OF COTTON FOR RESISTANCE TO SOUTHWESTERN COTTON RUST (*PUCCINIA CACABATA*)

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Abstract

The Southwestern cotton rust, caused by the fungus *Puccinia cacabata*, occurs once every 3-4 years in the southwest Cotton Belt including New Mexico and can cause serious damages to cotton growth. When a heavy rust infection occurred in New Mexico in the mid-2000s, a project in breeding cotton for rust resistance was initiated at New Mexico State University (NMSU). This report summarizes progresses made since then, including field screening for rust resistance in over 600 current and obsolete commercial cotton cultivars, and elite and obsolete breeding lines. An artificial nursery for gramma grasses, the primary host of the pathogen, was established for supplies of inoculum. Crosses between three resistant lines and one susceptible cultivar were made and screened for rust resistance under the field infection conditions.

Introduction

The Southwestern cotton rust, caused by the fungus *Puccinia cacabata* Arth. and Holw., occurs once every 3-4 years in the southwest Cotton Belt including New Mexico, and it can cause serious damages to cotton growth (Fig. 1). There have been at least three outbreaks (e.g., 2008 and 2015) of the disease in cotton in New Mexico since 2003. Under favorable environmental conditions including summer rains and high humidity, the disease can cause up to 50-75% yield loss, even a crop failure (http://www.plantwise.org/KnowledgeBank/Datasheet.aspx?dsid=45868). The disease requires gramma grass (*Bouteloua* spp.) as its primary host in the winter and cotton as the alternate host in the summer to complete its life cycle. When there is a rain in July and August, the spores produced on the gramma grass germinate and are spread to cotton plants, causing infections on leaves and other plant surface areas such as bracts and boll walls. When a heavy rust infection occurred in New Mexico in the mid-2000s, a project in breeding cotton for rust resistance was initiated at New Mexico State University (NMSU).

Currently, all the commercial Upland cultivars may be susceptible to this disease as no commercial breeding programs are located in the epidemic region. However, a few obsolete resistant Upland cotton lines were developed through the transfer of the resistance from diploid species *Gossypium arboreum* and *G. anomalum* in the early 1970's (Blank, 1971). The introgressed resistance was found to be conferred by a major resistance gene, *Pu* (Percy and Bird, 1985).

The objectives of this study were to evaluate commercial and obsolete cultivars and breeding lines for rust resistance in field conditions; and to evaluate elite breeding lines for rust resistance under field conditions.

Materials and Methods

Field Experiments

The field tests were conducted in the Leyendecker Plant Science Center, Las Cruces, NM, in 2015 and 2016. Seeds were planted in early May, and crop management practices followed local recommendations.

2015 tests

- 2 Advanced Yield Tests: designated 15H and 15M, each with 32 breeding lines (developed at NMSU) arranged in a randomized complete block design (RCBD) with 3 replications of single-row 31-ft long plots;

- 3 replicated tests: designated 15RB (Regional Breeders' Testing Network), 15NV (Official Variety Test) and 15HQ (High Quality Test), each with 32 commercial cultivars or elite breeding lines arranged in RCBD with 3-4 replications of 2-row 31-ft long plots;
- 1 National Pima Cotton Variety Test: designated 15B, with 8 Pima cotton genotypes arranged in RCBD with 4 replications of 2-row 31-ft long plots; and
- 1 test: designated 15G, with an association mapping panel of 350 obsolete cultivars and breeding lines arranged in an augmented design with single-row 31-ft long plots.

2016 tests

- 3 Advanced Yield Tests: designated 16F, 16G, and 16J, each with 32 breeding lines (developed at NMSU) arranged in a randomized complete block design (RCBD) with 3 replications of single-row 31-ft long plots;
- 3 replicated tests: designated 16RB (Regional Breeders' Testing Network), 16NV (Official Variety Test) and 16HQ (High Quality Test), each with 32 cultivars or elite breeding lines arranged in RCBD with 3-4 replications of 2-row 31-ft long plots;
- 1 National Pima Cotton Variety Test: designated 16B, with 8 Pima cotton genotypes arranged in RCBD with 4 replications of 2-row 31-ft long plots; and
- Three segregating populations derived from susceptible × resistant hybrids.

Screening Methods for Rust Resistance

2015: Due to the heavy infection of rust on cotton plants in July (Fig. 1), responses to the rust infection were rated as 'resistant' for no or minimum symptoms or 'susceptible' for plants with symptoms (i.e., bright yellow to orange spots, Fig. 1) in almost all leaves on a plot basis.

2016: Due to very light rust infections, individual plants in each plot were screened for leaves with rust symptoms in Sept. The percentage of infected plants was calculated on a plot or population basis.

Results and Analysis

Research Activities for Rust Resistance Since the Mid-2000's

After the project in breeding cotton for rust resistance was initiated at NMSU, some progresses have been made, including:

- The alternate host- gramma grasses were identified in the region with some plants moved to the greenhouse over several years (e.g., 2008, 2012, 2015 and 2016).
- Seeds for three gramma grass species were purchased in 2015 and grown in the greenhouse and field in 2016, resulting in the establishment of the nursery for gramma grass (Fig. 2).
- Seeds for rust resistant lines were requested from the National Germplasm Collection Center in 2012, and grown in the greenhouse and field in 2012-2013, and 2016.
- Hybrids between rust susceptible Acala 1517-08 and the rust resistant lines were made in the greenhouse in 2012 and grown in the field in 2013. Segregation populations from above hybrids were grown in the field in 2016. This allowed a segregation analysis of the resistance for developing molecular markers associated with the rust resistance.

Rust Responses in Commercial Cotton Cultivars

All current commercial Upland and Pima cotton cultivars tested in 15NV, 15HQ and 15B in 2015 and 16NV, 16HQ and 16B in 2016 were susceptible to rust infections under the natural field conditions (Table 1).

Rust Responses in Elite Breeding Lines

No elite breeding lines tested in 15H, 15M, 15RB, 16F, 16G, 16J and 16RB were resistant to rust infections under the natural field conditions (Table 2). Glandless cotton showed higher levels of susceptibility.

Rust Responses in Obsolete Cultivars and Breeding Lines

A few obsolete breeding lines appeared to have some levels of rust resistance, as a substantial number of plants had reduced rust damage (severity) under the heavy infected field conditions in 2015. However, further tests are needed to validate their resistance.

Segregating Analysis of Rust Resistance in F_2 Populations
The results (Table 3) from three F_2 populations between three resistant lines and a common susceptible cultivar detected at least one resistance gene for rust resistance.

References

Blank, L. M. 1971. Southwest cotton rust. Proc. Beltwide Cotton Prod. Res. Conf., pp. 76-77.

Percy, R. G., and L. S. Bird. 1985. Rust resistance expression in cotyledons, petioles, and stems of *Gossypium hirsutum* L. J. Hered. 76: 202-204.

Fig. 1. A rust infected field with symptoms on a leaf, Leyendecker Plant Science Center, New Mexico State University, Las Cruces, NM, July 2015.

Fig. 2. An artificial nursery of gramma grass, Fabian Garcia Plant Science Center, New Mexico State University, Las Cruces, NM, July 2016.

Table 1. Susceptible commercial cultivars and elite breeding lines.

Trial 15NV	Trial 15HQ	Trial 16NV	Trial 16HQ	Trial 15B
PHY 222 WRF	FM 2484B2F*	NG3406B2XF	13P1117	DP 348 RF
PHY 312 WRF	PHY 725RF*	NG5007B2XF	NM 13G1029	DP 358 RF
PHY 333 WRF	Ark 0606-50	NG4545B2XF	NM 13G2019	PHY 800
PHY 339 WRF	Ark 0701-4	NG3500XF	NM 13P1088	PHY 805 RF
PHY 444 WRF	Ark 0703-10	FM 1911 GLT	Acala 1517-99 Dosi	PHY 811 RF
PHY 499 WRF	DP 1321B2RF	FM 1830 GLT	Acala 1517-08	PHY 830
NG1511 B2RF	DP 1410B2RF	FM 2007 GLT	NuMex COT 15 GLS	PX 8188 RF
NG4111 RF	DP 1555B2RF	FM 2322 GL	FM 2484B2F*	PX 8431 RF
NG3406 B2XF	PHY 444WRF	ST 4747 GLB2	PHY 725RF*	
FM 1830GLT	PHY 552WRF	ST 4946 GLB2	Ark 0819-84	**Trial 16B**
FM 2334GLT	FM 1830GLT	PHY 312 WRF	Ark 0822-75	DP 348 RF
ST 4747GLB2	FM 2322GL	PHY 333 WRF	DP 1646B2XF	DP 358 RF
NM 13R1012	FM 2334GLT	PHY 444 WRF	DP 1614B2XF	NMSI 2032
NM 13R1014	ST 6448GLB2	PHY 499 WRF	DP 1555B2RF	NM 14C1102
NM 13P1121	LA 11309134	PHY 764 WRF	PHY 444WRF	PHY 805 RF
NM 13P1088	NM 13P1088	PHY 308 WRF	PHY 333WRF	PHY 811 RF
NM 14S1409	MD 10-5	DG 3109 B2XF	PHY 552WRF	PHY 841 RF
NM 14S1309	MD 87	DG 3445 B2XF	FM 1911GLT	PHY 881 RF
NM 14S1444	NM 13G1018	DG 3544 B2XF	FM 1830GLT	
NM 13G1019-B	NM 13G2019	DG 3385 B2XF	FM 2322GL	
NM 13G3002	NM 13G1019-B	DP 1612 B2XF	NM 13R1015	
Acala GLS	NM 13G3002	DP 1518 B2XF	TAM BB-2139	
NM 14S1262	NM 13G1007	DP 1522 B2XF	TAM 11K-13	
Acala 1517-99 Dosi	NM 13G1029	DP 1549 B2XF	TAM 11T-08	
Acala 1517-08 Dosi	Acala 1517-08	DP 1646 B2XF	MD 15-31	
Acala 1517-08-T2R1	DP 0912B2RF*	NM 13G1029	DP 0912B2RF	
NM 13G1007	PHY 725RF*	NM 13G2019	PHY 725RF	
NM 13G1018	PHY 499WRF	NM 13R1015	PHY 499WRF	
NM 13G1029	FM 2484B2F	NM 13P1088	FM 2484B2F	
NM 13G2019	DP 1359B2RF	Acala 1517-08	DP 1359 B2RF	
NM 14ISA BC3-B	FM 2322GL	NuMex COT 15 GLS	FM 2322GL	
NM 13R1012	PHY 755WRF	NM 13P1117	PHY 755WRF	

Table 2. Susceptible elite breeding lines to rust infections.

Trial 15RB	Trial 15H	Trial 15M	Trial 16RB	Trial 16F	Trial 16G	Trial 16J
0043-28 -1	13P1088	1517-08	NM 13R1015	14S1034	Acala 1517-08	Acala 1517-08
0045-14 -5	1517-08	14T1004	NM 13P1088	14S1057	NuMex COT	NuMex COT 15
PD 07092	14S1004	14T1005	Acala 1517-08	14S1072	15R1016	15R1422
PD 07116	14S1009	14T1006	NuMex COT 15 GLS	14S1106	15R1024	15R1426
PD 07105	14S1034	14T1007	TAM13Q-18	14S1214	15R1039	15R1432
PD 07040	14S1048	14T1019	TAM11L-24	14S1239	15R1088	15R1433
Ark 0711-2	14S1053	14T1029	PD07040	14S1189	15R1100	15R1456
Ark 0705-46	14S1057	14T1042	PD09084	14T1088	15R1110	15R1457
Ark 0712-9	14S1067	14T1077	PD08028	14T1169	15R1128	15R1460
Ark 0701-17	14S1069	14T1085	PD09046	14T1243	15R1154	15R1465
Ark 0707-33	14S1072	14T1088	Ark 0812-87ne	14T1243-B	15R1167	15R1484
13P1088	14S1078	14T1090	Ark 0818-23	14T1270	15R1190	15R1485
13W3017	14S1100	14T1139	Ark 0824-89	14T1330	15R1199	15R1493
13W3007	14S1106	14T1148	Ark 0822-48	14T1433	15R1209	15R1505
1517-08	14S1118	14T1169	Ark 0819-89	R1342-1,-3	15R1234	15R1509
GA 2010102	14S1130	14T1186	NM 13G1029	R1345-1, B	15R1237	15R1510
GA 2011124	14S1177	14T1197	NM 13G2019	15R1158-1	15R1238	15R1523
GA 2011004	14S1180	14T1198	AU77082	15R1158-2	15R1249	15R1524
LA12306010	14S1199	14T1223	AU82074	15FG-13P1117	15R1267	15R1532
LA12306017	14S1200	14T1233	GA 2011113	15RB3026	15R1285	15R1540
LA12306028	14S1212	14T1243	GA 2012050	13G1029	15R1288	15R1542
0042-3 -7	14S1213	14T1270	GA 2012082	13G2019	15R1296	15R1544
0045-14 -8	14S1214	14T1293	GA 2012141	13G1018	15R1298	15R1547
DP 393	14S1235	14T1313	MD 16-1	Acala 1517-99	15R1302	15R1554
SG 105	14S1239	14T1330	MD 16-2	15-13P1088	15R1320	15R1557
FM 958	14S1262	14T1375	MS 0152-3-11	15-13P1125	15R1364	15R1558
UA 222	14S1268	14T1385	MS 0043-28-1	15-ISA Sel	15R1366	15R1565
DP 491	14S1269	14T1414	DP 393 CK	15FG-Y1002B	15R1386	15R1576
13G3002	14S1273	14T1426	DP 493 CK	15FG-Y1005B	15R1388	15R1600
13G1019	14S1274	14T1433	FM 958 CK	15FG-Y1002B	15R1413	15R1608
13R1015	14S1288	14S1445	SG 105 CK	Acala 1517-08	15R1418	15R1640
13G2019	13S1309	14S1450	UA 222 CK	NuMex COT 15	15R1420	13P1088

Table 3. Segregating analysis of rust resistance in three F_2 populations.

Cross	**No. R**	**No. S**	**Expected ratio (3:1)**		χ^2
PI 602998 x Acala 1517-08	252	57	231.75	77.25	7.08
PI 595758 x Acala 1517-08	291	74	273.75	91.25	4.35
PI 603006 x Acala 1517-08	265	138	302.25	100.75	18.36

$\chi^2_{0.05} = 3.84$.