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Resistant Germplasm in *Gossypium* Species and Related Plants to *Rotylenchulus reniformis*[1]

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Abstract: *Gossypium hirsutum, G. herbaceum, G. arboreum, G. barbadense,* wild *Gossypium* spp., *Hibiscus* spp. and other Malvaceae were tested in the greenhouse to identify germplasm resistant to *Rotylenchulus reniformis* (Rr). Host resistance was based on Rr egg production per gram of root compared with known *G. hirsutum* susceptible 'Deltapine 16' as check. *G. longicalyx* and *Sida rhombifolia* were nonhosts. High levels of resistance were found in *G. stocksii, G. somalense,* and *G. barbadense* 'Texas 110.' Other cotton lines with potential value in breeding for Rr resistance were *G. herbaceum* P.I. 408775; *G. arboreum* P.I. 41895, P.I. 417891, CB 3839; and *G. hirsutum* 893. All these supported less than 20% of the egg production on the check. Seventy-three percent of the *Hibiscus* spp. tested were resistant. Female development and egg production reflected host resistance; healthy females and large egg masses were observed on susceptible plants, and degenerated females and small egg masses on resistant plants. Females penetrating nonhost *G. longicalyx* never matured to kidney shape.
Key words: cotton, reniform nematodes, egg production, immune hosts.

In cotton growing areas of Asia, Africa, and the Americas, the reniform nematode (Rr), *Rotylenchulus reniformis* Linford & Oliveira 1940, causes loss of cotton lint, delays maturity, and reduces total yields 30–60% (5,22). Nematicides are currently used to control Rr on cotton (2,5,15,16). However, while preplant nematicide applications protect the plants early in the season, they do not prevent reniform population build-up later in the season. The resultant Rr populations will be a threat to next year's crop, making nematicide applications necessary each year. Rotating cotton with a nonhost crop has been useful to control Rr (7,9). However, the rotation crop is usually of lower cash value. An effective and profitable means of Rr control would be to use resistant cotton varieties if resistant germplasm is available (13). Although resistance to Rr is known for soybeans (4,6,10,18) and sweetpotato (11), only recently was resistance found for cotton—in *G. arboreum* Nanking CP 1402 (8). All commercial cotton varieties that have been tested are susceptible to Rr (3,14). Cotton germplasm has not been widely explored for resistance to Rr. The objective of this research was to identify Rr resistant germplasm in cotton species and related plants.

MATERIALS AND METHODS

Two hundred plant species and cultivars were tested for Rr resistance, including 111 *G. hirsutum* entries, 7 *G. herbaceum,* 14 *G. arboreum,* 6 *G. barbadense,* 33 wild *Gossypium* spp., 22 *Hibiscus* spp., and single species in 7 other genera in the Malvaceae. Entries were tested in the greenhouse in a total of 20 separate tests between January and October 1980. The original Rr inoculum was soil from a naturally infested field at Burden Research Farm, Louisiana State University, Baton Rouge. The Rr population was maintained in the greenhouse on 'Deltapine 16' cotton and used as the source of inoculum for the tests.

Seeds of wild race stocks and commercial species of *Gossypium* and *Hibiscus* were obtained from the U.S. Department of Agriculture, Texas A&M University; National Seed Storage Laboratory, Colorado State University; and Louisiana State University. Seeds of other Malvaceae genera were collected around Baton Rouge, Louisiana.

Seeds were nicked at the distal ends to facilitate water penetration and germination. They were surface sterilized in 5.25% sodium hypochlorite solution for 3 minutes, rinsed in distilled water, and placed in 90-mm-d sterile plastic petri plates lined with paper tissue moistened with 3 ml distilled water; germination occurred within 7–10 days at 24 C. Seeds of *G. hirsutum* cv. Deltapine 16 were included as a check with each test.

Styrofoam cups (178 ml) with five 8-mm drainage holes were filled with loam tex-

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tured steam-sterilized soil. Seedlings with radicles of uniform lengths, but without lateral roots, were planted two per cup to give six replicates of each entry. Cups were arranged in a randomized block design on greenhouse benches. Temperatures were in the range of 20–32 C, and relative humidity at 60–80%. Tests were terminated after an average plant growth period of 35 days.

Nematodes were extracted from infested soil by a modified Sienhorst sieving and decanting technique. The nematode inoculum was adjusted to 500 nematodes/ml suspension, and 4 ml (2,000 nematodes) were pipetted into 5-ml test tubes.

Three days after transplanting, each cup was inoculated with 2,000 Rr young females, males, and juveniles. The inoculum was poured onto the exposed roots of the test plants, and steam-sterilized soil was added over the inoculated roots.

Entire root systems of the test plants were harvested to measure Rr egg production. The soil was removed by soaking the roots in water to expose the egg masses without injuring them. Roots were blotted dry with paper towels and weighed. Roots with egg masses were cut into 1-cm lengths and placed in 0.5% sodium hypochlorite solution for 10 minutes to free the eggs from the egg matrix. Roots were blended for 5 seconds to disperse the eggs. Eggs were separated from the root debris with a 45-μm mesh sieve, collected on an 18-μm mesh sieve, and washed with tap water to remove the hypochlorite. Eggs were suspended in 100 ml of water from which two 10-ml aliquots were counted, and the mean counts corrected for 100 ml. Eggs per gram root was determined for each plant. The data were analyzed statistically. Plants in different tests were analyzed as separate groups.

Relative plant resistance was based on egg production per gram root for each entry expressed as a percentage of the egg production per gram on check plants within that test. The host status, based on percentage of egg production per gram root, was 0% = immune, 1–10% = highly resistant, 11–25% = resistant, 26–40% = moderately resistant, 41–60% = low susceptible, 61–100% = susceptible as check, and above 100% = very susceptible. Resistant entries were retested once to confirm their resistance.

Results

Composite analysis of Rr egg production on *G. hirsutum* Deltapine 16 (check) from the 20 tests, January to October 1980, showed significant differences in the number of eggs per gram root ranging from 14,000 to 52,000. Plants in different tests were treated separately in the statistical analysis. However, the percentage of egg production relative to the checks facilitates comparison among all entries.

Of 32 entries of the 19 wild *Gossypium* spp. tested, 22 were susceptible to Rr. *G. longicalyx* (four entries) was immune (Table 1, #1–4), supporting no Rr egg production. *G. somalense* and *G. stocksii* were highly resistant (Table 1, #8 and 10) and *G. raimondi* (Table 1, #26) was resistant. *G. klotzschianum* #32, *G. trilobum,* and *G. thurberi* from the Molino Basin, Arizona, with egg productions of 368, 615, and 717%, respectively (Table 3, #80–82), were the most susceptible plants encountered in this research.

Sixty-seven race stocks of *G. hirsutum* tested were races (primitive types) of latifolium, palmeri, richmondi, marie galante, morrilli, and punctatum. Ninety-six percent of the races were susceptible. A race of marie galante from Haiti (893) was resistant (Table 1, #23).

All of the upland cotton cultivars tested were as susceptible (Table 2) or more susceptible (Table 3) than the check, except La RB 15702 was moderately resistant (Table 1, #41).

Forty-six percent of the *G. arboreum* entries tested were resistant to Rr. *G. arboreum* P.I. 41895 was highly resistant, with only 9% of the egg production on Deltapine 16; P.I. 417891 and CB 3839 were resistant; P.I. 417887 and P.I. 417892 were moderately resistant (Table 1, #13, 16, 25, 32, 38).

Among seven *G. herbaceum* entries tested, P.I. 408775 was resistant, with 16% of the egg production on Deltapine 16. P.I. 408778, P.I. 408782, and P.I. 408780 were moderately resistant (Table 1, #22, 33, 35, 36).

Among six *G. barbadense* tested, Texas 110 was highly resistant, supporting only 8% of the egg production on Deltapine 16 (Table 1, #12), whereas the root-knot nematode resistant *G. barbadense* var. *darwinii* was very susceptible (Table 3, #36).

TABLE 1. *Gossypium* spp., *Hibiscus* spp., and other Malvaceae resistant to *Rotylenchulus reniformis.*

Test plants and origin	Egg production* (%)	Host reaction†
1. *G. longicalyx* Hutch. & Lee—Africa	0	I
2. *G. longicalyx* Hutch. & Lee 'G'—Africa	0	I
3. *G. longicalyx* Hutch. & Lee A-18—Africa	0	I
4. *G. longicalyx* Hutch. & Lee #70—Africa	0	I
5. *Sida rhombifolia* L.	0	I
6. *H. diversifolius* A60-243	0.8	HR
7. *H. mutabilis*	3	HR
8. *G. somalense* (Gurke.) Hutch. 'M'—Africa	5	HR
9. *H. sabdariffa* A64-565	5	HR
10. *G. stocksii* Mast. ex Hook A-1—Arabia	6	HR
11. *H. cannabinus* P.I. 196988	6	HR
12. *G. barbadense* 'Texas 110'	8	HR
13. *G. arboreum* P.I. 41895	9	HR
14. *H. cannabinus* 'Everglades 71'	9	HR
15. *H. furcellatus* A59-86	10	HR
16. *G. arboreum* P.I. 417891	11	R
17. *H. radiatus* S60m39	11	R
18. *H. radiatus* S55m15	14	R
19. *H. radiatus* A59-53	14	R
20. *H. syriacus*	14	R
21. *Malvaviscus arboreus* var. *drummondii*	14	R
22. *G. herbaceum* P.I. 408775	16	R
23. *G. hirsutum* race marie galante 893—Haiti	16	R
24. *H. macranthus* A64-569	17	R
25. *G. arboreum* CB 3839	19	R
26. *G. raimondi* Ulbr. #9—Peru	20	R
27. *H. sabdariffa* A58-31	20	R
28. *H. sabdariffa* A59-68	21	R
29. *H. esculentus* 'Louisiana Green Velvet'	22	R
30. *G. hirsutum* race marie galante 903—Cuba	24	R
31. *H. esculentus* 'Dwarf Long Green Pod'	28	MR
32. *G. arboreum* P.I. 417887	29	MR
33. *G. herbaceum* P.I. 408778	29	MR
34. *G. hirsutum* race marie galante 874—St. Thomas	29	MR
35. *G. herbaceum* P.I. 408782	30	MR
36. *G. herbaceum* P.I. 408780	31	MR
37. *H. esculentus* 'Clemson Spineless'	33	MR
38. *G. arboreum* P.I. 417892	35	MR
39. *G. thurberi* Tod.—Sonoita, Arizona, USA	36	MR
40. *G. anomalum* Wawr. ex Wawr. & Peyr. #35—Africa	38	MR
41. *G. hirsutum* 'La RB 15702'	38	MR
42. *G. hirsutum* 'Deltapine 16'	100	S

* Egg production per gram of root with significantly less egg production than on *G. hirsutum* 'Deltapine 16' (100%) check. $P = 0.05$ according to Duncan's multiple-range test.

† 0% = immune (I), 1–10% = highly resistant (HR), 11–25% = resistant (R), 26–40% = moderately resistant (MR), 41–100% = susceptible (S).

Of the 22 *Hibiscus* entries tested (selected from 13 species), 16 (73%) were resistant to Rr. Among seven other genera of Malvaceae, *Sida rhombifolia* was a nonhost and *Malvaviscus arboreus* var. *drummondii* was resistant (Table 1). *Urena lobata* and *Modiola caroliniana* were susceptible and low susceptible, respectively (Table 2). *Anoda cristata* and *Abutilon theophrastii* were very susceptible (Table 3).

Host susceptibility was correlated with the degree of development of Rr females and by the number of eggs they produced. Females of Rr in susceptible Deltapine 16 roots were well developed and produced an average of 104 eggs/egg mass. Females developed poorly in roots of highly resistant *H. mutabilis, G. somalense,* and *H. syriacus,* producing less than three eggs/egg mass. Egg masses were not found on roots

TABLE 2. *Gossypium* spp., *Hibiscus* spp. and other Malvaceae susceptible to *Rotylenchulus reniformis.*

Test plants and origin	Egg production* (%)	Host reaction†
1. *Modiola caroliniana* (L.) G. Don	42	LS
2. *G. hirsutum* 020—Chiapas, Mexico	44	LS
3. *G. herbaceum* A-4	45	LS
4. *G. herbaceum* P.I. 408776	45	LS
5. *G. arboreum* P.I. 417888	48	LS
6. *G. hirsutum* race latifolium 069—Guatemala	48	LS
7. *G. hirsutum* 709—Nicaragua	48	LS
8. *G. hirsutum* 'La Mexican Smooth 15158'	49	LS
9. *G. hirsutum* race latifolium 016—Chiapas, Mexico	50	LS
10. *G. hirsutum* race latifolium 037—Chiapas, Mexico	54	LS
11. *G. hirsutum* race marie galante 820—Trinidad	54	LS
12. *G. armourianum* Lern. #17—Mexico	55	LS
13. *G. australe* F. Muell. A-2—Australia	55	LS
14. *G. hirsutum* race latifolium 160—Oaxaca, Mexico	56	LS
15. *G. hirsutum* race marie galante 834—Venezuela	56	LS
16. *H. cannabinus* BG 61-31	56	LS
17. *G. hirsutum* race latifolium 072—Guatemala	57	LS
18. *G. hirsutum* race latifolium 096—Guatemala	58	LS
19. *G. klotzschianum* Anderss. A-16—Galapagos	58	LS
20. *G. hirsutum* 'Brazos'	59	LS
21. *G. barbadense* 'Pima S-1'	60	LS
22. *G. hirsutum* 'Kapas Parao'	60	LS
23. *G. hirsutum* race latifolium 050—Chiapas, Mexico	60	LS
24. *G. hirsutum* race marie galante 867—Guadeloupe	61	S
25. *G. hirsutum* race latifolium 490—Yucatan, Mexico	62	S
26. *G. hirsutum* 'Lockett 48769'	65	S
27. *G. hirsutum* 'McNair 1032'	65	S
28. *Urena lobata* A59-81	65	S
29. *G. hirsutum* 'Atlas 59-63'	66	S
30. *G. hirsutum* race latifolium 080—Guatemala	67	S
31. *H. costatus* A60-243	67	S
32. *G. hirsutum* race latifolium 100—Guatemala	68	S
33. *G. hirsutum* race marie galante 368—Guatemala	68	S
34. *G. hirsutum* race punctatum 026—Chiapas, Mexico	68	S
35. *G. klotzschianum* var. *davidsonii* 'D'—Galapagos	68	S
36. *G. thurberi* Tod.—Mexico	68	S
37. *G. hirsutum* race marie galante 853—Grenada	69	S
38. *G. hirsutum* race marie galante 898—Haiti	69	S
39. *G. hirsutum* 'FTA 263'	71	S
40. *G. hirsutum* race morrilli 194—Oaxaca, Mexico	71	S
41. *G. arboreum* P.I. 417890	72	S
42. *G. barbadense* 'Coastland RN'	72	S
43. *G. hirsutum* 'Wild Mexican Jack Jones'	73	S
44. *G. hirsutum* race latifolium 053—Chiapas, Mexico	73	S
45. *G. hirsutum* 'FJA 348'	75	S
46. *G. hirsutum* race latifolium 067—Chiapas, Mexico	75	S
47. *G. hirsutum* 'Auburn 56'	77	S
48. *G. hirsutum* race latifolium 158—Guatemala	79	S
49. *G. hirsutum* race latifolium 004—Guerrero, Mexico	80	S
50. *G. hirsutum* race latifolium 375—Paraguay	81	S
51. *G. barbadense* 'Pima S-4'	82	S
52. *G. hirsutum* race morrilli 125—Oaxaca, Mexico	82	S
53. *G. hirsutum* 'Mo Del'	83	S
54. *G. hirsutum* race latifolium 078—Guatemala	84	S
55. *G. hirsutum* 933—USSR	85	S
56. *G. arboreum* P.I. 417893	89	S
57. *G. hirsutum* race latifolium 489—Yucatan, Mexico	89	S
58. *G. hirsutum* 'La-long 16 ne-24'	90	S
59. *G. aridum* (Rose & Standl.) Skov. #16—Mexico	91	S
60. *G. hirsutum* 'Earlistaple 7'	92	S
61. *G. hirsutum* race punctatum 448—Yucatan, Mexico	93	S
62. *G. barbadense* 'Pima S-3'	94	S

TABLE 2. Continued.

Test plants and origin	Egg production* (%)	Host reaction†
63. *G. hirsutum* 'Pee Dee 2165'	95	S
64. *G. hirsutum* race latifolium 113—Guatemala	95	S
65. *G. hirsutum* race latifolium 007—Puebla, Mexico	96	S
66. *G. hirsutum* 'Acala 1517 C'	98	S
67. *G. hirsutum* 'Acala 44 WR'	99	S
68. *G. hirsutum* 'Pee Dee 0259'	99	S
69. *G. hirsutum* race marie galante 373—Morelos, Mexico	99	S
70. *G. hirsutum* 932—USSR	100	S
71. *G. hirsutum* Hybrid 330-378	100	S
72. *G. hirsutum* race latifolium 196—El Salvador	100	S
73. *G. hirsutum* 'Deltapine 16'	100	S

* Egg production per gram of root not significantly different from *G. hirsutum* 'Deltapine 16' check. $P = 0.05$ according to Duncan's multiple-range test.
† 41–60% = low susceptible (LS), 61–100% = susceptible (S).

of *G. longicalyx*; females that penetrated roots remained vermiform during the 35-day test period without producing a gelatinous matrix or eggs.

DISCUSSION

Egg production by Rr on check plants of Deltapine 16 fluctuated significantly in the greenhouse during the 1-year period of these tests. The seasonal trend in egg production observed in the greenhouse, despite controlled temperature and light conditions, was similar to the trend observed by Birchfield and Jones (unpublished) in field populations in Louisiana.

Gossypium longicalyx, with immunity to Rr,

TABLE 3. List of test plants very susceptible to *Rotylenchulus reniformis*.

Test plants and origin	Egg production* (%)
1. *G. hirsutum* 'Deltapine 16'	0
2. *G. davidsonii* Kell.—Mexico	101
3. *G. hirsutum* race morrilli 210—Guatemala	101
4. *G. hirsutum* race morrilli 293—Oaxaca, Mexico	101
5. *G. hirsutum* race marie galante 832—Trinidad	102
6. *G. hirsutum* 'Deltapine 61'	103
7. *G. hirsutum* race marie galante 882—Puerto Rico	105
8. *G. hirsutum* 'Hopicala'	106
9. *G. hirsutum* race latifolium 195—El Salvador	106
10. *G. hirsutum* 931—USSR	107
11. *G. hirsutum* race marie galante 884—Dominican Republic	107
12. *G. hirsutum* 'Acala Hopi C6-5'	108
13. *G. hirsutum* 'Coker 201'	108
14. *H. rosa-sinensis* 'Southern Belle'	108
15. *G. hirsutum* race morrilli 172—Oaxaca, Mexico	111
16. *G. hirsutum* race marie galante 879—Puerto Rico	111
17. *G. hirsutum* 'Auburn M'	113
18. *G. hirsutum* 'Empire WR'	114
19. *G. arboreum* P.I. 417896	115
20. *G. hirsutum* race marie galante 840—Venezuela	115
21. *G. hirsutum* 'AC 235'	116
22. *G. hirsutum* 'Acala Imperial'	118
23. *G. hirsutum* race palmeri 878—Puerto Rico	119
24. *G. hirsutum* race marie galante 184—Guatemala	120
25. *G. armourianum* Kern—Mexico	122

TABLE 3. Continued.

Test plants and origin	Egg production* (%)
26. *G. hirsutum* 'Carolina Queen'	122
27. *G. hirsutum* race punctatum 481—Yucatan, Mexico	122
28. *G. hirsutum* race latifolium 087—Guatemala	123
29. *G. hirsutum* race palmeri 303—Oaxaca, Mexico	124
30. *G. harknessii* Brandg.—Mexico	125
31. *Abutilon theophrastii* Medicus	128
32. *G. hirsutum* race palmeri 001—Guerrero, Mexico	129
33. *G. anomalum* Wawr. ex Wawr. & Peyr.—Africa	130
34. *G. hirsutum* 'Atlas × E 57-202'	131
35. *G. hirsutum* 'CE 260'	133
36. *G. barbadense* var. *darwinii*	134
37. *G. hirsutum* 'Acala 1517 v'	134
38. *G. sturtianum* Willis A-9—Australia	134
39. *G. arboreum* 'V4'	136
40. *G. arboreum* P.I. 417894	137
41. *G. hirsutum* 'Atlas 59-92'	138
42. *G. hirsutum* race morrilli 126—Oaxaca, Mexico	139
43. *G. hirsutum* 'Atlas 59-182'	140
44. *G. hirsutum* race marie galante 866—Martinique	141
45. *G. hirsutum* race marie galante 246—Guerrero, Mexico	142
46. *G. hirsutum* race punctatum 144—Guatemala	142
47. *G. hirsutum* race latifolium 124—Guatemala	149
48. *G. hirsutum* 'Atlas 67'	150
49. *G. hirsutum* 'Stoneville 213'	151
50. *G. sturtianum* Willis I—Australia	151
51. *G. hirsutum* race marie galante 141—Guatemala	153
52. *G. arboreum* 'V2-8'	155
53. *G. hirsutum* race marie galante 370—Guatemala	155
54. *G. aridum* (Rose & Standl.) Skov. #8—Mexico	168
55. *G. hirsutum* 'FTA 266'	168
56. *G. hirsutum* race marie galante 833—Trinidad	168
57. *Anoda cristata* (L.) Schlecht.	171
58. *G. hirsutum* 'Acala 4-41'	175
59. *G. hirsutum* race richmondi 256—Oaxaca, Mexico	182
60. *G. sturtianum* Willis A-19—Australia	182
61. *G. hirsutum* race latifolium 021—Chiapas, Mexico	190
62. *G. hirsutum* race latifolium 117—Oaxaca, Mexico	192
63. *G. hirsutum* 'Austin 3361'	195
64. *G. bickii* Prokh. A-8—Australia	197
65. *H. militaris* Cav.	205
66. *G. hirsutum* race richmondi 461—Oaxaca, Mexico	207
67. *G. hirsutum* race palmeri 009—Oaxaca, Mexico	213
68. *G. hirsutum* race latifolium 227—El Salvador	215
69. *G. hirsutum* race marie galante 817—Nicaragua	220
70. *G. gossypioides* (Ulbr.) Standl.—Mexico	233
71. *G. arboreum* 'Garo Hill'	236
72. *G. hirsutum* race palmeri 051—Chiapas, Mexico	241
73. *G. hirsutum* 'TH 149'	242
74. *G. hirsutum* race morrilli 134—Oaxaca, Mexico	246
75. *G. bickii* Prokh.—Australia	251
76. *G. gossypioides* (Ulbr.) Standl. #10—Mexico	258
77. *G. tomentosum* Nutt. ex Sem.—Hawaii, USA	264
78. *H. furcellatus* A61-359	265
79. *G. hirsutum* 'FJA 347'	302
80. *G. klotzschianum* Anderss. #32—Galapagos	368
81. *G. trilobum* (Moc. & Ses. ex DC) Skov. emend. Kern—Mexico	615
82. *G. thurberi* Tod.—Molino Basin, Arizona, USA	717
83. *Cienfugosia drummondii* Cav.	25†
84. *H. lasiocarpos*	34†

* Egg production significantly more susceptible (over 100%) than *G. hirsutum* 'Deltapine 16' check. $P = 0.05$ according to Duncan's multiple-range test.

† Very susceptible hosts with severely damaged roots unable to support Rr egg production.

and *G. somalense* and *G. stocksii,* with high resistance, were species that occur geographically close to one another in East Africa (1). Such a concentration in a localized area of high Rr resistance in *Gossypium* spp., not previously known, is a valuable addition to our knowledge of cotton germplasm. These species possess poor agronomic characters but may be useful sources of Rr resistance in a cotton breeding program, if interspecies crossing can be achieved.

Gossypium hirsutum La. long 16ne-24 is a breeding line that has cytoplasm of the Rr-immune *G. longicalyx* and nuclear materials of the Rr-susceptible *G. hirsutum* Deltapine 16. Since it was susceptible to Rr (Table 2, #58), the *G. longicalyx* cytoplasm apparently did not confer Rr resistance.

Gossypium barbadense Texas 110 from Guatemala is agronomically unsuitable to the United States because of long photoperiod requirements, but it has high resistance to Rr. This is the first report of high resistance to Rr within this species, since all presently cultivated *G. barbadense* are susceptible to Rr (14).

Gossypium hirsutum with potential value in breeding programs are race marie galante 893, 903, and 874 from Haiti, Cuba, and St. Thomas, respectively; race latifolium 69 from Guatemala; race unknown 20 from Chiapas, Mexico; and two breeding lines from Louisiana State University, La. RB 15702 and La. Mexican Smooth 15158. The last two cottons were observed in greenhouse screening tests to support lower Rr populations relative to other upland cottons (J. E. Jones, personal communication). These observations were confirmed in this research.

Muralidharan and Sivakuma (12) tested *G. anomalum, G. armourianum, G. davidsonii, G. raimondi,* and *G. thurberi* for resistance to Rr in India. All five of these wild species were considered resistant, as Rr reproduced poorly on them. In our tests, one of two entries of *G. anomalum* (#35), one of three *G. thurberi* (Sonoita), and one *G. raimondi* (#9) were moderately resistant or resistant to Rr, while two *G. armourianum* and one *G. davidsonii* were susceptible, confirming to some degree the results of the Indian investigators. Different races of Rr may occur in India and the United States, accounting for such disparity in the host status of the *Gossypium* species.

Resistance to Rr seems to be widespread in *Hibiscus* spp., as only 4 of 22 entries tested were susceptible. These plants could be used in crop rotation with cotton in heavily Rr infested soil to reduce Rr populations in countries where some of these *Hibiscus* spp. are grown for food and fiber (especially Africa). *Hibiscus* spp. and other Malvaceae might be used in inter-generic crosses to introduce Rr resistance into cotton in the future.

Rebois et al. (17) showed that genes controlling resistance to soybean cyst nematodes in soybean also govern resistance to Rr, but no such relationship existed between resistance to root-knot nematode and Rr. *Gossypium hirsutum* 'Auburn M,' 'Auburn 56,' Wild Mexican Jack Jones, and *G. barbadense* var. *darwinii* are resistant to the root-knot nematode *Meloidogyne incognita* (3,20,21), but were susceptible to Rr in our research as well as in an earlier test (3). As in soybeans, resistance to Rr in cotton is not associated with resistance to root-knot nematodes.

Rohde (19) indicated that low nematode populations may be recovered when a host is either resistant or very susceptible. Severely injured plants may only be able to support low nematode populations and may therefore be mistakenly considered as resistant. Based on egg production alone, we would have concluded that *H. lasciocarpus* and *Cienfuegosia drummondii* (Table 3) were resistant and moderately resistant, respectively, to Rr. However, histopathological sections of infested roots showed severe cell damage by Rr. The low egg production was due to badly damaged root systems, which were unable to maintain the parasite optimally, rather than to defensive host reactions. Birchfield and Brister (3) also showed that *H. lasciocarpus* was susceptible to Rr in greenhouse tests.

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