Development of Grain Sorghum Lines with Resistance to Sugarcane Mosaic and Other Sorghum Diseases

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ABSTRACT

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Fifteen parental lines (QL6–17 and QL20–22) homozygous for the Krish source of sugarcane mosaic virus resistance were developed over 6 yr. Virus was not detected in new growth leaves following mechanical inoculation with sugarcane mosaic virus. Line QL19 contains the Q7539 source of resistance, which confers a high level of resistance to natural infection. QL19 averaged 13.5% infected plants in field experiments over 3 yr compared with 79% in the recurrent parent KS4. Percentage of infection in QL19 and Q7539 decreased as inoculum dilution increased. QL22 was highly resistant to sorghum downy mildew (*Peronosclerospora sorghi*) and QL20 was resistant to race 1 of head smut (*Sphacelotheca reiliana*), whereas QL7 and 13 were more resistant to rust (*Puccinia purpurea*) than their recurrent parents.

Strains of sugarcane mosaic virus (SCMV) cause necrotic and mosaic diseases of sorghum (*Sorghum bicolor* (L.) Moench) in most countries where the crop is grown. The importance of SCMV in sorghum has been reviewed recently by Toler (12). In Australia, a strain (SCMV-Jg) infecting Johnsongrass (*S. halepense* (L.) Pers.) induces three distinct symptoms on sorghum—mosaic, red leaf, and red stripe. Development of a particular symptom is dependent on genotype and temperature (7,10). Significant yield reductions occur in cultivars developing each of the three symptoms (4). Although Australian SCMV-Jg and American maize dwarf mosaic virus strain A (MDMV-A) both infect Johnsongrass, the former induces different symptoms on several sorghum lines (10) and the two strains have shown only distant serological affinity (8).

The most practical means of control for SCMV is the use of resistant cultivars. Several lines used in the sorghum conversion program of the U.S. Department of Agriculture and Texas A&M University have resistance to MDMV-A (12). In Australia, Krish sorghum—a tall, photoperiod-sensitive, forage cultivar bred in India (5)—is highly resistant to four strains of SCMV following mechanical inoculation (11). A grain sorghum from Nigeria, designated Q7539 in Australia, is highly resistant to natural infection by SCMV-Jg (6). The resistance in Krish is monogenic dominant to Australian SCMV strains (2), whereas that in Q7539 is of complex inheritance (6; Henzell and Persley, *unpublished*).

A breeding program was begun by the Queensland Department of Primary Industries and the University of Queensland to incorporate these resistance sources into important breeding lines. Four segregating lines (QL1–4) with Krish resistance were released by R. F. Moore in 1972. In this paper, the subsequent development and testing of parental lines are outlined.

MATERIALS AND METHODS

The fixed lines used as recurrent parents were RTAM422, RTx7078, KS19, and KS4. RTAM422 and RTx7078 are the male parents of Tx610SR and Tx610, respectively, two widely grown hybrids in Queensland. KS19 is a widely used male parent in hybrids marketed in Queensland because of its standability. KS4 is a red-seeded Combine Kafir-60 type. The methods used to incorporate the two sources of virus resistance differed substantially because of differences in the inheritance patterns of the resistances.

Because the Krish gene results in high resistance to systemic infection, resistant segregates were selected after inoculation of segregating progenies with SCMV-Jg using an airbrush technique (4). Up to 30,000 seedlings were tested in this manner each year. Virus-susceptible segregates were rogued and resistant segregates evaluated for good grain sorghum characteristics.

A field inoculation method was developed to evaluate progeny involving Q7539, which, although highly resistant to natural infection by aphid vectors, can be almost totally infected by mechanical inoculation. Replicated blocks of progeny lines were alternated with blocks or rows of SCMV-susceptible sweet corn that were inoculated with the virus. This method aided the development of an epidemic, and the resistance or susceptibility of the lines was related to disease levels occurring in the recurrent parents.

In an inoculum dilution experiment, crude sap was extracted from sweet corn plants (cv. Iochief Hybrid) 14 days after inoculation with SCMV-Jg and diluted with cold 0.1 M phosphate buffer, pH 7.0. Twenty to 25 plants of each line were inoculated with each sap dilution, and the numbers of infected plants were recorded 26 days later.

RESULTS

Development of lines with Krish resistance. During a 6-yr period, two to four backcrosses to the recurrent parents were made depending on the recovery of resistance in agronomically acceptable types. It was relatively easy to separate the grassy plant habit of Krish from the resistance gene while the open-head character of this parent was retained by positive selection. Twelve parental lines homozygous for Krish resistance were released in 1977 and three in 1980. Seven of these lines (QL6–12) are KS19 types, six (QL13–17 and QL20) are RTx7078 types, and two (QL21 and 22) are KS4 types. The pedigrees of QL6–QL17 are available (3). The pedigree of QL20 is RTx7078 × (RTAM422$_2$ × ((RTx414 × Krish 13) × RTx7078)). The line is similar in height and maturity to RTAM422 but is more open-headed. F_1 hybrids with AKS4 are similar to AKS4 × RTAM422 with respect to height, maturity, and yield but are more open-headed. QL21 was derived from KS4 × Krish (Seln 13) and is phenotypically very similar to KS4. It is a B line (nonrestorer) in the milo cytoplasm. Hybrids of QL21 and AKS4 with TAM422 are similar with respect to height, maturity, head type, and yield, as are hybrids of QL21 and AKS4 with KS19.

Development of line with Q7539 resistance. The development of QL19 involved backcrossing to the bc$_2$ stage and then selecting for virus-resistant

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Table 1. Assessment of field resistance of QL19 to Johnsongrass strain of sugarcane mosaic virus during 3 yr of tests

	Diseased plants (%)[a]				
	Hermitage		Gatton		
Line	1978	1979	1979	1980	Mean
QL19	19	8	11	16	13.5
Q7539	0	1	4	1	1.5
KS4	80	58	98	80	79.0
KS4 × Q7539 F_1	54	41	91	83	67.2
SC0097-14E[b]	3	NT[c]	NT	15	9.0
LSD 0.05	28.8	14.1	19.7	9.4	

[a] Data are averaged from three replicates in each trial. Trial design consisted of randomized blocks alternated with blocks of sweet corn inoculated with SCMV-Jg or of rows alternated with rows of inoculated sweet corn or sorghum.
[b] Resistant to maize dwarf mosaic virus strain A in Texas (12).
[c] NT = not tested.

Table 2. Infection of seven sorghum lines following mechanical inoculation with dilutions of Johnsongrass strain inoculum of sugarcane mosaic virus

	Plants infected (%)[a] at inoculum dilution			
Line	0	1/10	1/50	1/100
Q7539	100	75	0	0
QL19	100	95	60	48
KS4	100	100	100	100
QL20	0	0	0	0
QL21	0	0	0	0
SC0097-14E	100	100	14	45
BTx398	100	100	81	86

[a] Twenty to 25 plants were inoculated at each dilution and evaluated 26 days later.

segregates in the field using the indirect inoculation method. QL19 was released in 1980 following 5 yr of testing. A summary of the data obtained during the last 3 yr of testing is given in Table 1. The pedigree of QL19 is $KS4_3 \times Q7539$. QL19 is a grain sorghum type that is slightly taller but similar in maturity to KS4. It is a B line (nonrestorer) in the milo cytoplasm.

Additional testing of developed lines by manual inoculation. Mechanical inoculation of QL20 and 21 under glasshouse conditions confirmed the high resistance of lines containing the Krish resistance source (Table 2). SCMV was not detected by back-inoculation from new growth leaves to susceptible sorghum seedlings 3 wk after inoculation. Infection levels decreased in QL19 and Q7539 with increased inoculum dilution (Table 2). Q7539 was also resistant following manual inoculation with three other strains of SCMV reported from Australia that do not infect Johnsongrass (9).

Resistance to fungal pathogens. Several selections have shown higher resistance to rust (*Puccinia purpurea* Cooke) than the recurrent parent. In field assessments over 2 yr, using a rating scale of 0–5, average ratings for rust infection were 0.86 for QL7, 1.33 for the recurrent parent KS19, 2.03 for QL13, and 3.33 for the recurrent parent RTAM422. QL20 is resistant to race 1 of head smut *Sphacelotheca reiliana* (Kühn) Clint. (P. Mayers, *personal communication*).

The sorghum downy mildew pathogen, *Peronosclerospora sorghi* (Weston and Uppal) C. G. Shaw, has not been reported from Australia. QL3, however, has shown high resistance to sorghum downy mildew in the United States (1) and at all sites included in the International Sorghum Downy Mildew Nursery (14). A parental KS4 line, QL22, highly resistant to both SCMV and sorghum downy mildew (L. K. Mughogho, *personal communication*), was released in 1980.

DISCUSSION

The value of the 15 lines homozygous for Krish resistance and line QL19 containing the Q7539 source will depend on the durability of the resistances to SCMV strains occurring in countries where the lines are used. In the United States, QL10 was not infected following mechanical inoculation with MDMV-A (ATCC PV55) or SCMV strains A, B, D, E, H, I, K, L, and M (A. G. Gillaspie, Jr., *personal communication*).

QL11 was fully resistant to infection by an isolate of SCMV from Italy (SCMV-Bg [13]) following mechanical inoculation (M. Conti, *personal communication*). QL3 and QL11 were also highly resistant to an isolate of SCMV from sorghum in Venezuela (G. Malaguti, *personal communication*). The Q7539 source has not been tested as widely as the Krish QL lines, but it is resistant to MDMV-A in Texas (12).

The high resistance of QL3 to sorghum downy mildew in the four countries in which it has been tested is of considerable importance in relation to control of this major disease. Positive selection for this character was not possible in our program because of absence of the causal fungus. It would seem that the resistance was fortuitously transferred to some segregates from Krish sorghum with the gene conditioning SCMV resistance.

The SCMV-resistant QL lines are now being used in most commercial and public breeding programs in Australia. In 1980–1981, seven hybrids totally resistant to SCMV were available commercially.

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