Identification of QL-3 Sorghum, a Source of Resistance to *Peronosclerospora sorghi*

R. J. WILLIAMS, S. R. S. DANGE, L. K. MUGHOGHO, and K. N. RAO, International Crops Research Institute for the Semi-Arid Tropics, Patancheru P.O., Andhra Pradesh 502 324, India

ABSTRACT

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In 3 yr of testing in India, Botswana, Venezuela, and the USA, a selection of the Australian sorghum (*Sorghum bicolor*) line QL-3 has remained free from symptoms of sorghum downy mildew when exposed to oospores and conidia of *Peronosclerospora sorghi* in field trials. In addition, the QL-3 resistance has remained effective when inoculated with conidia of the fungus by four techniques that resulted in the breakdown of resistance of other field-resistant cultivars. QL-3 was developed first in Australia for resistance to the sugarcane mosaic virus, but this resistance to the virus has also been effective in Asia, Europe, and the Americas. Thus the QL-3 selection represents a valuable source of combined resistance to two important pathogens of sorghum.

Additional key words: multilocational testing

Sorghum downy mildew (SDM), caused by *Peronosclerospora sorghi* (Weston & Uppal) C. G. Shaw, is a serious disease of sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* L.) in many parts of Asia, Africa, and the Americas (4,6,8,11). Although seed treatment with metalaxyl (1,14) and certain cultural practices (13) have shown some promise for control of SDM, the use of cultivars resistant to the pathogen is likely to continue to be a major component in any control program. However, because *P. sorghi* has shown variability in pathogenicity at the host species level (3,9,11) and among sorghum cultivars (2,5), resistance "breakdown" due to the development and spread of more virulent races of the pathogen will probably complicate control based on resistant cultivars.

In an attempt to examine the stability of cultivars reported to be resistant in national program tests, the cultivars were exposed to several populations of *P. sorghi* in the cooperative International Sorghum Downy Mildew Nursery (ISDMN), organized and coordinated by phytopathologists in the sorghum improvement program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The most resistant cultivars from the ISDMN program were rigorously tested at the ICRISAT center by several inoculation techniques. In all of these tests, a selection of the released breeding line QL-3 from Australia remained completely free from SDM symptoms and signs. This paper presents evidence for the stability of resistance to the SDM fungus in QL-3, with information on the origin and a description of the characteristics of this line.

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MATERIALS AND METHODS

Multilocational testing. The ISDMN program, initiated in 1976 to identify sources of stable resistance to the SDM fungus and to obtain information on the variability of *P. sorghi*, was a cooperative program with the participation of scientists in national programs. The basic requirement of cooperators was that they be able to expose ISDMN test entries to local *P. sorghi* populations with sufficient pressure to provide meaningful data on reactions of cultivars to the pathogen.

The test entries used initially were cultivars reported resistant to the SDM fungus in national program tests. Each year two highly susceptible cultivars were included to monitor disease pressure. The seed of the test entries was assembled and multiplied at ICRISAT, and all cooperators received seed from the same seed lot. Seed sets were sent to cooperators, with information on experimental design, planting and fertilization, method of inoculum provision, time and method of scoring, and duplicate data record sheets for climatic and plant reaction data.

Generally, test entries were planted in field plots (two rows of 4 m), in two replications, in fields with a history of attack by the SDM fungus, and/or were planted among "infector" rows of a local sorghum cultivar susceptible to the pathogen to provide conidial inoculum to challenge the test cultivars. In 1976–1978 the program was tested at several locations in India, Botswana, Venezuela, and the USA (Table 1).

Field exposure to oospores and conidia at ICRISAT. The 1978 ISDMN test entries were planted in two 4-m row field plots, in two replications in one trial, in furrows treated with oospores (15 g of ground leaves per meter of row) from infected sorghum leaves from the previous season. Throughout the field, two test rows were alternated with rows of susceptible "conidial donor" cultivar DMS 652 that was similarly exposed to oospores in the furrows, and plants were also each inoculated with 2 ml of a suspension (6×10^4 conidia per milliliter) by injection into stems near the growing point.

Mist irrigation was used in the evenings of rainfree days to promote infection and conidial production. The incidence of SDM was recorded shortly after the emergence of the inflorescences.

Conidial suspension dip. Systemically infected sorghum leaves, collected from the field at about 1500 hr, were washed in tap water and rubbed gently with moist cotton wool to remove old conidiophores and conidia. The leaves were blotted dry and cut into pieces about 5×3 cm. The leaf pieces, lower surfaces upward, were incubated in moist chambers at 20 C, starting at 1700 hr in an incubator programmed to reduce the temperature

Table 1. Cooperators and locations in the International Sorghum Downy Mildew Nursery Program in 1976, 1977, and 1978

Cooperator	Location	Year(s)
K. H. Anahosur	Dharwar, India	1976, 1977, 1978
K. Gangadharan	Coimbatore, India	1976, 1977, 1978
K. M. Safeeulla	Mysore, India	1976, 1977, 1978
B. B. More	Digraj, India	1977, 1978
K. N. Rao, S. R. S. Dange	ICRISAT, India	1977, 1978
K. A. Balasubramanian	Hyderabad, India	1978
M. B. Boling	Gaborone, Botswana	1977, 1978
G. Malaguti	Maracay, Venezuela	1978
R. A. Frederiksen	Texas, USA	1978

to 5 C at midnight, when the conidia would be maturing, and to maintain this temperature until the next morning so that conidia would not germinate. Between 0800 and 0900 hr, conidia were harvested into distilled water for an inoculum suspension by gently rubbing the leaves with large camel's-hair brushes.

Sprouted seeds (after 24-hr incubation at 35 C and 10 hr after germination) of the cultivars were briefly dipped into the suspension (4.5×10^4 conidia per milliliter). The inoculated sprouted seeds were incubated in moist chambers at 20 C for 1 hr and then planted in moist soil (1:1 mixture by volume of red soil and farmyard manure) in 19.5-cm plastic pots in a greenhouse. The incidence of SDM was recorded from 10 to 25 days after inoculation.

Three tests were made with this technique, with four replications in the first test and three replications in the second and third tests. Seven replications of 24–60 plants per replication were accomplished in the three trials.

Table 2. Sorghum downy mildew (SDM) incidence in selected resistant cultivars and two susceptible cultivars in the International Sorghum Downy Mildew Nursery program

	SDM incidence (%) in					
	1976[a]		1977[b]		1978[c]	
Entry	Mean	Max.[d]	Mean	Max.[d]	Mean	Max.[d]
QL-3	0	0	0	0	0	0
CSV-4	<1	2	3	5	3	7
IS-173	3	9	4	10	2	8
UchV-2	2	9	4	11	2	6
UchV-1	2	8	2	3	3	13
IS-3799	2	6	5	11	5	16
SC-120-14	0	0	3	10	6	18
CSV-5	2	5	5	9	5	23
IS-5273	2	3	4	9	7	26
IS-2042	2	3	6	25	8	19
IS-7254	...[e]	...	...	...	5	11
CK-60B	...	...	...	...	4	12
SPV-35	...	...	...	...	5	12
E35-1	...	...	...	...	6	19
DMS-652[f]	31	50	70	92	56	100
CSV-2[f]	30	57	63	100	54	97

[a] Three locations in India.
[b] Four locations in India, one location in Botswana.
[c] Six locations in India, one location in Venezuela.
[d] Based on individual replication values.
[e] Not included in the trial.
[f] Cultivar susceptible to *Peronosclerospora sorghi.*

Table 3. Sorghum downy mildew (SDM) incidence in selected resistant cultivars and a susceptible cultivar inoculated with oospores and/or conidia of *Peronosclerospora sorghi* at ICRISAT

	SDM incidence (%) after							
	Field exposure to oospores and conidia		Seedling dip in conidial suspension		Seedling incubation with infected leaves		Stem injection with conidial suspension	
Entry	Mean[a]	Max.	Mean[b]	Max.	Mean[c]	Max.	Mean[d]	Max.
QL-3	0	0	0	0	0	0	0	0
CSV-4	4	4	2	8	55	75	80	91
IS-173	0	0	0	0	52	77	77	91
UchV-2	2	3	3	10	33	83	72	83
UchV-1	1	2	<1	5	59	72	51	66
IS-3799	11	17	<1	3	60	89	...[e]	...
SC-120-14	8	16	1	10	58	100	42	42[f]
CSV-5	5	8	1	14	56	78	63	63[f]
IS-5273	4	5	0	0	46	70	90	90[f]
IS-2042	4	7	3	13	51	82	80	80[f]
IS-7254	3	5	6	26	64	85	57	57[f]
CK-60B	3	5	<1	5	30	69	67	67[f]
SPV-35	4	6	7	19	75	91	35	35[f]
E35-1	6	9	2	7	68	92	79	79[f]
DMS-652[g]	48	56	28	43	76	98	89	100

[a] One trial with two replications.
[b] Three trials, a total of seven replications.
[c] Three trials, a total of five replications.
[d] Two trials with a total of three replications except as noted in footnote f.
[e] Not included in the trial.
[f] Included in only one replication of trial.
[g] Cultivar susceptible to *P. sorghi.*

Exposure to conidia from infected leaf pieces. Infected leaves were collected, washed, cleaned, and cut as described for the previous inoculation method. Some leaf pieces were placed, lower leaf surfaces upward, on moist blotting paper in the bottom of petri dishes and plastic trays. Sprouted sorghum seeds (after 26-hr incubation at 35 C) were placed on the leaf pieces and then covered with additional leaf pieces, lower leaf surface downward and directly against the developing seedlings. The petri dishes and plastic trays were covered with lids containing moist blotting paper. The sprouted seeds between infected leaf pieces were placed in an incubator at 20 C for about 16 hr (mature conidia formed on the leaf pieces in about 7–8 hr). After this inoculation-incubation, the sprouted seeds were planted in moist soil in pots as described and maintained in a greenhouse. The incidence of SDM was recorded 20 days after planting.

Three experiments, with the same cultivars, were conducted by this inoculation technique, with five replications of 50–60 plants per replication in three trials.

Inoculation by injection. Conidial suspensions were obtained as described for dip inoculations, adjusted to 6×10^4 conidia per milliliter, and injected (2 ml per plant) into the stems, near the growing points, of 30-day-old plants of the sorghum cultivars in field plots. The incidence of SDM was recorded after the emergence of the inflorescences.

Two experiments were conducted by this technique, with two replications in one test, one replication in the second, and 20–30 plants per replication.

RESULTS

Multilocational testing. Detailed results of the 1976, 1977, and 1978 ISDMN have been presented (15). Resistant reactions of the better entries, in terms of SDM incidence, and the reactions of two cultivars susceptible to *P. sorghi* (checks) are summarized in Table 2. The selection from QL-3 was free from SDM at all locations in the 3 yr. Compared with the susceptible checks, the other entries listed showed moderate to high levels of resistance to *P. sorghi.* The incidence of SDM ranged from 0 to 26% of the plants grown in individual replications at 15 locations.

Inoculations at ICRISAT. The resistant reactions of the cultivars after exposure to oospores and conidia of *P. sorghi* in the field and reactions of the entries after the seedling dip in conidial suspension were similar to those obtained in the ISDMN trials (Table 3). The selection from QL-3 was free from infection by *P. sorghi,* and most other entries were considered to have high to moderate resistance, in terms of SDM incidence. However, with the exception of QL-3, which remained free from SDM

symptoms, the test entries developed higher incidences of SDM after inoculation with conidia of *P. sorghi* by incubation of sprouted seed with infected leaf pieces and after conidial suspensions were injected into the stems of young plants near the growing point (Table 3).

DISCUSSION

The results of the experiments indicate high resistance to *P. sorghi* in the Australian sorghum line QL-3 that is effective in India, Botswana, and Venezuela and is effective after inoculations by methods that overcame the resistance of other resistant cultivars. Recent reports from Texas (2,5) indicate that QL-3 is highly resistant to the three sorghum pathotypes of *P. sorghi* found there.

QL-3 was released in Australia in 1972 as one of a series of lines possessing highly effective resistance genes to the sugarcane mosaic virus and has been effective against that virus in Australia, France, Hawaii, India, Italy, the Philippines, and the USA (12). The QL-3 line was derived from Krish sorghum (10), which is a tall, grassy, photoperiod-sensitive cultivar from the cross *S. halepense* L. Pers. × *S. bicolor* var. *roxburghii* (Stapf.) Haines (7). At the ICRISAT farm near Hyderabad, India, QL-3 grows to a height of 1.25 m, flowering in 66 days after emergence, has brown grain, and is highly susceptible to the leaf rust pathogen *Puccinia purpurea* Cke.

A project to determine the genetic basis of the resistance to *P. sorghi* in QL-3 is under way, and the line is being crossed with lines carrying other desirable traits. Small quantities of QL-3 seed are available at ICRISAT.

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