Characterization of Virulence and Geographic Distribution of *Striga gesnerioides* on Cowpea in West Africa

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ABSTRACT

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A series of four cowpea cultivars (Blackeye, 58-57, IT81D-994, and B301) was used to differentiate the virulence of *Striga gesnerioides* from seven West African countries. Five parasite races were recognized, and their distribution across West Africa was mapped. Parasite samples that developed only on cowpea cv. Blackeye (race 1) were mostly from Burkina Faso, but also from Mali, Nigeria, and Togo. All other samples from Mali were pathogenic on cvs. 58-57 and Blackeye (race 2). *Striga gesnerioides* from Niger and northern and eastern Nigeria was pathogenic on cvs. Blackeye, 58-57, and IT81D-994 (race 3). Race four of the parasite from southern Benin was pathogenic on cvs. Blackeye and B301. A fifth new race, pathogenic on cvs. IT81D-994 and Blackeye, was identified in parasite samples from Cameroon, Nigeria, Benin, and Burkina Faso. Additional sources of resistance against *S. gesnerioides* were sought in cowpea landraces. Six of 11 landraces tested were resistant to at least one race of *S. gesnerioides*.

Additional keywords: parasite races, parasitic angiosperm, *Vigna unguiculata*, witchweed

Cowpea (*Vigna unguiculata* (L.) Walp.) is the major food grain legume grown in West Africa. The parasitic angiosperm *Striga gesnerioides* (Willd.) Vatke (witchweed) infects the roots of cowpeas and can cause grain yield losses of up to 50% (2). Probably the most feasible and potentially effective way for subsistence farmers to control *S. gesnerioides* is to use resistant cultivars (8). Cowpea cultivars with resistance to *S. gesnerioides* have been identified (1,9). Mechanisms of resistance of several cowpea cultivars were determined with an in vitro growth system (5). On cv. 58-57, host tissue necrosis around invading *S. gesnerioides* radicles was associated with rapid parasite death. The necrotic reaction was also observed on cv. B301; in most cases *S. gesnerioides* tubercles formed but did not enlarge beyond 1 mm in diameter, and parasite stems failed to elongate. B301 is being used widely in breeding programs in West Africa, and resistant cowpea cultivars may be available to farmers within the next few years (10). Variation in virulence of *S. gesnerioides* was revealed when resistant cowpea cultivars were grown in pots with *S. gesnerioides* collected from 11 sites in West Africa. Three parasite races were described and the distribution of these races was thought to be discrete (9). Recently, a fourth race of *S. gesnerioides* with virulence on cv. B301 was identified from southern Benin (6).

In 1990, *S. gesnerioides* incidence on cowpea was assessed in seven West African countries and seeds of the parasite were collected (3). The aim of our study was to characterize and map the specific virulence of *S. gesnerioides* from the 1990 collections, and collections from other sites in West Africa, on a range of differential cowpea cultivars. In addition, seeds from 11 cowpea landraces that were also collected in 1990 were assessed for new sources of resistance to *S. gesnerioides*.

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MATERIALS AND METHODS

Germ plasm. The sources of the differential series of cowpea cvs. were Blackeye from the United States, 58-57 from Burkina Faso, and IT81D-994 and B301 from IITA in Nigeria. Landrace cowpea seeds were collected in 1990 from 11 fields where no *S. gesnerioides* was present in Burkina Faso, Mali, Niger, and Nigeria. Seeds of *S. gesnerioides* were collected from parasitized cowpea plants (cultivars unknown) from fields in Benin, Burkina Faso, Cameroon, Mali, Niger, Nigeria, and Togo during 1984 to 1993. Cowpea landraces were inoculated with *S. gesnerioides* from Fada Ngourma in Burkina Faso (Long Ashton Research Station code no. 85-26), Cinzana in Mali (85-15), and Tarna in Niger (87-29).

Inoculation and incubation. Seeds of cowpea plants were grown in moist vermiculite for 6 days in a growth cabinet at 30/27°C light/dark temperature, with 67% relative humidity and a 16-h daylength. The photosynthetic photon flux density was 180 $\mu E\ s^{-1}\ m^{-2}$. Roots of cowpea plants were spread out on a layer of moist glass-fiber filter paper on two layers of tissue paper in a shallow plastic tray (4). Imbibed parasite seeds were placed on 6-mm filter paper disks in contact with cowpea roots. Trays were enclosed in a polyethene bag, wrapped in aluminum foil to exclude light from the roots, and returned to the growth chamber. After 3 days, *S. gesnerioides* seedlings were removed from the filter paper and transferred to cowpea roots with a fine paint brush. Transfer of *S. gesnerioides* seedlings and subsequent parasite development was monitored with a stereo-microscope. Plants were maintained in the growth chamber under the conditions described for inoculation.

Virulence tests. Fifty *S. gesnerioides* seedlings of each sample were placed on each of four plants of each of the four cultivars of the differential series. In a few cases, when parasite germination was less than 20%, the number of seedlings was reduced (minimum of 52). There were two classifications of resistance, as follows: (i) the number of *S. gesnerioides* seedlings that died following penetration with an associated necrotic response in the surrounding host root tissue was counted at 13 days; and (ii) the diameters of parasite tubercles with stems were assessed at 20 days. Cowpea plants with either no living parasite infections due to the necrotic response or with *S. gesnerioides* tubercles that were less than 2.5 mm in diameter were classified as resistant. Those parasite samples with a different race from samples from nearby sites were reassessed to confirm results.

Assessment of cowpea landraces for resistance to *S. gesnerioides*. For each of races 1 to 3, 50 *S. gesnerioides* seedlings were transferred to the roots of three Blackeye plants and three plants of each of the cowpea landraces. Resistance to *S. gesnerioides* was assessed as described above for the virulence tests.

RESULTS

Virulence and geographic distribution. Forty-eight *S. gesnerioides* samples from seven West African countries were assessed with the differential series of cowpea cultivars (Tables 1 and 2). Fourteen parasite samples were pathogenic only on cv. Blackeye (race 1). Ten of these samples were from Burkina Faso, two were from southern Togo, one from central Nigeria, and one from central Mali. Nine *S. gesnerioides* samples (race 2) were pathogenic on cvs. Blackeye and 58-57. This virulence pattern was restricted to parasite samples from Mali. A third set of parasite samples (race 3), from Niger, northern Nigeria, and Bauchi in eastern Nigeria successfully infected all cowpea cultivars except B301. *Striga gesnerioides* from Zakpota in southern Benin was pathogenic on cvs. 58-57 and B301 (race 4). No other samples were pathogenic on cv. B301. *Striga gesnerioides* from Cameroon was pathogenic on cowpea cvs. Blackeye and IT81D-994. This race was also detected in parasite samples from Nigeria, Burkina Faso, and Benin. The distribution of these five races in West Africa is shown in Figure 1.

Table 1. Differential virulence of *Striga gesnerioides* from West Africa on four cowpea cultivars

		Cowpea cultivar			
Country of origin/location	**LARS code no.**[a]	**Blackeye**	**58-57**	**IT81D-994**	**B301**
Benin					
Kandi	90-56	S[b]	R1[c]	S	R3[c]
Zakpota	90-74	S	R1	R3	S
Zakpota	90-75	S	R1	R3	S
Burkina Faso					
Kamboinse	86-14	S	R1	R3	R3
West of Fada Ngourma	86-17	S	R1	R3	R3
Koupela	89-08	S	R1	R3	R3
Pobe Mengao	90-05	S	R1	R3	R3
East of Fada Ngourma	90-14	S	R1	R1	R3
East of Koupela	90-17	S	R1	R3	R3
Koupela	90-18	S	R1	R3	R3
Zorgo	90-19	S	R1	R3	R1
Ouagadougou	90-20	S	R1	R3	R3
Yako	90-21	S	R1	R3	R3
Zabre	90-57	S	R1	S	R3
Zabre	93-01	S	R1	S	R3
Cameroon					
Lara Kaele	87-05	S	R1	S	R3
Garoua	89-01	S	R3	S	R3
Maroua	89-03	S	R1	S	R3
Mali					
Sotuba	84-01	S	S	R3	R3
Koporokendie	84-03	S	S	R3	R3
Koutiala	85-16	S	S	R3	R3
Koporokendie	90-02	S	S	R3	R3
Mourdiah	90-11	S	S	R3	R3
Bamako	90-49	S	S	R3	R3
Santiguila	90-50	S	R1	R3	R3
Cinzana	90-51	S	S	R3	R3
Segou	90-52	S	S	R3	R3
Grindigue	90-66	S	S	R3	R3
Niger					
West of Guidiguir	86-08	S	S	S	R3
Filingue	88-03	S	S	S	R3
Dogondoutchi	90-41	S	S	S	R1
Southwest of Dogondoutchi	90-42	S	S	S	R3
Kare	90-43	S	S	S	R1
Niamey	90-46	S	S	S	R3
West of Niamey	90-47	S	S	S	R3
Nigeria					
Minjibir	90-24	S	S	S	R3
Bakura	90-29	S	S	S	R3
Kware	90-31	S	S	S	R3
Maiduguri	90-61	S	S	S	R3
West of Biu	90-77	S	R1	S	R3
East of Biu	90-78	S	R1	S	R3
Mokwa	90-79	S	R1	S	R3
Badeggi	90-80	S	R1	R3	R3
West of Bara	90-81	S	R1	S	R3
West of Gombe	90-82	S	R1	S	R3
Alkalere	90-84	S	S	S	R3
Togo					
Agbodrafo	90-70	S	R1	R2[c]	R3
Agbodrafo	90-76	S	R1	R3	R3

[a] Long Ashton Research Station.

[b] S = Susceptible, parasite tubercles ≥2.5 mm in diameter.

[c] R = Resistant: all parasite infections resulted in necrotic response of cowpea roots, associated with death of *S. gesnerioides* (R1); no necrotic response and all parasite tubercles were <2.5 mm in diameter (R2); parasite tubercles were <2.5 mm in diameter while other *S. gesnerioides* infections were dead with the associated necrotic response present in same host plant (R3).

Resistance of cowpea landraces to *S. gesnerioides*. Landrace 90-166 from Niger was resistant to races 1 through 3 (Table 3). All other landraces from Niger were susceptible to race 3. Landraces 90-167 and 90-169 were resistant to races 1 and 2. Two other landraces from Niger, 90-164 and 90-168, were susceptible to race 1, and some plants were resistant to race 2. The landraces from Burkina Faso, Mali, and Nigeria, and one landrace from Niger (90-165), were all susceptible to the three *S. gesnerioides* races. However, one plant of landrace 90-173 from Burkina Faso was resistant to race 3, whereas the two other plants were susceptible. In several previous tests, cowpea plants have been identified that were resistant, while other plants of the same accession were susceptible (7).

DISCUSSION

The distribution of races of *S. gesnerioides* from West Africa was characterized with a differential series of cowpeas that had been developed previously for race identification (6). On the basis of these results, five races were described (Table 2). Race 1 was prevalent in, but was not exclusive to Burkina Faso, race 2 was confined to Mali, race 3 was found in Niger and northern and eastern Nigeria, and race 4 was limited to one site in southern Benin. Race 5 is a new race that is widely distributed across West Africa. Nigeria had the most complex distribution of races; this perhaps reflects both the diverse agricultural systems present and the intensity of land use for agriculture in this country (K. F. Cardwell and J. A. Lane, unpublished data).

Present indications are that the major source of resistance to the most virulent race 3, cv. B301, is also effective against the other *S. gesnerioides* races that are extensively distributed throughout sahelian

Table 2. Races of *Striga gesnerioides* on cowpea

Differential cowpea cultivars	Races of *S. gesnerioides*				
	1	**2**	**3**	**4**	**5**
Blackeye	S[a]	S	S	S	S
58-57	R[b]	S	S	R	R
IT81D-994	R	R	S	R	S
B301	R	R	R	S	R

[a] S = Susceptible; parasite tubercles ≥2.5 mm in diameter.

[b] R = Resistant; parasite tubercles <2.5 mm in diameter and/or necrotic response present in cowpea roots, associated with death of *S. gesnerioides*.

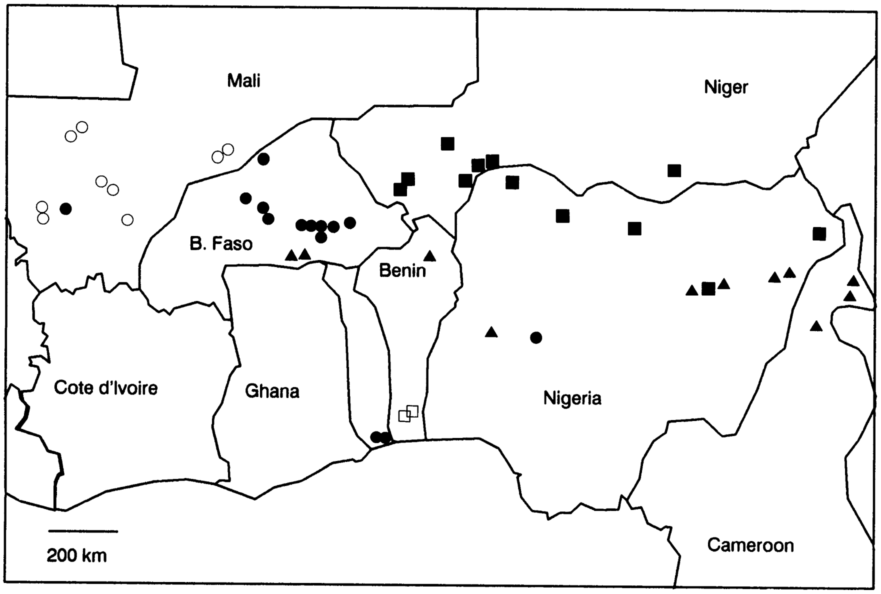

Fig. 1. Distribution of races of *Striga gesnerioides* in West Africa: closed circles, race 1; open circles, race 2; closed squares, race 3; open squares, race 4, and triangles, race 5.

Table 3. Responses of cowpea landraces to *Striga gesnerioides* samples from Burkina Faso, Mali, and Niger

Cowpea country of origin	LARS code no./cultivar[a]	Race and origin of *S. gesnerioides* Race 1[b]	Race 2	Race 3
Burkina Faso	90-170	S[c]	S	S
Burkina Faso	90-173	S	S	R[d]/S[e]
Mali	90-171	S	S	S
Mali	90-172	S	S	S
Niger	90-164	S	R/S[e]	S
Niger	90-165	S	S	S
Niger	90-166	R	R/S[f]	R
Niger	90-167	R	R	S
Niger	90-168	S	R/S[f]	S
Niger	90-169	R/S[f]	R	S
Nigeria	90-163	S	S	S
United States	Blackeye	S	S	S

[a] LARS = Long Ashton Research Station.
[b] Race 1 (from Burkina Faso) was virulent on Blackeye, race 2 (from Mali) was virulent on Blackeye and 58-57, and race 3 (from Niger) was virulent on Blackeye, 58-57, and IT81D-994.
[c] S = Susceptible, parasite tubercles ≥2.5 mm in diameter.
[d] R = Resistant, parasite tubercles were <2.5 mm in diameter.
[e] R/S = One cowpea plant was resistant, two were susceptible.
[f] R/S = Two cowpea plants were resistant, one was susceptible.

West Africa. However, a wider genetic base for resistance to *S. gesnerioides* in cowpea is essential, as the resistance of B301 will be useless if race 4 spreads from Benin into Nigeria and Niger, or if new races become prevalent. Cowpea landraces appear to be a good source of new resistance (7). In our study, six of the 11 landraces tested were resistant to one or more races. Many were heterogeneous in their responses to *S. gesnerioides*. However, it has already been shown that resistant cowpea plants can be clonally propagated very easily and homogenous resistant seed produced from a single plant (7). In this way, heterogenous material can be readily exploited to provide new resistance genes for breeding programs. Future screening for resistance should focus on landrace material from West Africa, because resistant germ plasm is probably already well adapted to the agronomic and climatic conditions of the region.

The results presented herein represent the first detailed study of the virulence and distribution for any *Striga* species. In only one other parasitic species, *Orobanche cumana*, has virulence been so precisely defined (11). Knowledge of the sympatric distribution of the races and the existence of a ubiquitous new race, coupled possibly with the need to avoid introducing new parasite races, has several implications for breeding resistant cowpeas. Cowpea genotypes could be assessed most rapidly and accurately against all five races with in vitro tests. However, if resistance is to be evaluated in field trials, multi-location trials are essential within and between countries to encompass all parasite variants. The map of virulence (Fig. 1) could provide a basis for future monitoring of parasite distribution of existing races and possible emergence of new *S. gesnerioides* races. Monitoring parasite virulence will become increasingly important as *Striga*-resistant germ plasm is more widely deployed throughout West Africa.

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