Seed Populations of *Striga* Species in Nigeria

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ABSTRACT

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Seeds of *Striga asiatica*, *S. gesnerioides*, and *S. hermonthica* were separated from soil with a 2.5 M sucrose flotation solution and 250- and 150-μm mesh screens. In 34 fields, the average and range of seeds·100 g^{-1} of soil were 8.2 and 0–75, respectively. Seeds were recovered from 28 of the 34 fields sampled. Eighteen, six, and four fields had 1–5, 6–20, and > 21 seeds·100 g^{-1} of soil, respectively. The maximum number of seeds·100 g^{-1} of soil was 202, collected from one sample site in a field. Emerged *S. asiatica*, *S. gesnerioides*, and *S. hermonthica* were counted from 28 fields, and neither seeds nor plants of *Striga* were counted in two fields. The average number of seeds per plant produced by *S. gesnerioides* was 6.4×10^4, and the average number of seeds per capsule was 604. Seed recovery and plant emergence were correlated ($r = 0.79$) at one site where 29 4 × 10 m plots were assessed.

Striga species, commonly referred to as witchweeds, reduce yields of a variety of crop plants (2,6,10). Three *Striga* species are widespread and destructive in West Africa (6,7,10,11,13). *S. asiatica* (L.) Kuntze and *S. hermonthica* (Del.) Benth. attack maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), pearl millet (*Pennisetum americanum* (L.) Leeke), rice (*Oryza sativa* L.), sugarcane (*Saccharum officinarum* L.), and several wild grasses (5,6,15). *Striga gesnerioides* (Willd.) Vatke parasitizes cowpea (*Vigna unguiculata* (L.) Walp.), tobacco (*Nicotiana tabacum* L.), and other dicotyledonous plants (6,7). In northern Nigeria, where the cropping season is between June and October, the three *Striga* species may occur in the same field because of intercropping of cowpea with millet or sorghum. Crop production in West Africa has been severely limited because of infection caused by *Striga* species (2,5,6,10).

Striga species have persisted and survived as noxious parasitic weeds because of their prolific seed production and their ability to survive in soil over extended periods of time. Plants produce many seeds per capsule, and single plants commonly have several stalks or stems. *S. asiatica* produces $5–50 \times 10^3$ seeds per plant (10,13), and the other species are equally prolific. These seeds can remain viable in soil for up to 11 yr (10,13). The seeds are striated with a double system of ridges and average 200–500 μm in length and 150 μm in width (8).

There are a few reports of seed populations of *Striga* in natural soils (4,12,18). In the United States, an average range of 5.34–12.4 seeds·500 g^{-1} of soil (2.5 seeds·100 g^{-1} of soil) was reported (4). Visser and Wentzel (18) used a series of sieves and sodium chloride to detect seeds of *Alectra* and *Striga* species from soil and reported the technique was over 90% efficient, with a recovery rate of 0–32 seeds·100 g^{-1} of soil. A similar wet-sieving flotation technique has been used to recover propagules of other soilborne pathogens, such as *Sclerotium cepivorum* Berk. (16).

Control methods using catch and trap crops, ethylene, and herbicides (2,4,9–11, 14) have not been widely adopted by subsistence farmers in West Africa, partially because of the lack of funds to purchase chemicals and/or the lack of efficacy of cultural practices. Research on control of *Striga* has been focused on the development of crops with resistance to the parasite (6,9,17).

The objectives of our study were to: 1) develop an easy technique to quantify seeds of *Striga* from soil, 2) conduct a survey to determine the occurrence of *Striga* species, and 3) estimate the number of seeds produced by plants of *S. gesnerioides*.

MATERIALS AND METHODS

Accuracy of recovery method. In March 1988, soil was sampled from fields infested with *Striga* species located in Kaduna and Mokwa, Nigeria. Soil samples were also collected from a noninfested field at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Sample sites, where soil was collected with a shovel to a depth of 10–20 cm, were distributed randomly at four locations within each field. The four samples were pooled, mixed, and air-dried before being used to evaluate techniques for isolating seeds of *Striga* species. To test the accuracy of the isolation techniques, we added 10 seeds of *S. hermonthica* per 25 g of the "clean" soil collected from a noninfested field at Ibadan.

Ten 25-g subsamples of soil infested with 10 seeds of *S. hermonthica* were placed on a 250-μm mesh screen underlaid with 150- and 43-μm mesh screens and washed with running tap water. The debris retained on the three sets of screens was backwashed onto 15-cm filter paper in a 15-cm culture plate. The excess water

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was evaporated and the debris observed under a stereomicroscope (×312).

Sucrose solutions, from 0.5 to 3.5 M in increments of 0.5 M, and a water control were mixed with 25 g of soil infested with 10 seeds of *S. hermonthica*. Then, 50 ml of each flotation solution and the water control were stirred with a magnetic stirrer for 15 min and allowed to settle for 1–2 hr. The floating organic debris was decanted onto filter paper or onto a 250-μm mesh screen with a 150-μm mesh screen below. The debris from the 150-μm mesh screen was backwashed onto a 15-cm filter in a funnel, the excess water was drained off, and the debris that remained on the filter paper was observed under a stereomicroscope. There were four replications for each sucrose concentration, and the experiment was repeated once.

The 2.5 M flotation solution was used along with the sieving-observation procedure to examine the effect of stirring time (5-min intervals from 0–25 min) on seed recovery and to determine the number of seeds in each of 15 subsamples from Kaduna and Mokwa soils.

Survey. Soil samples taken in a diamond-shaped pattern from four sites within each field were collected to a depth of 10 cm using a 2.5-cm-diameter soil probe. Four or five probes from each corner of the pattern were pooled to make four samples from each field. Soil was collected from 34 fields from the northeastern to northwestern cropping regions of Nigeria. The distance from east to west was about 900 km, with a north-to-south range of 200 km. The approximate center of the elliptical area was 100 km southeast of Kano, Nigeria. The primary crops in the fields sampled were millet and sorghum intercropped with cowpeas. The crops in most fields were in the late reproductive growth stages, and in a few fields, the crops had recently been harvested. All samples were collected during the last week of September 1988. Thirty-three of the 34 fields sampled were typical small-scale farmers' fields of less than 1 ha. Each sampled field was between 50 and 100 km apart. The collected soil was air-dried, and seeds for each sample were extracted by the sieve-flotation method using 2.5 M sucrose and 250- and 150-μm mesh screens as described previously. The number of seeds recovered from each 25-g soil sample was multiplied by four to report the number of seeds·100 g^{-1} of soil in each field.

The population of *Striga* from each field was visually estimated by using the following plant density index: 1 = no plants emerged, 2 = 1 or 2 plants per m^2, 3 = 3–5 plants per m^2, 4 = 6–10 plants per m^2, and 5 = > 10 plants per m^2. Populations of *S. gesnerioides* were differentiated from those of *S. aziatica* and *S. hermonthica*. Whole plants of *S. gesnerioides* were dug and removed from 16 fields, and the number of stems and capsules for each plant was recorded. Three capsules randomly selected from each plant were opened, and the seeds were teased out onto filter paper with 1-cm grid markings for counting. The number of seeds per plant was estimated by multiplying the number of capsules on a plant by the average number of seeds from three capsules.

At one location (Minjiberi, Nigeria), an experimental field of cowpea in the late reproductive growth stages, populations of emerged *S. gesnerioides* were counted and soil samples from 29 4 × 10 m plots were collected. Three randomly sampled soil cores collected to a depth of 10 cm with a 2.5-cm-diameter probe were pooled per plot. The soil was assayed for seeds with the sieve-flotation method described previously. These data were used to determine the relationship of seed density to plant population.

The number of seeds recovered from each 25-g soil sample was multiplied by four to report the number of seeds·100 g^{-1} of soil. Data were analyzed where appropriate by analysis of variance; counts of seed recovery from Minjiberi were compared with plant emergence after converting the data to $\log_{10}$ to stabilize sample variances.

RESULTS

Accuracy of recovery method. The percentage of seeds recovered from infested soil by the wet-sieving method alone averaged 3%, with a range of 0–10%. Seeds were only observed on the 150-μm mesh screen but were difficult to detect because of abundant organic matter. With flotation without sucrose, 0–20% of the seeds were detected. With the different molarities of sucrose and two screen sizes, however, the recovery of seed increased up to 92% as the concentration of sucrose increased (Fig. 1). Seeds were easily differentiated from organic debris under a stereomicroscope (Fig. 2). The difference in seed recovered between sucrose concentrations of 2.0 and 3.5 M was not statistically significant. Stirring time increased the recovery of seeds from 61% without stirring to 77, 88, and 97% for 5, 10, and 15 min, respectively, of stirring. Differences between stir times of 15–25 min were not significant. Seeds recovered from naturally infested soil collected at Kaduna averaged 9.1·100 g^{-1} of soil, with a range of 4–18 and a standard deviation of 4.9. Seeds recovered from Mokwa soil averaged 3·100 g^{-1} of soil, with a range 1–8 and a standard deviation of 2.1.

Survey. Seeds recovered from fields averaged 8.2·100 g^{-1} of soil, with a range of 0–75. Seeds were recovered in 28 of the 34 fields sampled: 18 fields had 1–5·100 g^{-1} of soil, six fields had 6–20·100 g^{-1} of soil, and four had over 21·100 g^{-1} of soil. The maximum number of seeds recovered from one sample site in a field was 202·100 g^{-1} of soil.

Striga species were found in 28 fields, 19 with *S. gesnerioides* and 21 with *S.*

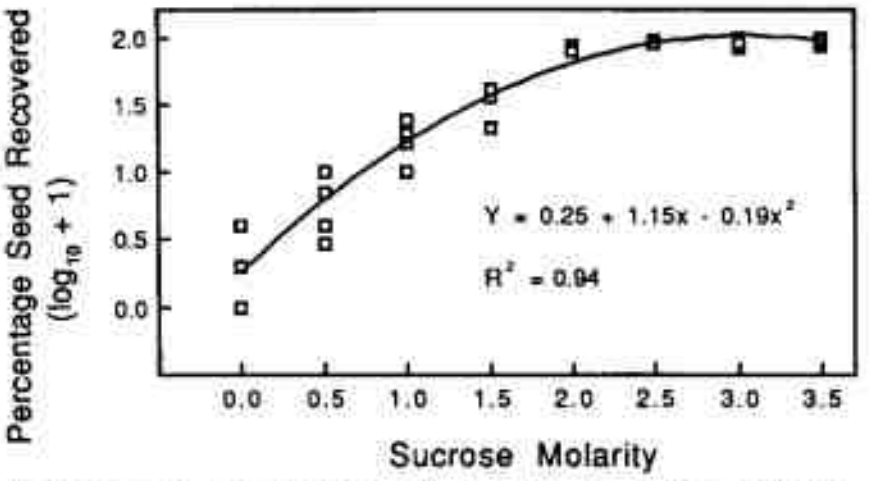

Fig. 1. The percentage of seeds of *Striga hermonthica* recovered on a 150-μm mesh screen from infested soil by using a range of sucrose concentrations and sieving the supernatant through a 250-μm mesh screen.

Fig. 2. Seeds of *Striga* species (arrows) mixed with organic debris on filter paper after isolation from soil. Scale bar = 0.5 mm.

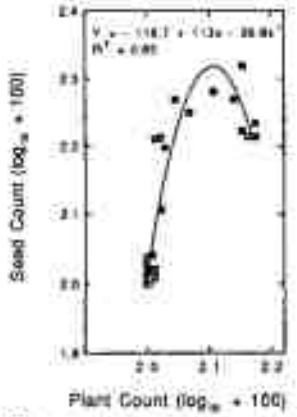

Fig. 3. Relationship of seed counts isolated from soil to plant counts of *Striga gesnerioides* at Minjiberi, Nigeria.

asiatica and *S. hermonthica*. Neither plants nor seeds were found in two fields. The average plant density index over all fields was 2.6 for *S. gesnerioides* and 2.9 for *S. asiatica* and *S. hermonthica*. In general, as the plant density index increased, the number of seeds recovered increased. The three fields with the highest population of seeds recovered—30, 54, and 75·100 g^{-1} of soil—had plant density indices of 4, 3.5, and 5, respectively.

Mature *S. gesnerioides* produced an average of 6.4 × 10^4 seeds per plant (range 2.7–18.1 × 10^4). The number of capsules per stem averaged 11.9 (range 28), the number of stems per plant averaged 10.3 (range 6–22), and the number of seeds per capsule averaged 604 (range 276–919).

At Minjiberi, plant emergence counts correlated significantly ($r = 0.79$; $P < 0.05$) with recovery of seeds from soil (Fig. 3). The number of seeds recovered from soil averaged 11.3 (range 0–45), and plant populations averaged 37.8 per 4 × 10 m plot (range 0–108). Seeds were recovered from 72% of the plots, and plants were counted in 88% of the plots. Neither seeds nor plants were recorded from 9% of the plots.

DISCUSSION

Other methods to quantify seeds of *Striga* from soil have used centrifugation or sodium chloride in combination with sieves (4,12,18). In our study, we found a 2.5 M sucrose solution and a series of sieves to be an efficient, simple means to quantify seeds. This method required few inputs and may be adapted for use where equipment is limited. The sets of screens were necessary for efficient isolation, but the use of a magnetic stirrer could be replaced by hand-shaking the soil solution in a sealed container or stirring manually. The soil solution separated into inorganic and organic fractions when mixed with a sucrose solution. We noticed that soils with a higher percentage of sand required less time for seed quantification because of the reduced organic debris mixed with the seeds. In our tests, the level of seed infestation in Nigeria was greater than in other areas where seeds have been quantified from soil (4,18).

Ashworth (1) quantified seeds of *Orobanche ramosa* L. in soil and suggested that seed population was a more reliable index of infestation than plant population. From our study, both plant and seed populations were useful to determine the infestation. In a few fields in our surveys, seeds were recovered where plants were not observed and, conversely, plants were counted without seed being recovered from soil. For accurate assessments, both types of counts are necessary, because soil sampling alone is not always accurate and because plant populations vary according to emergence, time of year, and weeding patterns. Surveys based on plant populations alone may often underestimate the incidence and severity of an infestation of *Striga*. Emergence and seed counts must be monitored several times during a season if the dynamics of populations over time are to be understood. Seed counts from soil can be done anytime during the year, whereas plant counts are seasonal and highly variable. One drawback of this seed isolation technique is that it does not record the viability of the seed. In our studies, however, all recovered seeds appeared healthy, without cracked coats or signs of degradation. Bebawi et al (3) showed that seed age, size, and weight influenced viability and germination, these factors could be tested once the seeds were isolated.

Research on the control of *Striga* in Africa has concentrated on utilizing resistance. Various screening protocols have been developed for this purpose (17), but few are based on defined soil populations, so that the uniformity in seed density and distribution within the field and from one site to the next may vary. Differences in strain and population levels are likely to play a major role in assessment of resistance.

The applications of enumerating seeds from soil would be to monitor the population over time and to better understand the relationship between seed numbers to disease incidence and severity. Also, the effects of fertilizer, cropping and tillage patterns, and resistant genotypes on seed populations could be monitored. There are no reports on the spatial distribution of seeds in soil, and there is a lack of understanding of how seeds of *Striga* are dispersed within a field and how seeds might spread from field to field under conditions in West Africa. To improve productivity in many West African agricultural regions, and also in other areas where *Striga* species are endemic, an effort must be made to understand the population dynamics of seeds of *Striga* and to develop effective control tactics.

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