BREEDING SORGHUM GENOTYPES WITH RESISTANCE TO *STRIGA ASIATICA* AT THE ICRISAT CENTER

M.J. Vasudeva Rao, V.L. Chidley, K.V. Ramaiah, and L.R. House

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SORGHUM IMPROVEMENT PROGRAM

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT Patancheru P.O.

Andhra Pradesh, India 502 324

Breeding Sorghum Genotypes with Resistance to *Striga asiatica* at the ICRISAT Center[1]

M.J. Vasudeva Rao, V.L. Chidley, K.V. Ramaiah, and L.R. House[2]

Striga, a root parasite of grasses, is recognized as a serious problem of the sorghum crop in several countries. Losses due to *Striga hermonthica* have assumed economic proportions on sorghum and millets in many African countries. *S. asiatica* which is more widespread than *S. hermonthica* has been identified as an important problem in Southern Africa, in part of the US and is recognized as an increasingly serious problem of sorghum in the low fertility soils of SAT India. Genetic resistance in sorghum to *Striga* is recognized as the most economic way to combat this problem. In this paper, an attempt has been made to describe the *Striga* resistance breeding activities at the ICRISAT Center and explain the developments on the screening methodology.

SCREENING FOR LOW STIMULANT PRODUCTION

Germplasm Screening

ICRISAT *Striga* resistance breeding work has the twin objectives of identifying *Striga* resistant sources and transferring the resistance into good agronomic backgrounds During the initial years, it was identified that *Striga*

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2 Plant Breeder, Research Technician, Cereals Breeder-*Striga* (ICRISAT, Upper Volta), and Leader, Sorghum Improvement Program, respectively, International Crops Research Institute for the Semi-Arid Tropics, ICRISAT Patancheru P.O., Andhra Pradesh 502324, India.

resistance in sorghum was a function of three independent mechanisms: 1) low stimulant production by the host roots, 2) mechanical barriers to the establishment of Striga, and 3) antibiosis factors (Doggett 1970). Field resistance is the total effect of one or more of these mechanisms. The initial task was to screen the germplasm for low stimulant producing lines and use them in breeding to incorporate this character into elite lines. To date more than 14,000 germplasm lines have been screened against the S. asiatica isolate of Patancheru and a set of 640 lines have been identified as low-stimulant producers.

Field Resistance of Low-Stimulant Lines

Laboratory screening to identify low-stimulant lines will be useful as a screening method only if the low-stimulant lines are less parasitized by Striga in the field. Therefore, to test the relationship between low-stimulant production and field resistance to S. asiatica, multilocational studies were undertaken by growing sets of low stimulant lines in Striga "sick" fields. Table 1 shows the number of low stimulant lines screened in multilocation testing and the number of lines selected for field resistance. The percentage of lines that were field resistants varied with year and location. The highest percentage of field resistants in low stimulant lines was from Phaltan during the 1979 rainy season. However, the lowest percentage was again from Phaltan during the 1980 rainy season. Therefore, the results indicate that not all low-stimulant lines are field resistant. In the field screening of advanced-generation breeding lines derived from Striga resistant x adapted crosses (Table 3), where both low and high stimulant lines were involved, similar results were obtained. By further refinement of the laboratory screening technique and the field screening procedures, it may be possible to improve the correlation between the low-stimulant production and field resistance.

Stimulant Production in Field Resistant Lines

During the 1980 rainy season, a set of 156 advance generation progenies derived from *Striga* resistant sources x adapted line crosses was studied for field reaction to *S. asiatica* in three trials at different locations. Twenty three advance-generation progenies were found to be field resistant at two to four locations (Table 2). When these lines were screened for stimulant production in the laboratory, 18 of the 23 resistant lines turned out to be low-stimulant producers. All the entries in these trials were screened for stimulant production against the *S. asiatica* seeds from Patancheru. Entries were reclassified based on the stimulant production and the proportion of field resistants in each category was verified (Table 3). Without exception, in all three trials at all locations, the proportions of field resistants in the low stimulant category was higher than the proportions of field resistants in the high stimulant category. It is of interest to note that all the derivatives are obtained from low and high stimulant crosses. However, in the process of selection for field resistance, a higher proportion of low-stimulant derivatives are turning out to be field resistant. Thus, the results suggested that low stimulant production screening could be a valuable adjunct in a *Striga* resistance breeding program. If the material is screened for low-stimulant production at least once during the process of selection, the chances of obtaining field resistance in the end product appear to be better. However, these preliminary results need confirmation.

Genetics of Stimulant Production in Sorghum

A seven-parent diallel set involving two low-stimulant field resistant types (SRN-4841 and IS-2221), three high stimulant field resistant types (N-13, NJ-1515 and IS-9985) and two high stimulant susceptible types (2219B and CK60B) were studied for the level of stimulant production needed to germinate the Patancheru isolate of S. asiatica. There was a preponderence of additive genetic variance compared to the non-additive genetic variance (Table 4) indicating the usefulness of straight selection for low-stimulant production. IS-2221 which is a low-stimulant field resistant type was also a good negative general combiner for low-stimulant production (Table 5) and was a good parent for use in breeding programs to incorporate this character.

BREEDING SORGHUMS FOR FIELD RESISTANCE TO STRIGA

ICRISAT Striga resistance breeding work at the main center has the objectives to identify source lines of sorghum resistant to S. asiatica and transfer the resistance into good agronomic backgrounds.

Identification of Sources

Multilocation field experiments were conducted since the 1977 rainy season to identify sources of resistance to Striga. Source lines reported to be resistant to the local strains of Striga have been assembled into source trials and field-tested in multilocation testing. Till todate, a total of 166 lines have been screened. The field reactions of selected resistant source lines against *S. asiatica* during the rainy seasons of 1977 to 1980 are given in Table 6. This List includes those promising lines which have been repeatedly tested and their resistance has been reasonably stable. It is clear from these data that there does not appear to exist any absolute resistance to *S. asiatica* in sorghum and the best available sources are low susceptibles to *S. asiatica*. Among the lines screened so far, N-13, 555, 16-3-4, Serena, IS-2203, IS-4202, IS-7471 and IS-9985 appear to be promising in breeding programs as low susceptible source lines of *S. asiatica*.

Transfer of Resistance to Elite Backgrounds

Efforts have been made in the past to incorporate *Striga* resistance into agronomically good backgrounds. Several hundred crosses have been made over the past few years between different resistant sources and agronomically elite and adapted stocks. Figure 1 indicate the flow of material for screening for field resistance to *Striga*. Absence of a valid screening technique to identify individual plants in segregating progenies resistant to *Striga* in the field constitutes a major hurdle even today for any predictable progress for *Striga* resistance. However, with the identification of a screening methodology to locate resistance in advanced generation lines, some progress may be possible. The segregating material has been advanced in *Striga* sick fields and selected for low levels of susceptibility.

Selection has been generally to correct the undesirable traits in the original source lines retaining Striga resistance in them so that they could be used as good breeding stocks. In this process of selection, many of the source lines have been eliminated since they do not offer any good segregates. One parent, 555, a resistant source line has been a parent in a number of useful advanced lines.

SCREENING METHODOLOGY FOR STRIGA RESISTANCE BREEDING

Research efforts to incorporate Striga resistance into an agronomically elite background in the past indicate that several problems exist in Striga resistance breeding. In the ensuing part, an attempt is made to analyse the existing systems of screening methodology and some improved screening methodologies are considered.

Existing Screening Systems

The recognition and influence of the host roots on the parasite occur during three stages of the parasite development, viz., Striga seed germination, Striga haustorial establishment, and the final growth and establishment of Striga plant. Three mechanisms have been recorded, viz., low stimulant production, mechanical barriers to haustorial establishment and antibiosis factors, which confer resistance to sorghum roots against the parasitization of Striga (Doggett 1970). Field resistance to Striga is the combined effect of all the individual mechanisms. Therefore, field techniques screen the host lines for the final manifestation of the individual mechanisms while the laboratory techniques screen for one or more mechanisms, either individually or in combination.

Laboratory techniques. Several laboratory screening techniques are available like the double pot technique, Pasteur pipette technique, root slope technique, sandwich techniques, anti-haustorial factor screening etc. Laboratory techniques have several advantages. They are easy, fairly streamlined and standardized, least dependent on the environmental conditions, fairly quick and repeatable. However, they have been frequently commented upon for their lack of usefulness as screening techniques in breeding for field resistance to *Striga*. This lacuna arises from the basic fact that the field resistance to *Striga* cannot be explained by any one mechanism and secondly, that there are strong environmental interactions influencing the field results that are not allowed to act in laboratory techniques.

Pot screening techniques. Generally, pot screening involves growing the host in pots of different dimensions artificially inoculated with *Striga* seeds. The *Striga* reaction of the host is judged by quantifying the *Striga* that emerge above the ground. Pot tests as a screening technique in a *Striga* resistance breeding program could be very useful since the *Striga* infestation in pot tests is more definite than in artificially infested sick fields, where it is yet unreliable.

Field screening techniques. Growing the sorghum lines in a field which is naturally or artificially infested with *Striga* and screening for field resistance has been a very common and useful technique. Field screening is often not useful due to unreliable and ununiform Striga infestation.

Efficiency Requirements of the Screening Technique

The efficiency requirements expected of the screening technique depend on the kind of material and the statistical accuracy required. The kinds of material which usually form part of a Striga resistance breeding program are:

i) resistant source materials,

ii) segregating progenies, usually from crosses between Striga resistant and adapted high yielding but susceptible varieties, and

iii) advanced generation lines.

In the cases of resistant source material and advanced generation lines, the material is available in the form of an established land race or a farmer's cultivar or an advanced generation homozygous progeny. The screening efficiency has to be highest in this case and, if available, the test must be able to identify absolute resistance. The testing has to be carried out on a replicated basis in this case. Among the segregating progenies F_2 has to be treated on an individual plant basis while from F_3 onwards, they could be treated on a family basis though single plant screening would still be advisable. Even the presence of one susceptible plant in a segregating progeny, could vitiate the observation on other resistant plants.

However, in a practical Striga resistance breeding program, a balance has to be struck between several factors like the area of Striga sick field, availability of seed material, efficiency requirements etc.

The Seed Pan Technique

At ICRISAT, a seed pan technique is under development. The procedure involves growing of the test material in a shallow concave seed pan containing a soil medium. The shape and size of the pan are important. The pan measures approximately 35 cm in top diameter, 15 cm in bottom diameter and a height of 15 cm. These dimensions accommodate about 2½ kg of a mixture of sand and clay soil. This specific shape of the pan concentrates the host roots and thus favors a higher proportion of the Striga establishment. A 1:1 mixture of sand and clay soil has been found to provide optimum conditions for the growth of Striga. Striga seed has to be pre-tested in the laboratory for its germination before planting and planted 10 to 15 days preceeding the planting of the test material so as to condition the Striga seeds before they come in contact with the host roots. The pan must be kept watered till it is planted. Striga seeds are recommended to be sown at the rate of 100 mg per pan which would be approximately 20,000 Striga seeds. To obtain uniform infestation across pans, it is useful to mix the Striga seeds required for all the pans with soil required for all pans in one lot and distribute to the pans equally based on soil weight.

Two alternatives are available with this technique for measuring the Striga reaction of the test entry. It is possible to uproot the plant at about 50 days after sowing and count the subterranian Striga initials or the host may be allowed to grow further and the Striga could be counted after they emerge above the soil surface.

It may often be required that the host being tested for Striga resistance, be continued to maturity. In such cases, the soil in the seed pan is insufficient. A wooden flat with the dimensions of 60 x 60 x 15 cm has been found useful instead of a seed pan. The other procedure is same as in the seed pan.

A few experiments have been conducted using both seed pan and wooden flats for verifying usefulness of these techniques. The experiments generally have indicated that this technique is useful. Two experiments are described below.

Experiment 1: Comparison between resistant and susceptible cultivars in seed pans. Two susceptibles, CSH-1 (hybrid) and Swarna (variety), and a resistant variety N-13, were compared using the seed pan technique. Subterranian *Striga* initials were counted starting from 20 days after sowing till 50 days in replicated samples to determine the optimum number of days for taking observations using this technique. Comparisons were made over four normal sorghum growing seasons at ICRISAT Center, Patancheru with at least six replications for each observation. The mean subterranian *Striga* counts of the three varieties are given in Table 7 and Figure 2. The experiments were independently analysed using the split plot technique with days to observations as main plot and varieties as subplots. Highly significant differences were observed between the varieties in all the seasons (Table 8). Variation between replications (pans) was nonsignificant in all the seasons. Table 7 and Figure 2 indicated that rainy and summer seasons are the best seasons for conducting the experiments with seed pans for differentiating resistant and susceptible varieties. In postrainy season the differences, though statistically significant, were not pronounced probably due to the low temperatures prevailing during the period of *Striga* establishment.

Experiment 2: Comparison of 25 sorghum lines in seed pans. Another experiment was conducted using 21 resistant sorghum lines and four susceptible sorghum lines during summer 1981 in a randomized block design with four replications to observe the differences between the varieties for Striga reaction. Significant differences were observed between test entries for the 55 day-counts of the subterranian Striga (Figure 3). The resistant and susceptible groups differed significantly from each other.

Improved Field Screening Methodology

Field screening is often unreliable due to ununiform Striga infestation. The common problems in field screening are:

i) unreliable occurrence of Striga over years in the same field,

ii) absence of any control on levels of infestation,

iii) ununiform Striga distribution in the field,

iv) significant environmental influence on Striga infestation, and

v) high CV's in the experiments, making the conclusions unreliable.

At ICRISAT, an improved system of testing for field resistance to Striga is under development and test. Basically, this involves a three-stage testing procedure.

Observation nursery. This stage consists of an unreplicated trial of a large number of test entries with a frequently replicated susceptible check. Test entries may be grown in two row plots and Striga observed in between the two rows. Any augmented design may be followed for yield observations, while, for Striga resistance, lines may be rejected based on the presence of Striga.

Preliminary screening. This is the second stage of testing and includes those nursery entries which were agronomically good and on which *Striga* was low or did not appear in the first stage. The entries are tested in 3 row plots and they are replicated at least thrice with a systematic check which is arranged in such a way that every test plot will have one check plot adjacent to it (Fig. 4). The existing system of data interpretation from multilocation preliminary screening has been to obtain the *Striga* reaction of the test entry as a percent of the adjacent systematic check to adjust for ununiformity in the field and then average over replications. However, the CV's in the experiment are still high. Therefore, the interpretation of data from the existing system of preliminary screening for field resistance has been modified to include the following set of criteria:

i) High *Striga* counts in the checks - comparison valid ii) Test entry *Striga* reactions less than 10% of the adjacent check	) Test entries selected

iii) Test entry selected in all the replications in a location

iv) Test entry selected across locations

v) No averages to be used.

Based on the above criteria, test entries can be classified into six classes of *Striga* reactions. They are:

		Reaction	Symbols
i)	Confirmed Resistant	(R)	√
ii)	Confirmed Susceptible	(S)	x
iii)	Check Low, therefore, comparison not reliable	(NR)	NR
iv)	Resistant, Susceptible	(R/S)	√/x
v)	Resistant, Not Reliable	(R/NR)	√/NR
vi)	Susceptible, Not Reliable	(S/NR)	x/NR

The confirmed resistants are those which have less than 10% *Striga* count of the adjacent check when the comparison is valid (high *Striga* count in the check). Further, selected entries show a valid resistance reaction across all replications and locations. The confirmed susceptibles are those which have shown more than 10% of the check. This group also includes those which are infested irrespective of the infestation in the check. The third category comprises those entries where the comparison was not valid since the check had low *Striga* counts. Resistant/Susceptible category includes those which are showing resistant and susceptible reaction across replications or locations. Resistant/Susceptible reaction across locations may be an indication of *Striga* strain differences. The last two categories are again those which are showing different combinations of the first three categories of reactions. The above six classes give a set of valid criteria for evaluating *Striga* resistance. It is proposed to call this system of data interpretation in the preliminary screening stage as that based on single unit comparison. We have analysed two years of trial data across locations and the results are encouraging.

To test the relative merits of the two selection criteria, the Striga reaction data on a common set of 28 breeding lines from the preliminary trial-2 conducted at Akola during 1979 and 1980 rainy seasons was chosen. The Striga reactions were computed first based on the Striga counts as percent of the systematic check averaged over replications and then based on the single unit comparison (Table 9). Based on the averaged counts, out of the 24 lines which were resistant in 1979, only eight remained resistant in 1980 and the number in the 'breakdown' class was ver high (17) (Table 10). Based on the single unit comparison, out of the 18 entries which were resistant in 1979, 11 remained resistant in 1980 and nearly 60% entries were retained as resistant in both years. Therefore, the new set of selection criteria based on single unit comparisons of the test entry Striga reaction with its adjacent systematic check and not base on averages, appear to be efficient in identifying field resistance to Striga.

Advance screening. This is the final stage of testing in which the confirmed resistant entries from family screening will be tested in large plots with a susceptible check plot all around the test entry. Figure 5 represents the field layout for such a trial. Each plot would be at least a 5 row plot so that yield estimates and Striga reaction could be obtaine from fairly reliable plot sizes. The entire trial has to be covered on all four sides with a strip of the susceptible check plots as shown in Figure 5. For want of a name, we have called this type of field layout as chess-board layout. The layout could be useful in screening the Striga resistant sources and advanced generation lines which require higher precision and wherein it should be possible for us to have reliable estimates of yield. It is possible to use statistical designs in this layout. The test entry *Striga* reaction could be adjusted by using the *Striga* reactions of four adjacent check plots as a covariate. Further, this layout is likely to avoid creating nonuniformity of *Striga* infestation because of differences in the susceptibility among the previous season genotypes in those plots. Advance screening stage was identified only recently. Therefore, the usefulness of the layout and designs is yet to be confirmed.

STRAIN SITUATION IN *STRIGA* ASIATICA

Striga asiatica exhibits variability in plant structure and flower color. It is also very widely distributed. Apart from apparent morphological variability, *Striga* as a genus appear to possess intrinsic physiological differentiation leading to the existence of physiological strains. Reports on the existence of strains in *S. hermonthica* are available (King and Zummo 1977, ICRISAT 1980). However, in *S. asiatica*, such information is not available. Preliminary observations indicate that there are morphological variants, and different species coexist together as a polymorphic *Striga* complex. Variation in *Striga* plants has been observed in the leaf form, branching habits, presence of roots, seed characters and bract shape. *S. asiatica* and *S. densiflora* coexist in regions in India where both rainy and postrainy sorghums are grown. Preliminary observations indicate that postrainy environment favors *S. densiflora* while *S. asiatica* comes up in both environments. In North West India, *Striga* attacks millets and not sorghum while in other regions, *Striga* attacks sorghum, sugarcane, maize and some minor millets and not pearl millets. Recently, it was observed that Striga noticed on maize and sorghum in adjacent fields near Hyderabad were morphologically different. An experiment was carried out in the 1981 rainy season with *S. asiatica* collected from five different locations in India and their effect was studied on three resistant and one susceptible varieties utilizing the wooden flat technique. The 75-day Striga counts on these lines is expressed as percent of the significant differences among varieties (Table 11 and Fig. 6). N-13 and IS-5106 were found resistant at all locations while SRN-4882B was found resistant at three and susceptible at two locations. Analysis of variance (Table 12) indicated that there were significant strain x variety interactions indicating that varieties react differentially to Striga collected from different locations. However, existence of varieties which offer stable resistance across locations is a useful indication.

PRIORITIES IN STRIGA RESEARCH FOR FUTURE

Following are some of the priority areas in research on Striga:

Host-Parasite Relationships

Three mechanisms of resistance have been identified. Significant progress has been made in understanding the nature, action and artificial synthesis and use of stimulants. An array of lines with low-stimulant production have been identified. However, very little has been understood about the mechanical and chemical barriers that hinder the parasite establishment. Understanding the distribution of these two mechanisms in the sorghum lines and their interaction with other mechanisms would greatly assist breeding.

Environmental Interactions Influencing *Striga*

Quantified information on the influences of various environmental factors on *Striga* infestation is conspicuously lacking. This information would be useful in two ways: (i) To increase the *Striga* infestation by simulating these factors in *Striga* sick fields for screening purposes, and (ii) to avoid the occurrence of these factors while formulating cultural management practices to reduce a *Striga* attack as a part of the agronomic package to control *Striga*.

Screening Methodology

Intensive research is required on developing new screening methods especially to screen single plants for host plant resistance to *Striga*. Research efforts are also required on the field screening procedures to effectively identify resistant material with more confidence.

Management of *Striga* Sick Field

Striga sick fields are a very useful tool for screening sorghums for *Striga* resistance. However, we do not have any information on how to manage the sick field. Studies on the most favorable environmental parameters would be helpful in simulating the same in *Striga* sick fields for getting uniformly graded levels of *Striga* infestations in the sick field.

Species and Race Complexes

Initial studies on *S. asiatica* collected from five different locations in India indicate quantitative differences in infestation levels. It is suspected that the distribution of *Striga* species follow specific environmental patterns. Morphological variations have also been noticed in the native *Striga* complexes. Studies are required to understand the pollination systems, natural crossing and different types of *Striga*, be it morphological or physiological, so that the breeding for *Striga* resistance could be more meaningful.

SUMMARY

An attempt has been made in this paper to describe the *Striga* resistance breeding work in sorghum at ICRISAT and enumerate the progress so far. Fourteen thousand sorghum germplasm lines have been screened in the laboratory for their stimulant production and a set of 640 low stimulant lines have been identified. Verification of the field resistance of low stimulant lines indicated that not all low stimulant lines are field resistant. However, the process of selection for field resistance resulted in higher proportion of field resistants in the low stimulant than in high stimulant category. Studies on genetics of stimulant production indicated that there was a preponderance of additive compared to non-additive genetic variance. The field resistance reaction of suspected resistant source lines in multilocation testing during 1977 to 1980 suggested that the best available low susceptible source lines to *S. asiatica* are N-13, 555, 16-3-4, Serena, IS-2203, IS-4202, IS-7471 and IS-9985. The seed pan technique,

which is under development at ICRISAT for the purpose of differentiating resistant and susceptible lines has been described. Results of two experiments comparing resistant and susceptible sorghum lines using seed pan technique.indicated the usefulness of this technique. An improved system of testing for field resistance to Striga, which involves a three-stage screening procedure, is under development at ICRISAT. Initial studies on Striga collected from five different locations in India and four varieties indicated that there was significant strain x variety interactions and SRN-4882B gave differential reaction. Intensive studies on host-parasite relationships, environmental interactions influencing Striga, screening methodology, guidelines to manage Striga sick fields and surveys to understand species and race complexes have been projected as some of the priority areas of Striga research to make breeding for Striga resistance more effective.

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Table 1. Field resistance of low stimulant lines from germplasm

Year	Location	No. of Lines Tested	No. of Lines* Resistant	Resistant Lines (%)
1978K	Patancheru	79	21	28%
1979K	Bhavanisagar	196	18	9%
	Phaltan	392	276	70%
1980K	Akola	80	26	32%
	Phaltan	80	4	5%

* Striga resistance classification: 1978 - based on Striga counts percent of systematic check averaged over replications, 1979 and 1980 - based on single unit comparisons of Striga counts in test entry and its adjacent systematic check.

Table 2. Stimulant production and field reaction of the best advance generation progenies (kharif 1980) (1980 Rainy Season)

Origin	Pedigree	St. Prod. of Derivative (Patancheru)	St. Prod. of Parents 1	St. Prod. of Parents 2	Field Reaction to *Striga asiatica** Akola	Bhavanisagar	Hayatnagar	Phaltan	Patancheru
1/4	(555 x 168)-23-2-2-2	-	-	+	√	√	√	√	NT
1/6	(148 x 555)-19-2-1	-	+	-	x	√	√	√	NT
1/8	(555 x 168)-1-1	-	-	+	√	x	√	√	NT
1/9	(148 x 555)-bk	-	+	-	√	x	√	√	NT
1/15	(555 x 168)-23-1-5-2	+	-	+	√	x	√	√	NT
1/16	(KD-22-10 x 148)-bk	-	+	+	√	x	√	√	NT
1/21	(555 x 168)-23-1-bk	-	-	+	√	x	√	√	NT
1/37	(IS-2643 x 555)-2-1	-	-	-	√	√	√	√	NT
2/1	(555 x 168)-23-1-1	-	-	+	√	x	NT	√	√
2/3	(148 x 555)-1-2	+	+	-	√	√	NT	x	√
2/5	(148 x 555)-33-1-3	-	+	-	√	√	NT	√	√
2/7	(555 x 168)-16	-	-	+	√	√	NT	x	√
2/14	(Framida x 168)-9-2-3	-	-	+	√	√	NT	x	√
31/1	(SRN-4841 x SPV-104)-3	-	-	+	√	√	NT	√	NT
31/2	[SRN-4841 x (WABC x P-3)-2]-11-2	+	-	+	√	x	NT	√	NT
31/4	[SRN-4841 x (WABC x P-3)-3]-7-3	-	-	+	√	x	NT	√	NT
31/17	(555 x CS-3687)-8-1	-	-	+	√	√	NT	√	NT
31/19	(555 x EC-64734)-3	+	-	+	√	√	NT	√	NT
31/21	[555 x (PD x CS-3541)-29-3]-4-2-1	-	-	+	√	√	NT	√	NT
31/22	[555 x (PD x CS-3541)-29-3]-5-2-1	-	-	+	√	√	NT	√	NT
31/30	(IS-7227 x E35-1)-15-2	-	-	+	√	√	NT	√	NT
31/31	(IS-7227 x E35-1)-19-2	-	-	+	√	√	NT	√	NT
31/59	(IS-2203 x SPV-105)-3-2	+	+	+	√	√	NT	√	NT
		18- · 5+							

√ = Test entry *Striga* reaction less than 10% of CSH-1
x = Test entry *Striga* reaction more than 10% of CSH-1
NT = Not tested.

Table 3. Role of low stimulant production in field resistance to Striga

Trial	Stimulant Production	No. of Lines Tested	Number of Lines Resistant											
			Akola		Bhavani-sagar		Phaltan		Hayatnagar		Patancheru		Across Locations	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	Low	14	9	64.3	6	42.8	7	50.0	8	57.1	-	-	7	50.0
	High	34	10	29.4	1	2.9	7	20.6	4	11.8	-	-	1	2.9
	Total:	48	19	39.6	7	14.6	14	29.2	12	25.0	-	-	8	16.6
2	Low	23	13	56.5	9	39.1	6	26.1	-	-	10	43.4	4	17.4
	High	8	3	37.5	3	37.5	0	0.0	-	-	2	25.0	1	12.5
	Total:	31	16	51.6	12	38.7	6	19.4	-	-	12	38.7	5	16.1
3-1	Low (<10%)	34	21	61.7	10	29.4	22	64.7	-	-	-	-	8	23.5
	High (>10%)	43	16	37.2	7	16.3	17	39.5	-	-	-	-	2	4.6
	Total:	77	37	48.0	17	22.1	39	50.6	-	-	-	-	10	12.9

Table 4. Analysis of variance for combining ability for stimulant production

Source of Variation	D.F.	Mean Square
GCA	6	2038.38**
SCA	21	1579.64**
Error	54	110.79

Table 5. GCA effects of the parents

S.No.	Parent	GCA Effect
1	SRN-4841	13.57**
2	IS-2221	-26.03**
3	N-13	4.91
4	NJ-1515	1.45
5	IS-9985	1.66
6	2219B	17.35**
7	CK60B	-12.92**

S.E. $(\hat{g}_i)$ = 3.25
S.E. $(\hat{g}_i-\hat{g}_j)$ = 4.96

Table 6. *Striga* reaction of selected *Striga* resistant source lines against *S. asiatica* in multilocation testing during the 1977-80 rainy seasons

S.No.	Pedigree	1977		1978				1979				1980			
		AKL	BSR	DWR	AKL	PNI	NAND	AKL	BSR	PNI	PTN	AKL	BSR	PTN	PCR
1	N-13	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓	x	✓	x
2	555	-	-	✓	✓	x	x	✓	x	x	✓	✓	✓	✓	✓
3	16-3-4	-	✓	x	✓	x	✓	✓	x	x	✓	✓	✓	x	✓
4	Serena	-	-	✓	x	x	x	✓	✓	✓	✓	-	-	-	-
5	IS-2203	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-
6	IS-4202	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	-	-
7	IS-7471	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	✓	-
8	IS-9985	✓	✓	✓	✓	x	x	-	-	-	✓	✓	✓	x	x
9	IS-2403C	-	-	-	-	-	-	✓	x	✓	✓	-	-	-	-
10	IS-4242	✓	✓	x	✓	✓	x	✓	x	✓	x	x	x	x	-
11	IS-5603	✓	✓	x	✓	✓	x	-	-	-	-	✓	✓	✓	x
12	IS-6041	-	-	-	-	-	-	✓	x	✓	✓	x	x	✓	-
13	IS-6942	✓	✓	✓	✓	x	x	x	x	x	x	✓	✓	✓	x
14	IS-7091	-	-	-	-	-	-	✓	x	✓	✓	x	x	✓	-
15	IS-7245	-	-	-	-	-	-	✓	x	x	✓	✓	x	x	-
16	SRN-4841	✓	✓	x	✓	x	x	✓	x	x	✓	✓	✓	x	x
17	NJ-1515	✓	✓	✓	✓	x	✓	✓	x	✓	✓	x	x	x	x
18	SRN-4882B	-	-	✓	✓	x	x	✓	✓	✓	✓	x	✓	✓	✓

✓ = Test entry *Striga* reaction less than 10% of CSH-1
x = Test entry *Striga* reaction more than 10% of CSH-1
\- = Not tested or not reliable

(Note: 1977, 1978 results based on *Striga* counts percent of systematic checks averaged over replications; 1979, 1980 results based on single unit comparisons).

AKL - Akola, BSR - Bhavanisagar, DWR - Dharwar, PNI - Parbhani, NAND - Nandyal, PTN - Phaltan and PCR - Patancheru.

Table 7. Mean subterranian Striga counts on resistant and susceptible sorghums in seed pans

Season	Date of Sowing	Genotype	Host Age (Days to Observation)				
			27	29	31	35	49
Rainy Season 1980	8.7.80	CSH-1	2.00	4.00	4.75	8.58	7.60
		Swarna	3.00	3.00	5.00	4.20	12.33
		N-13	0.50	0.33	0.00	0.20	0.00
			20	25	32	40	50
Postrainy Season 1980	24.10.80	CSH-1	0.00	0.33	1.25	0.66	1.17
		Swarna	0.00	0.50	1.37	2.55	4.33
		N-13	0.00	0.33	0.75	0.00	0.00
			22	28	32	42	52
Summer 1981	23.2.81	CSH-1	0.00	0.25	0.38	7.00	10.50
		Swarna	0.00	0.00	0.38	2.87	7.13
		N-13	0.00	0.25	0.00	0.50	0.33
			20	25	30	40	50
Rainy Season 1981	17.6.81	CSH-1	0.16	1.16	3.00	10.16	13.00
		Swarna	0.33	1.16	3.00	9.50	11.00
		N-13	0.00	0.00	0.00	0.23	0.50

Table 8. Analysis of variance for subterranian *Striga* counts in seed pan over three seasons

Source of Variation	Postrainy season 80		Summer 81		Rainy Season 81	
	DF	MS	DF	MS	DF	MS
Blocks	5	1.546	7	7.24	5	3.29
Main Plots (Days)	4	8.933*	4	171.28**	4	218.18**
Error (A)	20	2.530	28	5.97	20	8.83
Subplots (Varieties)	2	16.53**	2	115.90**	2	243.38**
Days x Varieties	8	6.20*	8	104.46**	8	50.43**
Error (B)	50	2.38	79	2.01	50	7.44
Total	89	2.78	120	17.74	89	3.68

Table 9. Relative merits of selection criteria for *Striga* resistance reaction in sorghum*

1979 Entry No.	1980 Entry No.	1979 Rainy Season		1980 Rainy Season	
		Striga Counts (% CSH-1)	Reaction Category	*Striga* Counts (% CSH-1)	Reaction Category
1	1	7.87	√	6.20	√
2	2	6.88	√	111.70	x
3	3	1.18	√	14.50	√
4	4	3.01	√	15.80	√
5	5	7.06	x	4.10	√
8	6	2.43	√	38.90	x
9	7	0.14	√	4.00	√
10	8	1.67	√	21.80	x
11	9	9.54	x	34.10	x
15	10	1.63	√	122.80	x
17	11	3.54	√	4.50	√
19	12	23.38	x	98.50	x
20	13	9.38	x	11.20	√
21	14	0.93	√	3.20	√
22	15	1.94	√	0.90	√
23	16	5.61	√	11.30	x
24	17	5.27	√	15.30	x
25	18	1.84	√	10.90	√
27	19	9.66	x	61.10	x
28	20	16.91	x	9.70	√
29	21	3.84	√	13.00	√
30	22	18.05	x	15.80	x
35	23	9.63	x	25.60	x
38	24	95.80	x	68.10	x
39	25	3.21	√	12.20	x
43	26	8.34	x	20.80	√
53	27	0.59	√	24.60	√
56	29	3.21	√	4.90	√

√ = Test entry *Striga* reaction less than 10% of CSH-1
x = Test entry *Striga* reaction more than 10% of CSH-1
* = Results from Preliminary *Striga* Resistance Trial-2 conducted at Akola.

Table 10. Efficiency of the two selection criteria for *Striga* selection

A. Based on the *Striga* counts % of systematic check averaged over replications:

		1980		
		<10%	>10%	Totals
1979	<10%	7	17	24
	>10%	1	3	4
Totals		8	20	28

B. Based on single unit comparisons:

		1980		
		√	x	Totals
1979	√	11	7	18
	x	4	6	10
Totals		15	13	28

Table 11. Striga counts expressed as percent of check of each location

	Paţancheru	Akola	Phaltan	Anantapur	Bhavanisagar	Average
SRN-4882B	6.15	38.44	2.12	10.78	2.04	8.92
N-13	1.53	8.75	2 35	0.82	4.40	3.21
IS-5106	1.53	6.08	3.41	3.29	4.65	4.04
Swarna	100.00	100.00	100.00	100.00	100.00	100.00

Table 12. Analysis of variance for Striga counts

Source of Variation	D.F	MS
Replications	2	2750.02
Strains	4	25330.04
Error (A)	8	9813.52
Varieties	3	212183.13**
Strains x Varieties	12	20999.31*
Error (B)	30	7501.24

Figure 1. Flow chart of material for screening for field resistance to striga

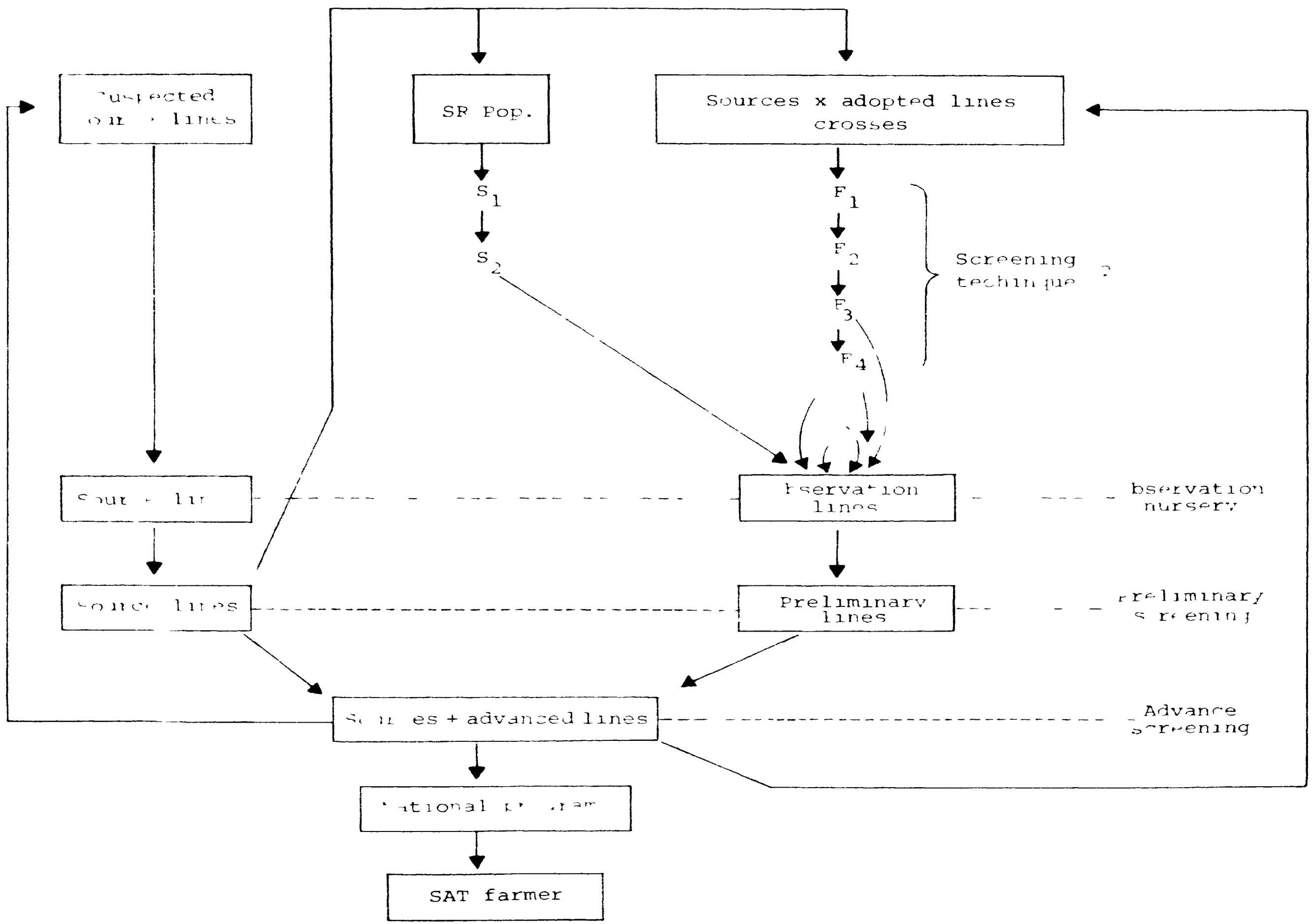

Figure 2. Subterranian striga counts on the roots of resistant and susceptible cultivars of sorghum

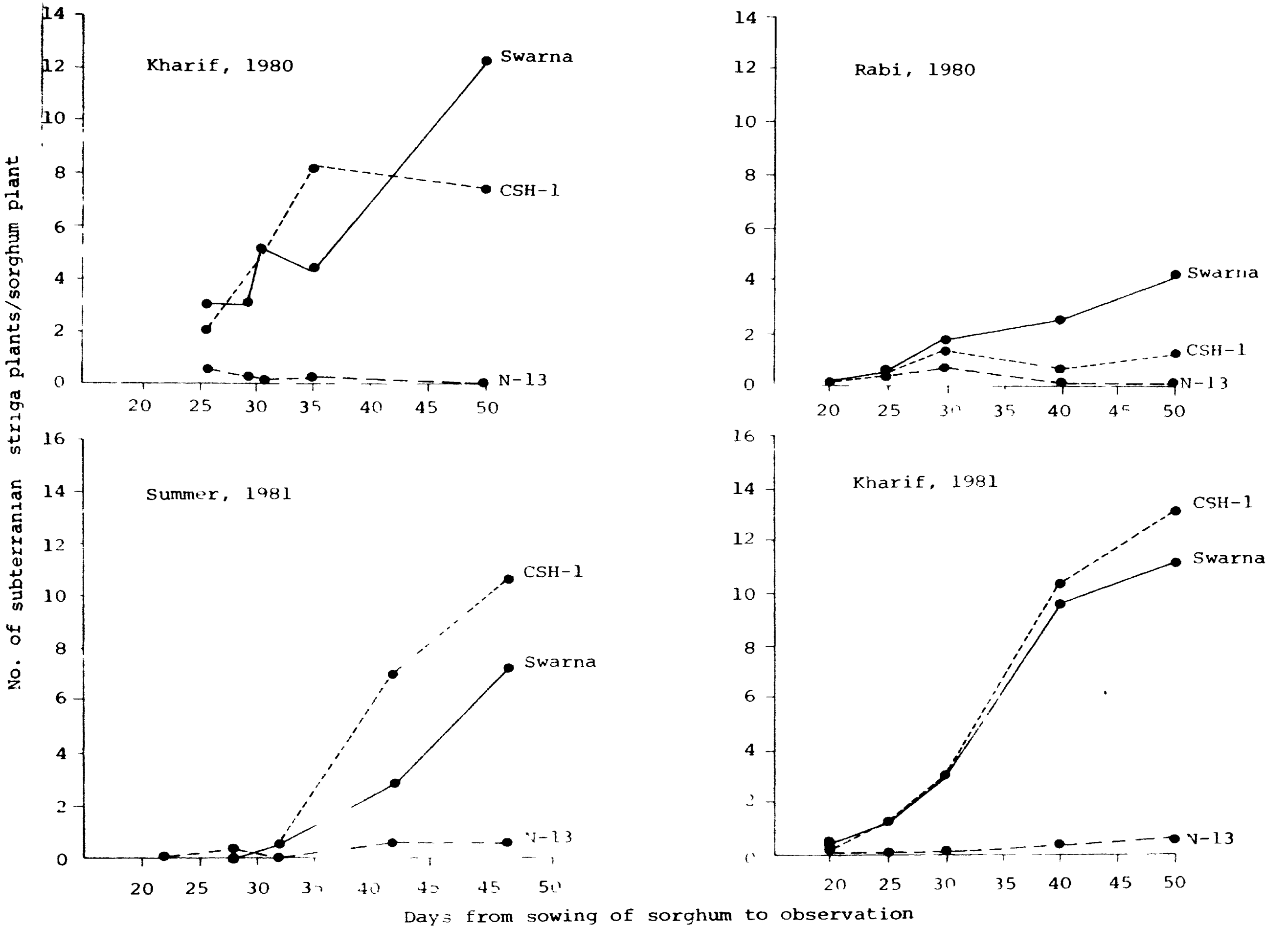

Figure 3. Subterranian striga counts of 25 sorghum lines in seed pans. (55 day-counts) (D/S : 30. 1. 81)

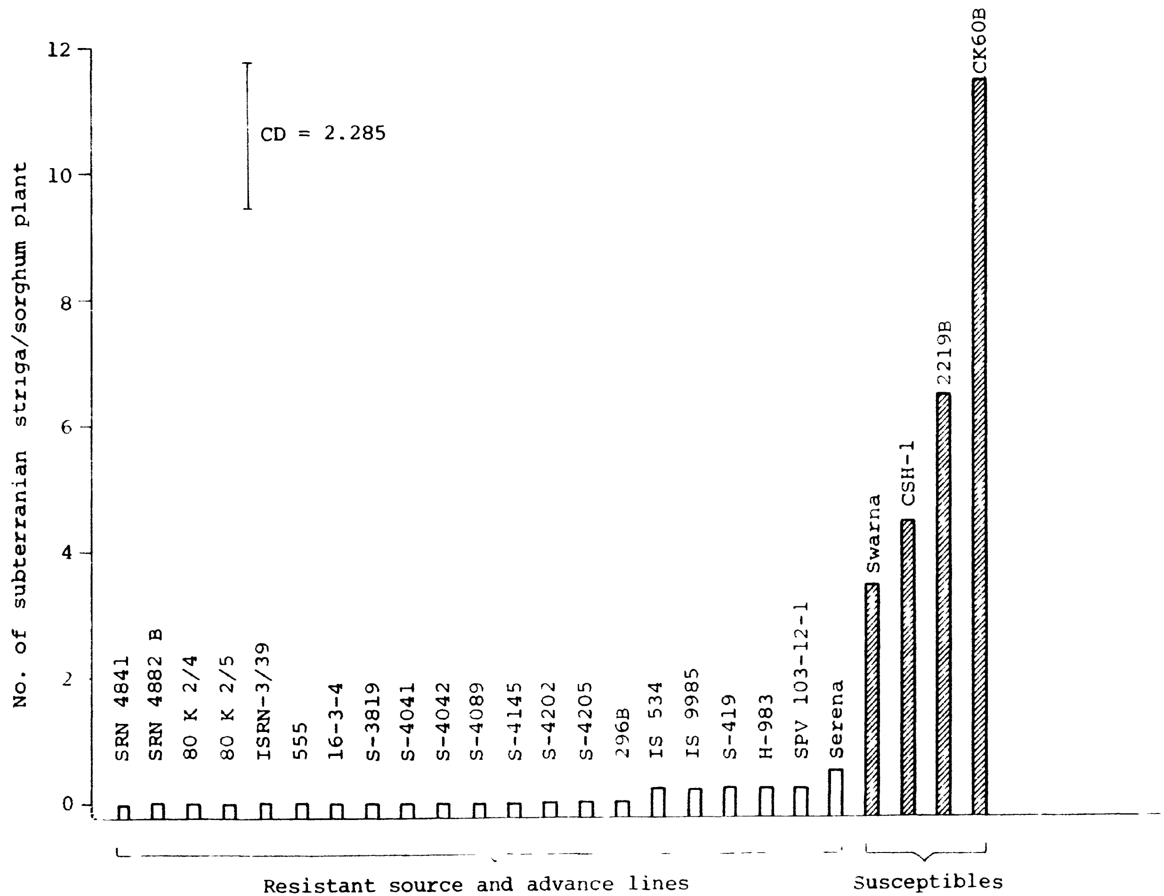

Figure 4. PRELIMINARY SCREENING FOR STRIGA RESISTANCE

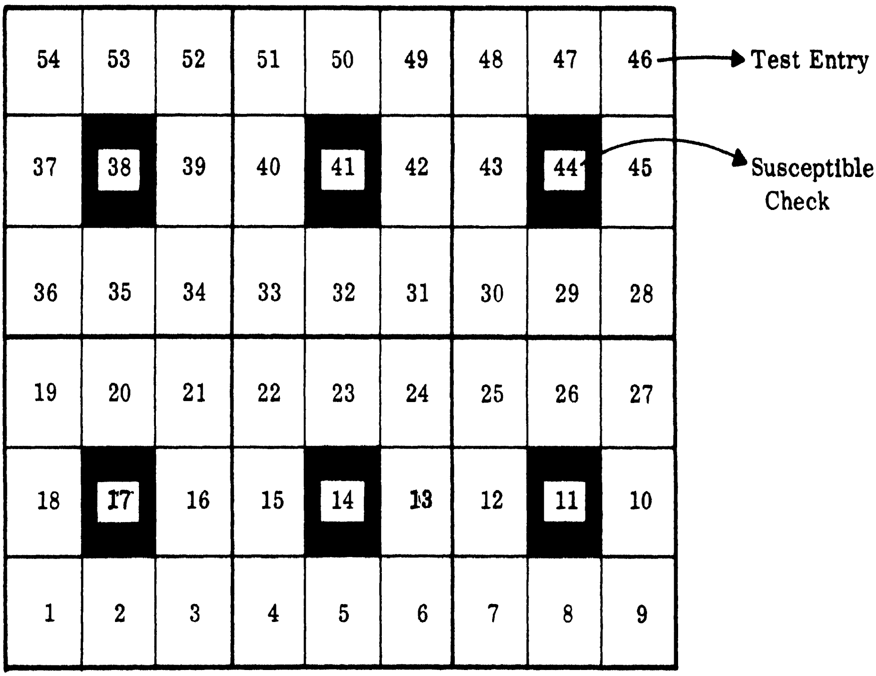

Figure 5.

CHESS BOARD LAYOUT FOR ADVANCE SCREENING IN STRIGA RESISTANCE BREEDING

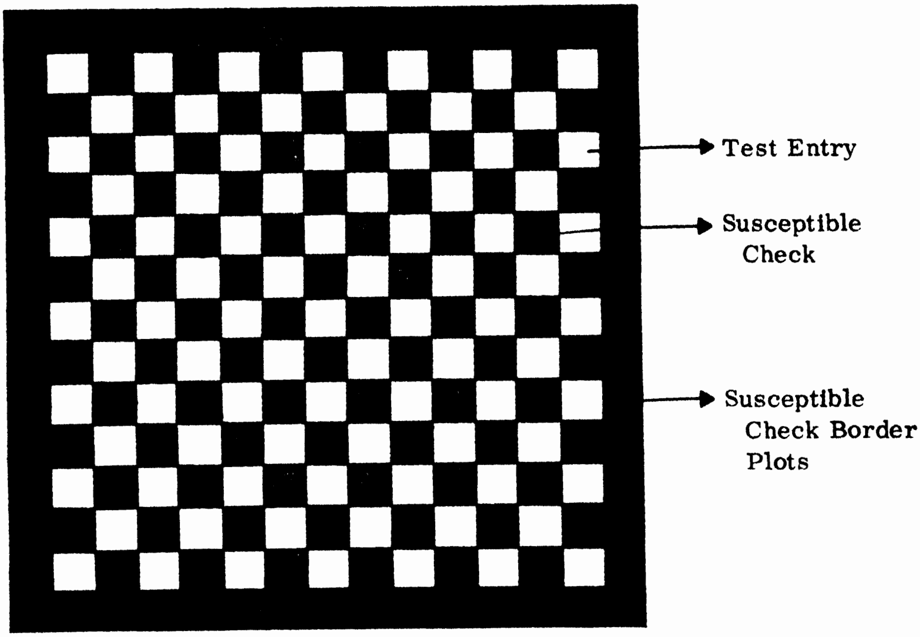

Figure 6. Striga reactions of four cultivars of sorghum across five locations.