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PATTERNS OF STRIGA RESISTANCE IN SORGHUM AND MILLETS WITH SPECIAL EMPHASIS ON AFRICA

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SUMMARY

Although host plant resistance in sorghum was demonstrated as early as 1920 both in Africa and India, its exploitation in breeding broad-spectrum stable resistant cultivars started only recently. In pearl millet, however, the existence of host plant resistance is not yet clearly demonstrated. Striga-resistant sorghum varieties are in general agronomically poor. Multi-locational evaluation in Africa revealed that Framida and N 13 are the most stable resistant varieties. These two varieties were resistant to both S. asiatica and S. hermonthica. Some of the varieties like Najjadh, 12610C and IS 9830 revealed a narrow spectrum of resistance when tested across different seed samples of S. hermonthica. Genetic analysis of field resistance in sorghum revealed that it is controlled predominantly by additive gene action and thus straight selection is effective. A pedigree approach to transfer resistance into elite agronomic backgrounds was successful. Several selections with promising levels of resistance, stable grain yields and good grain quality were identified and are now in 'on farm' tests. In millet, a few less susceptible lines have been identified. Intercrossing them and following the pedigree system of selection resulted in increased levels of resistance and grain yields. The need for integrated Striga management, including resistant cultivars and complementary agronomic control practices, is emphasised.

INTRODUCTION

Breeding for increased grain yields and quality in cereals has been known for several years. Spectacular yield increases were obtained in several cereal crops like wheat, rice, maize and sorghum, leading to the Green Revolution in several countries. Insect and other disease pests have drawn the attention of plant breeders to the fact that these pests are important yield-reducing factors. Relatively recently, work on the development of crop varieties resistant to those pests was initiated. Striga is still considered merely as a weed, but not as an important crop pest by farmers and administrators alike. As such, very little attention has been paid to its control. Many farmers are not even aware that Striga produces seed and that the seed production should be checked by weeding out Striga before it flowers. Resistant varieties of sorghum were identified as early as 1920, but serious efforts to exploit them and develop stable resistant cultivars with acceptable food quality and increased grain yields started only recently. Striga is widespread throughout the semi-arid tropical regions of Africa; it is very rare that one finds a filed of sorghum or millet without a Striga plant. Being an obligate parasite, it causes enormous damage to the host plant.

LOSSES DUE TO STRIGA

Striga hermonthica causes serious crop losses in sorghum and millet and it is present in most areas where these crops are grown. Yield loss estimates vary. In our own trials we found that yield reduction varied from 10-35%. In ordinary farm crops, the losses are much higher and often lead to total crop failure. Doggett (1965) estimated reduction in yield to be about 1 kg for every 1,000 plants of Striga. In one of our trials it was found that a yield reduction of 10% represented the presence of Striga density of 15,000/ha. In peasant farms the Striga densities are often much higher.

Sorghum and millet are the principal staple food crops in Africa and are grown in almost all African countries. The area under cultivation, average grain yields (kg/ha), and total production for sorghum, millet and maize and also the figures for all cereals, including wheat and rice are given in Table 1. The value of all the cereals in Africa is estimated at US $17.479 billion, based on 1983 prices for coarse grains. Striga can attack all the rainfed cereals in Africa, particularly sorghum, millet and maize. The approximate value of these three crops is US $12.438 billions. Yield losses due to Striga range anywhere from 10 to 100%. Thus, if Striga spreads to all the areas where these crops are grown, the value of the crop loss due to Striga may range from US $1.2 billions to total loss. Even though Striga is not present everywhere now, it is likely to spread to other non-infested areas in due course. Thus it is expected to pose a serious threat to the cultivation of rainfed cereals in Africa if adequate control measures are not taken immediately.

STRIGA CONTROL

Striga can be controlled in several ways, namely :

a) by methods which lead to the depletion of Striga from the soil, such as trap crops, catch crops, ethylene gas, strigol analogues, methyl bromide fumigation, etc., and
b) by those which limit and/or reduce Striga reproduction, such as hand weeding before flowering, herbicides, seed hardening, resistant varieties, fertilizers, irrigation, shading-intercropping, or mulching or high crop density, biological control, etc.

HOST PLANT RESISTANCE IN SORGHUM

Exploitation of host plant resistance in sorghum started in South Africa in the 1920's (Saunders, 1933) and then in Nigeria, Sudan, Ethiopia and in Upper Volta. The resistant varieties reported in South Africa, Zimbabwe, Tanzania, Sudan and Nigeria are listed in Table 2. Most of these varieties, with the exception of SRN 4841 (Framida), have local usefulness with narrow spectrum resistance. Varieties like 37R9, 37R29, 37R37, N Sorte and P 41 are not available now. An ICRISAT project, based in Upper Volta, has been testing several varieties of sorghum from the world collection in breeding programmes and from other programmes in Africa in its regional trials since 1977. A few varieties are identified as possessing satisfactory levels of resistance. The promising varieties are listed in Table 3. The agronomic characteristics of some of the promising varieties are given in Table 4. Among these varieties, IS 9830, Tetron and Entry 39 are low stimulant producers, whereas Framida is a low stimulant and has root cell wall thickenings (El Hiweris, personal communication). Other varieties such as N 13, Najjad and SPV 103 produce stimulants, and so are suspected of having other forms of resistance such as anti-haustorial factors, etc.

The stability analysis (Ramaiah, 1983a) of some sorghum varieties in several African countries revealed N 13 and Framida as the most stable varieties for Striga resistance as indicated by their very low mean emergence of Striga plants and a regression coefficient close to zero (Table 5).

Extensive field trials conducted in Upper Volta by breeders, agronomists and economists revealed that Framida, in addition to Striga resistance, has several other desirable traits like stable grain yields, excellent seedling establishment and early seedling drought resistance, acceptable food quality and is suitable for intercropping. The results of 'on farm' testing in 1980, 1981 and 1982 are presented in Table 6. In 1980, the results from several African countries revealed that N 13, and SPV 103 were resistant, whereas Framida exhibited moderate levels of resistance. Grain yields with Framida were, however, superior to all the varieties tested. N 13 and SPV 103 produced grain yields much inferior to the local varieties. Because of its higher yield potential, in 1981, Framida continued to be tested in Upper Volta on six fields which were heavily infested with Striga. In the presence of Striga, Framida's superior yield over the local varieties was very striking, showing an overall increase in yield of 80%. Encouragingly, Framida is attacked by only 25% Striga compared to the local varieties. In 1982, the results from ICRISAT's economic programme in Upper Volta demonstrated the stability of Framida under both traditional and improved managements.

RESISTANCE OF SORGHUM VARIETIES ACROSS STRIGA spp.

There are two major Striga spp., S. hermonthica and S. asiatica, for which host plant resistance is sought. There has been only one report that resistance of sorghum varieties to S. asiatica (South Africa) does not hold against S. hermonthica (Doughty, 1941). At the ICRISAT Centre in India, several varieties have been identified as resistant to S. asiatica (Indian). These were further tested at other locations, in India against S. asiatica and in several locations in Africa against S. hermonthica, The results (expressed as percentage of a standard susceptible variety) are presented in Table 7. Some of the varieties like Framida, N 13 and 16-3-4 have exhibited some level of resistance to both species of Striga whereas the other varieties were only resistant to S. asiatica as measured by the number of emerged Striga plants. It seems therefore, that there is a lack of general uniformity in the ways the crops are resistant to S. asiatica and S. hermonthica.

In the breeding programme, selections have been tested against both S. asiatica (at ICRISAT Cente, India) and S. hermonthica with the objective of finding crop cultivars resistant to both species. Much breeding material has been generated. The segregating generations have been simultaneously screened for resistance to both species. In this volume, Dr. Rao has presented a list of promising cultivars which were derived from crosses involving 148, 555 and Framida (SRN 4841) as parents. In Upper Volta, selected progenies were made from crossing involving E 35-1, Framida, etc. The derivatives of crosses involving 148 and 555, which are Indian varieties, did not adapt to African conditions. While these progenies were in general, short, early and low yielding, the progenies from crosses involving E 35-1 and Framida as parents were medium tall, partially photosensitive, and high yielding. Thus, apart from resistance to Striga there are other general adaptation characters which need to be taken into consideration.

One of the selections (entry no. 39 in ISRST-3) from a cross between 148 (an Indian variety) and Framida (an African variety) had shown good levels of resistance to both species and it also has good agronomic characters. 148 was moderately resistant to S. asiatica, whereas Framida is resistant to both species. The selection from this cross was a tan plant with white grain, like 148, and head-shaped with elongated internodes from Framida. Thus, by careful selection from judiciously planned crosses, one could select cultivars resistant to both species.

RESISTANCE OF SORGHUM VARIETIES TO STRAINS OF STRIGA HERMONTHICA

Striga hermonthica is a highly variable species because of cross pollination. There is clear evidence of the presence of at least two strains, one specific to millet and the other to sorghum (Wilson Jones, 1955; Zummo, 1975; Parker & Reid, 1979; Bebawi, 1981; Ramaiah, 1983). The crop specificity is reported to be based on germination stimulant compounds present in the host crop root exudates (Parker & Reid, 1979). The distribution of Striga strains in relation to ecological zones in west Africa indicates that millet and sorghum are the principal hosts in the Sahel and Sudan savanna zones respectively. However, in the northern Guinea savanna and a transition zone between the Sahel and Sudan savanna zones, both millet and sorghum act as hosts (Ramaiah, 1983).

Sorghum is extensively grown in the Sudan savanna zone where S. hermonthica perhaps has evolved different strains. In east Africa the presence of physiological strains in S. hermonthica attacking sorghum was suspected (Doggett, 1952), because two of the sorghum varieties, Dobbs and P 41, that were resistant in one location in Tanzania, were susceptible in another. Our multilocational trials in the Sudan savanna present similar results. It is important in a breeding programme to determine how variable a pathogen is in order to decide the breeding strategies to develop cultivars with stable and broad-spectrum resistance. The results of two of our pot experiments conducted in 1980 and 1981 (Table 8) indicate significant differences among the sorghum varieties and among Striga samples each year. The interaction between varieties and Striga samples was significant in 1981. Sorghum varieties resistant in one year were not resistant in another. For example, Najjad had shown resistance to all three Striga samples in 1980, but showed susceptibility to STS 6 in 1981. Similarly IS 9830 was resistant to all the strains in 1981 but showed susceptibility to STS 2 in 1980. However, IS 1261C had a similar response both years. Framida was consistantly resistant and CK60B was consistently susceptible in both the years. These results indicate the instability of resistance of some of the sorghum varieties and the probable presence of intracrop variants of S. hermonthica which threaten host-plant resistance in sorghum. Availability of varieties with stable resistance like Framida and N 13 (Ramaiah, 1983) indicates the possibility of breeding high yielding cultivars with stable broad-spectrum resistance.

GENETIC ANALYSIS OF FIELD RESISTANCE IN SORGHUM

There are no reports in the literature on the nature of inheritance of resistance to S. hermonthica in sorghum. During the 1982 crop season, the field resistance in some sorghum varieties was analyzed through generation means, diallel, and line x tester analyses. The results are presented in ICRISAT/Upper Volta, Annual Report, 1982. In this paper the results of a pot experiment of a 7x7 diallel are presented.

Seven varieties of sorghum, out of which N 13, Framida, SPV 103 and IS 9830 are resistant, and three varieties, IS 9849, VS 702 and BTx623, are susceptible, were crossed in all possible combinations without reciprocity. Parents and 21 crosses were planted in pots in a Randomised Block Design, with six replications. Observations were taken on the number of emerged Striga plants and their fresh weight.

Heterosis : the means of parents and crosses for the number of emerged Striga plants and Striga fresh weight are presented in Table 9, along with estimates of heterosis over the mid-parent (MP) value. A critical examination of the heterosis values indicate that those cross combinations (involving both resistant parents) which have exhibited maximum positive heterosis have the parents with different resistance mechanisms. Examples are N 13 x Framida, N 13 x IS 9830, Framida x SPV 103, and SPV 103 x IS 9830. On the contrary, crosses involving the parents with the same resistance mechanisms have not exhibited any heterosis. Table 4 shows resistance mechanisms of parents involved in the crosses. The observation that parents with two different resistance mechanisms exhibit positive heterosis in cross combination, indicates that they are probably controlled by different gene loci and that resistance is recessive. When they segregate, it is possible to select for recombinants with both the gene systems. IS 9830 as a female parent in crosses with susceptible varieties did not exhibit any heterosis and perhaps its resistance may be quantitatively inherited. IS 9849 exhibited negative heterosis with N 13, SPV 103 and VS 702.

Combining ability : was analyzed according to method 2 and Model 2 of Griffing (1956). The analysis of combining ability of Striga number and Striga fresh weight is presented in Table 10. For Striga number, both general and specific combining abilities were highly significant, whereas for Striga fresh weight only, general combining ability was significant. For both characters the general combining ability was more important as revealed by the ratio GCA/SCA. Thus, Striga resistance as measured by these two characters is predominantly controlled by the additive genetic factors and therefore straight selection to improve Striga resistance is quite effective.

The general combining ability effects (GCA) of the parents are presented in Table 11. Negative estimates indicate a tendency towards resistance, while positive values refer to susceptibility. All the resistant parents except Framida, produced a significant negative effect, and thus are good general combiners for resistance. Susceptible varieties like BTx623 and IS 9849 were poor combiners for number of Striga plants. For Striga fresh weight, SPV 103 and BTx623 produced significant negative and positive effects respectively. SPV 103 is the best combiner for both Striga number as well as Striga fresh weight.

HOST PLANT RESISTANCE IN MILLET

Pearl millet was not researched for resistance to S. hermonthica until 1979 when ICRISAT started to work on this crop in Upper Volta. Progress was rather slow. During the first few years, several west African local varieties and several introduced varieties were tested in Striga sick plots and selfed to isolate resistant inbred lines. Pot experiments are now being used to screen and isolate single plants from less susceptible varieties identified in the field trials. Two sick plots, one in northern Upper Volta (farmer's field) and one in Niger (Tarna Research Station in Maradi) are being used for screening in the rainy season. A few promising, less susceptible varieties are listed in Table 12, along with their grain yields over several locations and reaction to Striga when tested in Striga sick plots and in pots. Out of the 20 varieties tested, only results for nine are presented. In pot experiments, the Striga infestation was very high, resulting in the death of highly susceptible plants within two months of planting. To show the susceptibility, the number of killed plants was expressed as the percentage of the total number of plants established as seedling for each variety. In 1982, the susceptible check (ex-Bornu) was killed in all the pots; whereas in entry nos. 2, 3, 9 and 15, about 70% of the plants survived. 1983 pot experiments closely agree with the 1982 pot results as well as 1983 field screening. Over the three experiments the promising entries for resistance are 3 (P 2661-3-5), 9 (P 449-1-29) and 15 (P 2627-1-19). They are in general poor grain yielders. In contrast, some of the high yielding entries like 6 (P 2627-2-11), 20 (local) and IS (P 2627-2-18) supported more Striga. Considerable breeding work is required to intercross and select high yielding progenies with less susceptibility.

RESISTANCE IN SEMI-WILD MILLETS (SHIBRAS)

Parker and Wilson (1983) reported semi-wild millets (shibras) collected from Niger as showing promising levels of resistance. Four of their most promising progenies were tested in our pot experiments in 1983, using millet strain of S. hermonthica, collected from the northern region of Upper Volta. A susceptible variety (82W214) was included as a check. Ten plants (one plant in each pot) for each variety were tested. All five varieties showed a high level of susceptibility as indicated by the number of emerged Striga plants and the percentage of millet plants killed in each variety when observed eleven weeks after sowing. A few plants in each variety survived, which were selfed for further testing.

BREEDING STRATEGIES

Breeding procedures largely depend on the nature of gene action controlling a particular character under selection. In sorghum fields, resistance to Striga is controlled predominantly by additive gene action. Selection procedures like pedigree, back cross and recurrent selection systems should be very effective. Similar procedures should also be useful in pearl millet, although population improvement through recurrent selection is easy and effective.

Pedigree Approach

Sorghum : improvement of resistant varieties of sorghum for various agronomic traits was initiated using pedigree and back cross procedures. In the African ICRISAT Striga programme, the main focus has been the improvement of Framida for grain colour (from red to white), resistance to insects and disease and improvement of E 35-1 for resistance to Striga, good seedling establishment and good panicle exsertion.

Over the past four years, several progenies from crosses involving Framida and E 35-1 as parents were tested in several African locations for Striga resistance and grain yield. They were also screened in pots in 1982 and 1983. Some of the promising entries were also tested for cooking quality (Tô). The results are presented in Table 13.

Two selections from crosses involving E 35-1 and IS 8785, a Striga resistant variety from Kenya, emerged as the best. They are 82-S-50 |(IS 8785 x E 35-1)-1-4-2|, and 82-S-47|(IS 8785 x E 35-1)-1-4-3|. They not only out-yielded E 35-1, but also exhibited very good levels of Striga resistance, good seedling establishment, superior food quality and non-senescent sweet stems. In our 'on farm' tests conducted in 1982, 82-S-50 produced 50% more yield (2,098 kg/ha) than E 35-1 (1,400 kg.ha). In 1983 'on farm' tests in Upper Volta, 82-S-50 and 82-S-47 had exhibited excellent levels of resistance to Striga compared to the local varieties.

Among the crosses involving Framida, entry no. 7 |(Framida x SPV 329)-2-1| had shown some promise. It is an early cycle variety and has coloured glumes. There are now several selections involving Framida with tan plant colour and grain mould resistance.

Millet : some of the less susceptible selections identified in 1979 and 1980 were intercrossed and advanced as a pedigree system. The segregating F_2 populations were screened for downy mildew resistance. Good selfed plants were tested in Striga sick plots in Aourèma (Upper Volta) and Maradi (Niger) in 1982. A few selected progenies were advanced in 1982 winter and selfed. 45 F_5 progenies were again screened in both locations in 1983.

A sandwich technique in which two test varieties (2x2 = 4 rows) are placed between two plants (2x2 rows) of ex-Bornu on either side is used for assessing the intensity of Striga infestation. Striga emergence on each variety is expressed as the percentage of that on the adjacent plot of ex-Bornu. This trial was replicated four times. Actual number of emerged Striga plants was analyzed after log transformation. The selected progenies are listed in Table 14.

Striga infestation at Maradi and Aourèma was satisfactory. The best entries in both the locations were 45, 20, 26, 14 and 21. It is encouraging that we are able to obtain levels of resistance comparable to that of Aourèma local variety (this variety used to be the best in all our trials from 1980-82) and increase the yields substantially. Our selections are about two weeks earlier than the local.

Population Improvement

Population improvement through recurrent selection offers good scope in both sorghum and millet. In sorghum, male sterile genes are used to facilitate crossing.

Millet : several crosses were made between less *Striga* susceptible varieties, the F_1 bulk was random-mated three times and grown out in *Striga* sick plots in Aourèma and Maradi in 1983. Full-sibs were made and at harvest only those full-sibs where one or both the parents were free from *Striga* were retained. Several S_1s and half-sibs free from *Striga* were also selected at harvest. All the three recurrent selection procedures, i.e. S_1, full-sib and half-sib testing will be compared.

Sorghum : a procedure similar to that of millet is proposed. Several crosses were made onto genetic male steriles and are being random mated.

SCREENING TECHNIQUES

It is not intended to review here the problems of screening in the field and in the laboratory. Planting of susceptible variety (indicator rows) at frequent intervals as local control appears to be the best approach at present. There are field layouts called sandwich technique and checker board layout. In sandwich technique, two rows of a susceptible variety are planted on either side of two test varieties, whereas in checker board layout, each test variety is surrounded by a susceptible variety on all four sides. Sandwich technique is more practical when the sick plot area is limited and test varieties are numerous. 'However, if only a few varieties are to be tested, and if there is enough sick plot area available, checker board layout is a better choice. Hill plot technique was also used in Nigeria to advantage. This is useful for screening large numbers of pure line varieties if one could use several susceptible plots as local control.

Laboratory screening is only available now for identifying low stimulant varieties or progenies (Parker et el, 1977). Although most of the low stimulant varieties from germplasm supported a lot of *Striga* when field tested, several of the breeding progenies involving low stimulant varieties retained the low stimulant character when selected after repeated field testing (Rao et al, 1983). Any one resistance mechanism may not confer complete field resistance to *Striga* because of significant influences of soil and climatic factors. Thus the laboratory should be able to identify varieties with various components of resistance, such as low stimulant compounds, haustorial initiation factors, anti-haustorial, antibiosis and some as yet unknown factors. This would enable the breeders to put these various resistances together using appropriate breeding procedures. The segregating progenies need to be screened again, thus a good screening laboratory is a necessary complement for an effective breeding programme.

RESISTANT VARIETIES IN INTEGRATED STRIGA MANAGEMENT

Host plant resistance is used as a component in an integrated programme of insect control in several crops. For example, in cotton, the traits of 'earliness' and 'nectariless' are valuable components in the management of cotton insects. A good level of resistance to greenbug is available in sorghum, but insect control is obtained only when resistant hybrids are grown in areas where predators can have a significant impact on the greenbug population.

For Striga, partial resistances are available in sorghum, and they should be used in combination with other methods to achieve complete control. There are several agronomic management systems that could be used very successfully with the resistant cultivars. They include optimum date of planting, rotation with trap crops, N-fertilizers, tied ridges with mulch, etc. Some of the results are reported in ICRISAT/Upper Volta Annual Report, 1982. They are briefly described below.

1. Resistant cultivars and hand weeding : resistant varieties support significantly fewer numbers of Striga plants compared to susceptible varieties. Smaller numbers of Striga plants can more easily be pulled out or sprayed with herbicides using pistol-grip sprayers. Both these practices were found to be tedious and not practicable with the high density of Striga infestation associated with susceptible varieties.

2. Resistant varieties in crop rotation : this is perhaps the best long term solution of Striga eradication. Resistant varieties reduce Striga build-up significantly. Rotation with trap crops helps to get rid of Striga seed reservoirs from the soil.

3. Resistant varieties and N-fertilizers : nitrogen fertilizers in general reduce Striga infestation. Very high doses of nitrogen are required to bring about an economic increase in yield and significant reduction in Striga infestation. Our results, using resistant and susceptible varieties, indicate that a very low dose of 14 kg/N/ha is enough to reduce Striga infestation and increase grain yields significantly with resistant varieties like Framida. A high dose of 150 kg/N/ha is required to suppress Striga in susceptible varieties. In Africa, where the farmers in some countries have started to use N-fertilizers, the Striga problem is going to increase if they use their local susceptible varieties. It is evident that improved sorghum varieties that are recommended for cultivation should possess some level of resistance to Striga.

4. Tied ridge with mulch : high soil moisture reduces or delays Striga emergence. Heavy rains or continuous irrigation are not favourable to Striga growth. Striga do not attack crops like rice, under irrigation.

   In west Africa irrigation facilities for sorghum and millet are almost absent. Tied ridges, to conserve soil moisture, in sorghum and millet resulted in almost doubling of crop yields (ICRISAT/Upper Volta Annual Report, 1982). Our experiments in 1982, using tied ridges in Striga sick plots, did not reduce Striga significantly. In 1983 tied ridge with mulching significantly increased Striga growth where the sorghum crop on control plots (flat planting) completely failed because of the drought. Tied ridges in west Africa therefore means better conditions for crop growth as well as for Striga. However, they do not provide sufficiently wet conditions to reduce Striga emergence. Resistant varieties in this context are evidently required.

In addition, there are a whole range of control methods which have proved impractical and uneconomical and which can be made more economical and practicable with the resistant varieties. *Striga*-resistant cultivars with appropriate complementary agronomic practices should be the most ideal control package.

Table 1 : Production figures of cereals grown in Africa

	Area (000 ha)	Grain Yield (kg/ha)	Production (000 t)	Crop Value* (US $ m)
Sorghum	15,312	730	11,174	2,558
Millet	16,691	616	10,282	2,355
Maize	22,583	1,455	32,860	7,525
All cereals	73,056	1,045	76,329	17,479

(FAO Production Yearbook, 1981 data)

* 1 t = US $229 (based on 1983 prices for sorghum, millet and maize in Ouagadougou, Upper Volta). The value of "all cereals" shown in the Table is a lower estimate since they include rice and wheat, whose prices are generally much higher than sorghum, millet and maize

Table 2 : *Striga* resistant sorghum varieties identified in Africa

Resistant variety	*Striga* species	Country	Reference
37RP*, 37R29, 37R27	S.a.	South Africa	Saunders (1942)
N Sorte*	S.a.	Northern Rhodesia	Moore (1933)
Dobbs & P 41	S.h.	Tanzania	Doggett (1952 & 1954)
Najjad	S.h.	Sudan	Kambal (1974)
SRN 4841, Framida & SRN 6838A	S.h.	Nigeria	Zummo (1975)

*Not available now

S.a. = *Striga asiatica*
S.h. = *Striga hermonthica*

Table 3 : Sorghum varieties resistant to Striga for different African countries

Country	Resistant varieties
Sudan	IS 9830, Entry 39, Tetron, Framida
Ethiopia	N 13, Framida, SPV 103, 12610 C
Kenya	N 13, Framida
Cameroun	N 13, Framida, NJ 1515, IS 8785
Nigeria	N 13, Framida, SRN 6838A, L 187
Niger	N 13, Framida
Upper Volta	N 13, Framida, SPV 103, Entry 39
Mali	N 13, Framida, IS 2203
Ghana	N 13, Framida, Najjad, IS 9830, Entry 39
Mauritania	N 13, Framida, IS 9830, SPV 103, Najjad

Table 4 : Agronomic characteristics of some Striga resistant sorghum varieties

Variety	Origin	Days to Flower	Plant Height (cm)	Grain Yield (kg/ha)	Grain Colour	Mechanism of Resistance
N 13	India	89	306	760	Yellow	Anti-haustorial factors
Framida	Africa	80	253	1930	Brown	Low stimulant + mechanical barriers*
IS 9830	Sudan	61	281	920	White	Low stimulant + moderate root cell wall thickening*
SPV 103	India	65	153	910	White	Anti-haustorial factors(?)
Najjad	Sudan	78	216	1010	White	Anti-haustorial factors(?)
Ent.39 (148xFramida)	India	70	150	1500	White	Low stimulant

*El Hiweris, personal communication

(?) Both varieties are stimulant positive but field resistant. They are suspected of having anti-haustorial factors or some other mechanisms of resistance

Table 5 : Stability analysis of some sorghum varieties for Striga resistance

Variety	Stability Parameters		
	Mean no. of Striga plants	bi	sdi
N 13	7.1	-0.82	2.2
Framida	7.7	0.01	2.4
IS 5603	12.4	1.87	1.3
2219 B	13.2	1.40	1.6
1202 B	16.0	1.74	11.2
CK60B	17.7	0.65	7.3

Table 6 : Results of multilocation on-farm testing of a few Striga resistant sorghum varieties

	1980[a]		1981[b]		1982[c]	
	Susceptibility (% local)	Grain yield (kg/ha)	No. of Striga/ha	Grain yield (kg/ha)	Grain yield (kg/ha) Traditional Management	Grain yield (kg/ha) Improved Management
N-13	16	778 (78)[d]				
SPV 103	28	743 (54)				
Framida	60	1281 (119)	28,625 (25)	1630 (181)	412 (125)	880 (131)
Local	100	997 (100)	116,688 (100)	903 (100)	300 (100)	672 (100)

a = Based on 4-15 locations in Africa (Annual Report 1980, ICRISAT/Upper Volta)

b = Based on 6 locations in Upper Volta (Annual Report, 1981, ICRISAT/Upper Volta)

c = Based on 69 locations in Upper Volta for Framida and 60 for local variety (Annual Report 1982, ICRISAT/Upper Volta)

d = Figures in parentheses are percentages compared with the local variety

Table 7 : Resistance of some sorghum varieties across two species of Striga. The number of emerged Striga plants/pots of test varieties are expressed as percentage of susceptible check variety used in each trial

	Striga hermonthica					Striga asiatica (Indian)					
	Ethiopia (1977)	Ethiopia (1978)	Cameroun (1977)	U. Volta (1979)	Mean ± SD	Akola (1977)	B'Sagar (1977)	Parbhani (1978)	Dharwar (1978)	Nandyal (1978)	Mean ± SD
Framida (SRN4841)	9	33	9	3	13.5±11.5	0	1	30	16	-	11.8±12.3
N-13	0	39	17	37	23.3±15.9	0	2	4	8	8	4.4± 3.2
555	46	47	38	53	46.0+ 5.3	8	11	31	9	9	13.6± 8.7
IS 4242	5	43	62	16	31.5±22.4	0	1	2	32	5	8.2±12.0
IS 5218	32	53	34	62	45.3±12.7	5	1	1	3	2	2.4± 1.5
IS 9985	70	133	94	117	103.5±23+8	0	0	4	6	11	5.8± 3.7
IS 4202	14	31	62	100	51.8±32.7	0	1	4	7	3	3.0± 2.4
16-3-4	5	22	35	25	21.8±10.8	10	-	30	23	4	16.8±10.3
Suscept-ible check	100(22)	100(84)	100(225)	100(428)		100(10)	100(472)	100(300)	100(96)	100(143)	

Figures in parentheses are actual number of emerged Striga plants/plot

Table 8 : Resistance of some sorghum varieties against a few samples of Striga hermonthica tested in pots

	Striga samples[a]						Variety means[b]	
	STS-9 Gas-Tougan		STS-6 Kokologo		STS-2 Farako-Bâ			
	1980	1981	1980	1981	1980	1981	1980	1981
IS 12610 C	0.6	0.2	0.8	1.2	1.4	0.7	1.05	0.69
IS 9830	0.6	0.0	0.2	0.2	1.1	0.1	0.80	0.14
CK60B	1.4	0.6	1.3	1.3	1.4	1.1	1.36	1.00
Framida	0.4	0.0	0.5	0.5	0.7	0.1	0.65	0.20
Najjad	0.4	0.0	0.3	1.2	0.5	0.4	0.68	0.55
Striga means[c]	0.65	0.18	0.63	0.90	1.00	0.47		

		1980	1981
a =	LSD (5%) for Striga at same variety level	0.66	0.38
	LSD (5%) for varieties at same Striga level	0.65	0.39
b =	LSD (5%) varieties	0.32	0.14
c =	LSD (5%) Striga	0.30	0.17

Table 9 : Mean and heterosis for <u>Striga</u> number (SN) and <u>Striga</u> fresh weight (SF) in 7x7 diallel in pots

Parent/Cross		Mean/Pot		Heterosis over MP	
		SN	SF	SN	SF
N 13		5.7	7.1		
Framida		4.0	5.4		
SPV 103		2.5	2.6		
IS 9830		9.7	2.7		
IS 9839		33.0	7.7		
BTx623		46.8	12.3		
VS 702		19.5	8.0		
N 13	x Framida	15.5	7.0	221	12
	x SPV 103	4.8	3.8	18	-22
	x IS 9830	15.0	6.3	96	29
	x IS 9849	10.0	5.3	-48	-28
	x BTx623	51.2	12.2	95	26
	x VS 702	15.2	4.8	21	-36
Framida	x SPV 103	13.2	4.4	613	10
	x IS 9830	4.7	4.9	-32	21
	x IS 9849	28.8	10.1	56	54
	x BTx623	55.3	10.6	118	20
	x VS 702	13.5	6.4	15	-5
SPV 103	x IS 9830	12.0	8.3	97	215
	x IS 9849	15.7	6.7	-12	30
	x BTx23	4.2	0.4	-83	-95
	x VS 702	29.3	4.4	256	-16
IS 9830	x IS 9849	21.3	7.0	0	34
	x BTx623	25.3	7.6	-10	1
	x VS 702	14.2	5.0	-3	-6
IS 9849	x BTx623	49.8	9.3	25	-7
	x VS 702	14.8	7.7	-44	-2
BTx623	x VS 702	38.7	8.4	17	-17
Mean	20.85	6.65			
SE ±	7.01	2.18			

Table 10 : Analysis of variance table for combining ability analysis of sorghum varieties for *Striga* resistance

Source of variation	DF	Mean sum of Squares	
		Striga Number	*Striga* Fresh Wt
General combining ability (gca)	6	648.606*	17.627*
Specific combining ability (sca)	21	123.142*	5.025
Error	135	49.182	4.763
GCA/SCA		5.267	3.508

* Significant of 1% probability level

Table 11 : General combining ability effects (gca) of parents for *Striga* resistance in sorghum

	Striga number	*Striga* fresh wt
N 13	-4.860*	0.040
Framida	-1.970	0.100
SPV 103	-8.070**	-2.240**
IS 9830	-6.100**	-0.990
IS 9849	4.430*	0.920
BTx623	16.820**	2.220**
VS 702	-0.230	-0.040
SE (gi)	+2.164	+0.674
SE (gi-gj)	+3.306	+1.029

Significant of 5% probability level

Significant at 1% probability level

Table 12 : Striga resistance and grain yield of a few selected millet varieties

Entry No.	Pedigree	Grain Yield (kg/ha) - 1982: Aouréma U.Volta	Kamboinsé U.Volta	Farako-Bâ U.Volta	Maradi Niger	Louga Senegal	Mean	Striga: Aouréma 1983 (Mean No/plot[a])		In Pots[b] (% killed) 1982	1983
18	P2627-2-18	806	1440	730	2254	525	1151	2.2	(51)[c]	67	67
15	P2627-1-19	273	1116	703	2138	462	938	2.3	(67)	29	40
7	Inbred 5258-1-10	172	1602	730	1242	424	834	2.3	(61)	50	-
3	P2661-3-5	398	807	839	1546	321	782	1.9	(31)	14	7
2	Inbred 5258-1-19	715	452	573	1502	435	735	2.1	(63)	33	60
9	P449-1-29	299	1044	495	953	153	589	2.1	(49)	33	40
6	P2627-2-11	649	1698	1094	2499	664	1321	2.6	(80)	57	60
20	Local	420	-	896	3192	633	1285	2.2	(60)	100	60
	Ex-Bornu (susceptible check)							494[d]			
	Mean	433	1202	732	1828	507		2.3			
	SE ±	±164.7	±339.6	±360.2	±334.0	±251.1		±0.28			

a = Log transformed data

b = Number of plants killed expressed as percentage of total number of plants in each variety

c = Expressed as percentage of four adjacent plots of ex-Bornu in a checker-board layout

d = Number of emerged Striga plants/plot (6 m^2) averaged over 136 plots in four replicationss in the checkerboard

Table 13 : Grain yield, Striga resistance, and food quality of a few sorghum cultivars

Entry No	Origin	Pedigree	Grain yield[a] (kg/ha)	Number of Striga[b]				Food quality[c]	
				Kamboinsé	Pabré	Farako-Bâ	Sudan	Elast-icity	Taste
6	82-S-50	(IS 8785xE 35-1)-1-4-2	1044	1.7	2.3	1.5	1.2	67	73
7	82-S-51	(Framida x SPV 329)-2-1	949	1.8	1.8	1.7	1.4	NT	NT
5	82-S-49	(IS 8785xE 35-1)-1-4-1	887	1.0	2.0	1.9	1.7	NT	NT
3	82-S-47	(IS 8785xE 35-1)-1-4-3	809	1.8	1.9	1.8	1.7	80	80
18	82-S-53	(Framida x GG)-1-1-1	792	2.2	1.8	1.5	1.2	NT	NT
8	82-S-52	(Framida x SPV 105)-2	717	1.6	1.6	1.7	1.3	NT	NT
16	-	E 35-1	766	1.9	1.8	1.6	1.9	80	73
17	-	Framida	602	1.5	2.5	1.5	1.0	87	90
		Mean		1.81	1.91	1.70	1.51		
		SE ±		±0.23	±0.39	±0.49	±0.49		

a = Mean over seven locations in four African countries

b = Log (X+1.1) transformation of number of emerged Striga plants/plot

c = Food Quality (T6) is based on test by 15 villagers
Local variety is 93% and 100% for elasticity and taste respectively

NT = Not tested

Table 14 : Striga resistance and grain yield of a few selected F_5 progenies of millet

Entry No.	Origin	Pedigree	Number of Striga[a] Maradi		Number of Striga[a] Aouréma		Grain yield (kg/ha) Auoréma	
45	82W?13	(80R351-6-1xP 508-1)-1	1.2	(17)[c]	2.2	(59)[c]	122	(271)[b]
26	194	(Sel.Thiou-2-1-6xP 1538-1)-3	1.6	(39)	2.3	(62)	179	(398)
20	188	(P23-1-18xSerere 2 A-9-2-23)-4	1.3	(25)	2.1	(85)	202	(499)
14	182	(Sel.Thiou-4-1-4xSerere 2 A-9-2)-1	1.4	(25)	2.1	(59)	288	(640)
33	201	(Sel.Thiou-2-1-6xP1538-1)-7	1.1	(27)	1.9	(74)	197	(438)
34	202	(P 1527-1-4xP 23-1-2)-25	1.5	(31)	2.1	(51)	116	(258)
21	189	(P 354-3-24xP 2861-1-1-3)-6	1.7	(32)	1.8	(24)	139	(309)
8	176	(P 357-3-4xSerere 2 A-9-2-8)-4	1.7	(33)	2.1	(78)	286	(636)
46		Local	2.07	(78)	2.22	(59)	118	(262)
		Ex-Bornu (susceptible check)[d]	34		23			
	Mean		1.79		2.21		169.5	(377)
	SE ±		±0.32		±0.31		±76.29	

a = Log transformation of number of emerged Striga plants/plot

b = In parentheses kg/ha

c = In parentheses - number of Striga plants expressed as percentage of adjacent indicator row plot in sandwich layout

d = Mean number of emerged Striga plants/m^2, averaged over 120 plots in 4 replications in sandwich layout

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PATTERNS OF RESISTANCE TO STRIGA ASIATICA IN SORGHUM AND MILLETS, WITH SPECIAL REFERENCE TO ASIA

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INTRODUCTION

Striga, an old world root parasite of cereals and legumes, has attracted much attention of late, as a causative agent for serious losses in crop production in the semi-arid tropics. There are three general options available for its control : a) genetic (using resistant varieties); b) agronomic (using cultural manipulation and chemicals); and c) biological (using insect pests and pathogens). The genetic option appears to be economically the most viable because a resistant variety that can avert the subterranean damage by *Striga* is a non-cost input for the farmer. In this paper the distribution and nature of the *Striga* problem in different Asian countries is briefly described, with special reference to sorghum and pearl millet.

1. *Striga* in Asia

Striga is reported to occur in almost all sorghum-growing semi-arid parts of Asia, including India, Pakistan, China, Japan, Indonesia, Thailand and Burma. *Striga* is a serious problem in India and certain parts of Pakistan on sorghum and pearl millet. In other countries, *Striga* is a recognized yield reducer on crops such as maize (Thailand), sugarcane (Australia), and rice (Burma, Indonesia, Thailand). In addition to being a major problem on sorghum and pearl millet in restricted areas in India, *Striga* is also a problem on sugarcane, maize, rice and minor millets.

There are at least two morphotypes of *S. asiatica* occurring in Asia. White-flowered *S. asiatica* is reported from India, Pakistan and Burma, and a yellow-flowered variety is reported from Thailand and Indonesia. There are also reports of yellow-flowered types of *S. asiatica* in the Malnad tract of Karnataka state in India (Hosmani, 1978). There could be some implications of this with reference to host reactions and consequently on breeding of resistance lines.

2. *Striga* in India

In India, which has the largest area under sorghum in Asia, *Striga* was a problem with marginal economic implications for traditional farmers using local cultivars. The problem has, however, grown in magnitude since the introduction of hybrids, as all the released hybrids are highly susceptible. In several places sorghum cultivation has been abandoned because of *Striga* after some years of hybrid cultivation (House & V. Rao, 1982). Under traditional farming systems using local varieties, some *Striga* seed is always present in the soil because most local varieties are tolerant and yield well in spite of *Striga* infestations. Even though some local cultivars have evolved resistance because of their