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SESSION I

OPENING SESSION

Chairman: **R.W. Gibbons** Rapporteur: **B.S. Rana**

WELCOME ADDRESS

R.W. Gibbons

It is my pleasure today to welcome the Project Director and his colleagues from the All India Coordinated Sorghum Improvement Project at Rajendranagar, the scientists from the All India Dryland Project (AICRPDA) and scientists from various universities and institutions in the states of Andhra Pradesh, Maharashtra, Karnataka and Rajasthan. I am delighted that a working group on *Striga* has got together as a result of the recommendation of the Annual Sorghum Workshop held in May this year; and that it is jointly sponsored by AICSIP and ICRISAT. A joint Workshop of this sort, of the size of this one, and involving scientists of many disciplines can very effectively review the past and present work and formulate the future research strategies that are needed. The program looks very balanced with formal presentations, field vists and most important of all an afternoon session on the last day to discuss and plan for the future.

We all know the importance of the plant parasites that attack our crops and of these *Striga* must be the most important of them all although Alectra, a parasite on legumes, is causing more concern now in Africa than it did in the past. At ICRISAT we are fully aware of the *Striga* menace and have a *Striga* scientist working on both millet and sorghum in Africa. I am sure you all know Dr. Ramaiah as he used to work here at ICRISAT Center. We also have a strong program on *Striga* at the ICRISAT Center and I was very impressed with the breeding program of Dr. Vasudeva Rao when I saw it recently. I am glad you will have the opportunity to see this program during your field visit. We also have work on the management of *Striga* which Dr. Shetty will be talking about later.

Resistance is very important and it is very cost effective but we need to know a lot more about the parasite, its biology, the host parasite relationships and host specificities and strain x variety interactions. We also need to take a more detailed look at tolerance - and I use tolerance to mean whereby the plant can be attacked as though it were susceptible but yield is little affected. In those circumstances what happens to the parasite? Does it grow and reproduce so effectively on tolerant or resistant sorghum as it does on susceptible ones? Are the *Striga* seeds as viable ? I do not know these answers although they may already be well known to you. In groundnut rust for example we are finding that in highly resistant varieties the rust fungus has a longer incubation period and pustules are produced later, the pustules often do not rupture, if they do rupture then fewer spores are produced and their germinability is also reduced. Do we get a similar situation with *Striga* on resistant or tolerant hosts ? If we do then the menace becomes less because fewer seeds of the parasite are produced.

One of the reasons why *Striga* research in the past was spasmodic and fragmentary was because screening techniques both in the laboratory and in the field were unreliable. Great progress appears to have been made recently and biometrical advice is being sought and offered to facilitate reliable and reproducable results.

I am sure that your meeting will be both fruitful and useful. If you can reduce the *Striga* menace by a combination of a few or several strategies then the sorghum farmer will be eternally grateful to you. I look forward to reading the conclusions of this meeting and the proposed plan of action in due course.

Thank you.

OBJECTIVES AND SCOPE OF THE MEETING

R.V. Vidyabhushanam

Striga, the parasitic weed, has long been recognised as a serious problem on sorghum in India and many African countries. In India, it is known to occur in many parts causing severe damage to the sorghum crop. It is posing a serious threat to the cultivation of high yielding sorghum hybrids in some areas as they were found to be more susceptible to the pest. In view of this, there is now a greater awareness of the *Striga* problem and the need to combat the growing menace is being stressed in several forums.

The problem of *Striga* is a very complex one and is not amenable for an easy solution. Several control measures based on cultural, chemical, biochemical, biological and genetic methods have been evolved. Yet none of them could provide a satisfactory control and thus the problem continue to be as serious as before. An integrated approach involving the various methods is likely to be more rewarding for which appropriate technology is yet to be developed.

A great deal of valuable basic information is now available on host-parasite relationships. The different mechanisms of resistance and nature of their inheritance are better understood. Several diverse sources of resistance have been identified and some reliable laboratory and field screening techniques developed. Nevertheless, there are some gaps in our knowledge on various aspects of *Striga* and its control. There is a need to intensify efforts on management aspects to evolve simple and economic control measures which can be adopted by the farmers. Similarly, greater emphasis need to be placed in breeding for resistance.

It is felt that the current efforts in the country to tackle the *Striga* problem in an isolated way by several organisations will not be able to meet the challenge. The Annual Sorghum Workshop held in May, 1982 at Pune after careful consideration of the situation decided to organize a working group meeting with scientists involved in research on *Striga* to review the past work and decide the future strategy on control of *Striga*.

Such a meeting of active research workers on *Striga*, it is hoped, would afford an opportunity to exchange views and promote better understanding of the complex problem.

The meeting jointly sponsored by AICSIP and ICRISAT is convened to achieve the following objectives:

1. To understand the magnitude of the problem and to identify the areas affected by *Striga*.
2. To review the available information on *Striga* and its utilization in more effective control of the pest.
3. To identify the gaps in research and fix priorities for future research needs.
4. To critically examine the various suggested methods of *Striga* management and control to ascertain the prospects of their practical utility.
5. To explore the possibility of evolving an integrated control strategy based on practical considerations.
6. To discuss the implications of *Striga* problem under various cropping systems.
7. To evolve appropriate breeding methodology to combine *Striga* resistance with high yield.
8. To consider the various laboratory and field screening techniques for evaluating resistance to *Striga* to identify more reliable procedure.
9. To develop collaborative work plans between AICSIP, ICRISAT and other Organizations involved in *Striga* research.

The present research efforts on *Striga* in the country are grossly inadequate and are also not carried in an organized way. As pointed out earlier, the problem is a very complex one requiring a multidisciplinary team approach and coordination of work at National level. The major aim of the meeting is to promote such a coordinated team approach.

It is hoped that the discussions in the present meeting will lead to better understanding of the problem and increased research input enabling to achieve a quick breakthrough in *Striga* control.

STRIGA - PROBLEMS AND PROSPECTS[1]

L.R. House and M.J. Vasudeva Rao[2]

Striga, a root parasite of most cereals, is recognized as a serious problem of the sorghum crop in several countries. *Striga* sp. has a wide range of hosts including several economically important crops of the semi-arid tropics. In this paper, an attempt is made to analyse the *Striga* problem and highlight the shortcomings of the present research capabilities to effectively counter this menance.

The Problem

Among the 25 odd species of *Striga* reported to occur in the world, only three species are considered to be of economic consequences. They are *S. hermonthica* and *S. asiatica* parasitizing sorghum, pearl millet, sugarcane, maize, rice and several minor millets and grasses, and *S. gesnerioides* parasitizing cowpeas. *Striga densiflora*, a species among the lesser known members of the genus *Striga* is important in the Deccan rabi sorghum areas in India. *Striga* is a known old world tropical and sub-tropical species, mostly confined to Africa, Asia and Australia. It is an introduced species in USA. Tarr (1962) reports that though it is not found anywhere else in the Western Hemisphere, it will eventually find its way into Central and South America.

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[1] A working paper presented in the ICRISAT-ICAR Working Group Meeting on *Striga* Control, 30 Sep - 1 Oct 1982, ICRISAT Center, ICRISAT Patancheru P.O., Andhra Pradesh 502324, India.

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Striga is a well recognized problem for centuries in different countries in the Semi-Arid Tropics. Work on control measures for *Striga asiatica* started as early as 1910 in India, Burma and South Africa. Work on control measures to reduce *S. hermonthica* in East Africa began in the 1930's. Parker (1982) quotes Watt (1936), who published recommendations like manuring, rotation etc. to control *Striga*. Pulling out of *Striga* plants was made compulsory and farmers got into the habit of pulling out flowering *Striga* plants and throwing them on the road prior to the arrival of officials to make it obvious that they are obeying the regulations.

In India, *Striga* was a problem with marginal economic implications to the traditional farmer. Most of the local cultivars are not absolutely resistant to *Striga*; however, they are highly tolerant. Consequently, a small *Striga* population is always present and in years highly favorable to *Striga* build up, it assumes economic proportions even on the local cultivars. However, some *Striga* resistant local cultivars have evolved in pockets where soils and climate are highly favorable to *Striga*. For example, the local red types of sorghum used in the Telangana region of Andhra Pradesh are known to be *Striga* resistant and farmers, in casual discussion, indicated that the local reds are grown in severely infested fields. However, they are not grown extensively because they fetch a lower price in the market due to their unacceptable color.

The *Striga* problem in India has certainly grown in magnitude since the introduction of new hybrids. CSH-1, which is cultivated on large areas in Maharashtra and other states, is highly susceptible to *Striga*. Several examples are available where fields were abandoned after the hybrid had been grown for several years. A reason for this meeting is to recommend a stronger research thrust to counter this increasingly severe problem in the country.

The Biology and Distribution of *Striga* Species

Many researchers have described different species of *Striga*. Several reports are available describing about 50-60 species. Musselman (1980) is of the opinion that there could be only about 25 species and has given a comprehensive list of *Striga* species which are of economic importance. However, taking into account the global economic loss caused to food crops, only the following species appear important: *S. asiatica*, *S. hermonthica*, *S. gesnerioides* and *S. densiflora*. The last one occurs only in India. There is a vast amount of confusion in identification and classification of the different species of *Striga*. The descriptions available are incomplete, especially for those species which are of less economic importance.

S. hermonthica is distributed exclusively in the African continent north of approximately 5° south longitude extending from Senegal in West Africa to Egypt in east. *S. asiatica* is more widespread compared to *S. hermonthica*. The white flowered form of *S. asiatica* is found in India, while the red flowered form is present in South African region. The yellow flowered types is present in South Asian countries. The red flowered types in USA is supposed to be introduced from one of the South African countries. It is interesting to note that the distribution of the *S. hermonthica* and *S. asiatica* are mostly exclusive. However, two recent reports (Renaud 1982 and Musselman and Parker 1982) indicate the possible existence of red and yellow flowered *S. asiatica* in West Africa.

An interesting observation was recently made by Musselman and Parker (1982) that *S. hermonthica* is cross-pollinated while the red flowered *S. asiatica* of USA is self-pollinated. Further it has been now shown both in *S. hermonthica* and *S. asiatica* that an enormous amount of variability exists in the naturally occurring populations of striga. Vasudeva Rao et al. (1982) showed that variation existed in the white flowered *S. asiatica* for corolla shape and size, rooting habit, branching habit, leaf shape and size and seed characters. Also, it is known that in certain parts of India, all three white folwered *Striga* species coexist together in the same field. These observations indicate that the natural populations of *Striga* are not a single *Striga* type as is generally understood but are "polymorphic complexes" including different species morphological variants, and possibly physiological strains.

The Host-Parasite Interactions

Striga is a root parasite which spends a considerable portion of its destructive phase in a subterranean form. With high levels of *Striga* infestation, the symptoms of attack appear much earlier than their emergence above ground. Severe subterranean *Striga* pressure results in symptoms similar to those of drought even when the soil is saturated with moisture. However, *S. hermonthica* induces chlorotic lesions on sorghum leaves unlike the drought symptoms of *S. asiatica* (Parker, personal communication). The damage symptoms are severe on poorer soils with low fertility.

A "poisoning" effect of the *Striga* on the host has been suggested because the stunting of the host cannot be explained in terms of the nutrient loss only. Drennan and El-Hiweris (1979) reported that the levels of cytokinins and giberrelins was markedly low in sorghum plants paratisitized by *S. hermonthica* compared to unaffected plants. The concentration of inhibitors like abscissic acid and farnesol, however, increased slightly in the parasitized plants.

Recently Musselman (1982) postulated that one other way in which *Striga* could damage the host is by causing a disruption of the host growth regulating system. This it does by absorbing the sugars in the roots thereby reducing the nitrogen carrying capacity of the phloem of the host roots to the aerial parts of the host. This reduces photosynthesis because of a shortage of nitrogen, which results in a reduced amino acid synthesis and growth of the host. Consequently, the amount of photosynthates carried to the roots is lowered. Thus a vicious cycle is established.

Parker (1976) reported an interesting discovery that the infestation by *Striga* has a stimulatory effect on the host roots. The host shoot growth is inhibited resulting in a pronounced increase in root : shoot ratio.

Another direct effect of *Striga* includes a differential absorption of minerals including P, K, S and Fe (Musselman 1980).

Individual *Striga* plant causes very little damage. Doggett (1965) estimated that the losses ranged from 1.8 to 3.0 lbs grains for every 1000 *Striga* plants per acre. The virulence of *Striga*, thus, lies in their enormous numbers which collectively result in losses upto 95% of the potential yield.

Crop Loss and Estimates

Systematic work on crop loss studies with _Striga_ are conspicuously sparce.

Parker (1982) summarized the situation on _Striga_ yield loss estimates - "The scale of the problem certainly deserves increased research effort but what is the exact scale of the problem? Can we say how much yield is being lost? In the past, any effort at estimating yield losses have depended on very indirect statistical procedures and the results have not been dramatically convincing." O.J. Webster considers _Striga_ to be the primary yield limiting factor in Western Africa (personal communication).

The few estimates of crop loss due to _Striga_ which are available are described below.

Parker (1982) quoted Sawyer (1925) to have reported a 4-46% loss to sorghum caused by _S_. _asiatica_ in Burma. Lewin (1932) reported that _Striga_ was evident on maize in Southern Rhodesia in 1916 and in spite of efforts to control it, _Striga_ was affecting some 70,000 acres of cultivated land in 1929. Saunders (1933) reported from South Africa that _Striga_ caused enormous crop losses to maize and estimated it to be greater than the combined losses due to all funfus diseases and insect pests except stalk-borer. Hosmani (1978) reported that _Striga_ in India causes a yield loss ranging from 15 to 100% depending on the severity of infestation. He further reported that in Andhra Pradesh alone, 25,000 tons of sorghum grain worth Rs.60 lakhs annually is lost due to _Striga_.

Losses caused by Striga to other economically important host crops like sugarcane, maize, pearl millet and other minor millets are not available. In India, it is reported that Striga attacks pearl millet only in the Northwest (Gujarat and Rajasthan). However, last year we noticed severe Striga infestation on pearl millet near Anantapur. Casual discussions with local farmers indicated that it is doing similar damage in nearby villages also.

Current Status of Research

The Proceedings of the recent Striga Workshop held in Ouagadougou, Upper Volta, last October presents a reasonable statement of the current state of work on Striga. The International Development Research Centre of Canada (IDRC) has provided funding for the Striga research of ICRISAT in Upper Volta and of Striga research in the Sudan. There has been a growing concern that the investment on control of Striga is so inadequate with respect to the magnitude of the problem that it raises a question of the usefulness of the present level of investment. This is a relatively pessimistic view; overly pessimistic in the light of recent development of agronomically good resistant lines. Striga research in the world follows many avenues of investigation - breeding for resistance, cultural control, mechanisms of resistance, germination stimulants, morphological and taxonomic considerations. Some initial steps have been taken to organize a working meeting of donors and knowledgeable scientists to explore ways to strengthen coordination of these activities and to strengthen the overall research input. Once the Proceedings of the Striga Workshop are available we will pursue this international meeting. Research activities on *Striga* over the years in India have included many relevant topic areas. Hopefully, past research can be evaluated and from this meeting we can project a coordinated research thrust that can be presented to the ICAR and others for planning and support consideration.

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SESSION II

SETTING THE SCENE

Chairman: **R.V. Vidyabhushanam** Rapporteur: **P. Joshi**

GENETIC CONTROL OF STRIGA ASIATICA IN SORGHUM[1]

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

1. INTRODUCTION

Striga species are root parasites causing losses in economic proportions to several important food crops in the semi-arid tropics. Breeding resistant varieties offer an economically viable option to control this problem for two reasons - (i) a resistant variety is a noncost input in any improved technology and (ii) no other control method than genetic resistance is able to lessen the subterranean damage by Striga.

In this paper we describe briefly the history of breeding sorghums for Striga resistance and present the progress at ICRISAT Center on Striga resistance breeding activities.

2. PAST WORK ON BREEDING SORGHUMS RESISTANT TO STRIGA ASIATICA

The earliest efforts on breeding Striga resistant sorghums were by Saunders in South Africa (Saunders 1933) who started some classical studies on Striga in 1920's at Rotchefstroom farm in Transvala, Natal, South Africa and made some selections for Striga resistant sorghum varieties. It led to the release of 'Radar' and several other resistant varieties. However, the resistance in 'Radar' eventually failed probably

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[1] A working paper presented in the ICRISAT-ICAR Working Group Meeting on Striga Control, 30 Sep - 1 Oct 1982, at ICRISAT Center, ICRISAT Patancheru P.O., Andhra Pradesh 502324, India.

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due to outcrossing and consequent loss of purity (Grobbelaar 1952). In India, work on breeding sorghums resistant to Striga asiatica started as early as 1933. Bilichigan, a selection made from local Maldandi was developed in erstwhile Bombay State. During the same period, several other varieties like Mudinandyal, Burma K.K., Burma Y.K., Agikodal and Malleswar were found to be resistant to Striga (Jenkins 1944). There were also some attempts to make crosses between the local sorghums and the resistant types in the erstwhile Bombay and Madras States.

Hosmani (1978) has comprehensively described the past work on resistance breeding in India. The following varieties were reported resistant to S. asiatica.

Genotype	Remarks	Reference	Place
Bilichigan	Selection from Maldandi	Gadgil (1933)	Temburni
Mudinandyal Burma K.K. Burma Y.K. Agikodal Malleswar	Resistant in pot tests	Jenkins (1944)	Poona
Burma K.K. x Bonganhilo	Selections made	Chavan (1952)	Mohol
S. versicolor S. purpureosericeum S. nitidum	Difficulty in transfer - chromosome numbers different	Deodikar (1951)	Poona
AS 4003 (Bonganhilo) AS 4693 (Bilichigan) CO-7, CO-11 CO-20 (AS 9028)	-	Sivaraman (1952)	Coimbatore
N-13	Selection from local Patcha Jonna	Nagur et al. (1962) Venkateswara Rao et al. (1970)	Nandyal

BH-4-1-4	Resistant to SDM	Kajjari et al. (1967)	Bailhongal
BO-1	Selection from NJ-156	Khade	Akola

A study of the past efforts to breed *Striga* resistant sorghums indicate that the progress is not commensurate with the effort. The following broad conclusions can be made.

(i) The past research programs have not been adequately sustained; most have had short term objectives and were terminated after partially achieving the objective.

(ii) Most screening has been done either in pots or natural *Striga* sick fields.

(iii) Even where *Striga* seeds were added to the soil, the infestation has not been uniform.

(iv) The number of good sources of resistance are few and extensive effort to cross them to direct and speed up the evolution of *Striga* resistant lines has been conspicuously inadequate in the past.

Following are some of the possible reasons for the slow progress in breeding for *Striga* resistance.

(i) Absence of long term support, both fiscal and physical to sustain the continuity of the research efforts.

(ii) Absence of absolute resistance to *Striga* resulting in confoundin the resistance and tolerance effects of the host, thus, reducing the chances of obtaining a real resistant type.

(iii) Probably of greatest importance has been the difficulty of reliable screening Procedures for field resistance.

3. BREEDING FOR *STRIGA* RESISTANCE AT ICRISAT

ICRISAT *Striga* resistance breeding work has the twin objectives of identifying resistant sources (gene identification) and transferring the resistance to varieties with agronomically good background (gene transfer). *Striga* resistance in the field is the final result of action and interactions involving at least the three reported mechanisms of resistance, viz., low stimulant production, mechanical barriers to haustorial penetration and unidentified antibiosis factors. A good foundation to the ICRISAT *Striga* resistance breeding work was laid by Dr. K.V. Ramaiah by screening the sorghum germplasm for low stimulant producers. We have screened nearly 14,000 germplasm lines against *S. asiatica* and a set of 640 lines have been identified as low stimulant producers.

3.1. Low Stimulant Producing Lines and Field Resistance to *Striga*

Screening for low stimulant production in the laboratory will be useful only if the laboratory results are well correlated with field reactions. However, it is improper to expect a perfect correlation since there could be mechanisms other than low stimulant production contributing field resistance to sorghum lines.

Screening for low stimulant production is a valuable adjunct in a *Striga* resistance breeding program. 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 five locations (Vasudeva Rao et al. 1981). Twenty three advance generation progenies were found to be field resistant at two to four locations. In all the three trials at all the locations, the proportion of field resistants in the low stimulant category was higher than the proportion of field resistants in the high stimulant category (Table 1). All the field resistant 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 turned out to be field resistant. 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 final selections appear to be better. Further to these preliminary indications, the breeding lines in the advanced trial during kharif 1981 were used to obtain simple correlation coefficient between stimulant production and field reactions at the three locations where they were tested (Table 2). All the r values were positive and only those from Akola and Bhavanisagar significant. At Akola, a very high r value was obtained. The correlation coefficient thus indicated that the stimulant production could be a useful indicator of field reaction.

Interlocation correlations were obtained for field reactions and stimulant production to know the predictive value of screening work at one location to the results of other locations (Table 3). Results indicated that all the correlation coefficients were positive and some were highly significant. It appeared that the field reactions and stimulant production could be more confidently predicted between some locations as compared to others. This needs more analysis using larger samples and *Striga* from diverse locations.

3.2. Identification of Sources of Resistance

Since 1977, lines reported to be resistant to local strains of Striga are being tested multilocationally to identify strong source lines for resistance (Vasudeva Rao et al. 1982). There is no absolute resistance to S. asiatica in sorghum and the best available sources are low susceptibles N-13, 555, IS-2203, IS-4202, IS-7471 and IS-9985 appear to be promising as source lines for use in breeding programs. Apart from these sources of field resistance, a set of 640 low stimulant producing germplasm lines constitute possible source for which evaluation of field resistance is required. N-13 is an identified source of mechanical barriers. However, the identification of other sources for different resistance mechanisms is required.

3.3. Transfer of Resistance to Elite Backgrounds

Several hundred crosses have been made over the past few years between different sources and agronomically elite and adapted stocks at ICRISAT Center. Absence of a fool-proof screening technique to identify individual plants in segregating progenies that have field resistance to Striga constitutes a major hurdle. The segregating material has been advanced in Striga sick fields and selected for low levels of susceptibility. Selection has also been to correct undesirable traits in the original source lines, retaining Striga resistance, so that they can be used as good breeding stocks. In this process, many of the source lines have been eliminated since they do not offer good segregates. 555, a resistant source line, has been a common parent in a number of useful advanced lines. The best advance generation progenies are being identified as SAR (*Stri* *asiatica* Resistant) lines. Several of the SAR lines are now doing very well in multilocation *Striga* resistance trials. Resistant sources other than 555 like N-13, SRN-4841 are found in the pedigrees of new SAR lines. Performance of the selected SAR lines is presented in Table 4. It is to be recognized that the *Striga* resistant advance generation lines are not yet very high yielders. None-the-less, SAR lines are good breeding stocks as some undesirable traits like plant height and late maturity of the original sources have corrected without loosing the *Striga* resistance.

4. STABILITY OF *STRIGA* RESISTANCE

Striga is a very versatile parasite capable of adapting to different hosts, different environments, and probably capable of adapting to the commonly grown host variety over a short period of time. *Striga* has the capacity to attack many crops and there could be more than one species of *Striga* coexisting in the same location as a "complex". Hence, it is not only essential to incorporate resistance to *Striga* at one location for one species, but also necessary to have resistance across all the species occurring in the region. Recent observations from near Anantapur, where *Striga* in a restricted area, has adapted itself to pearl millet, indicates the need for close monitoring of *Striga* appearance on that crop in other areas.

Another aspect that needs to be considered is the breakdown of *Striga* resistance in the identified striga resistant varieties. "Radar", the variety resistant to the South African *S. asiatica*, failed to maintain resistance after ten years. Similarly, N-13 is also noticed to be loosing its resistance under severe drought and higher infestation levels. Whether this is a "breakdown" of resistance, or "adaptation" of the parasite, or is an environmentally induced temporary breakdown of resistance is a subject for future research.

The necessity of breeding lines with stable resistance is apparent. The resistance has to hold against, at least the species occurring in any geographical region, and all the different morphotypes and physiological strains of the same species. Future breeding efforts have to be directed to achieve stable resistance to Striga.

5. OTHER STUDIES ON STRIGA AT ICRISAT CENTER

Apart from major efforts on breeding, some preliminary studies and observations are being made at the Center which are expected to lead to a better understanding of Striga. Results from some of these studies are described below.

5.1. Strain Situation in Striga asiatica

Striga asiatica exhibits variability in plant structure and flower color and geographical distribution. Besides, Striga, as a genus appear to posses intrinsic physiological differentiation leading to the existence of physiological strains. Though there are indications of the existence of strains in Striga hermonthica (King and Zummo 1977), they are yet to be established in Striga asiatica. Preliminary observations indicate that there are morphological variants, and different species coexist 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. *Striga asiatica*, *Striga densiflora* and *Striga angustifolia* coexist in regions in India where both rainy and postrainy sorghums are grown. In Northwest India, *Striga* attacks millet and not sorghum while in other regions, *Striga* attacks sorghum, sugarcane, maize and some minor millets and not pearl millets (Hosmani 1978). These observations thus indicate that the native *Striga* populations cannot be considered as a single *Striga* type and that it exists as a complex containing different species, morphotypes and probably physiological strains.

With this background, an experiment was carried out in the 1981 rainy season at Patancheru with *Striga asiatica* collected from five different locations in India on three resistant and one susceptible cultivars utilizing the wooden flat technique (Vasudeva Rao et al. 1982). Results indicated that N-13 and IS-5106 were found resistant at all locations while SRN-4882B was found resistant to *Striga* from three and susceptible to *Striga* from two locations. Further, the analysis of variance showed that there were significant strain x variety interactions indicating that the cultivars reacted differently to *Striga* collected from different locations. However, existence of varieties which offer stable resistance across strains is a useful indication.

5.2. Cross Infectivity Studies

It is known that *Striga* attack several crops like sorghum, maize, sugarcane, millets, rice and several grasses. In some areas like North-western India, host specific strains of *S. asiatica* (specific to pearl millet or sorghum) could be found. However, in most parts of India, the same species is known to attack different crops in adjacent or the same fields. In order to find out whether there was any host specificity with the *Striga* populations, a cross infectivity study was undertaken using the following contrasts.

Striga hosts	Location of striga collection	Remarks about *Striga*
Maize vs sorghum *Striga*	Taddanapalle, AP	Miaze had a higher proportion of *S. densiflora* while sorghum had a higher proportion of *S. asiatica* in its *Striga* populations.
Sugarcane vs sorghum *Striga*	Bhavanisagar, TN	*Striga* on both the crops was *S. asiatica*.
Pearl millet vs sorghum *Striga*	Near Anantapur, AP	Fields were separated by about 10 km. *Striga* recently seen to be causing economic damage to pearl millet in a small area near Anantapur.

Striga seeds collected from these crops in the same season were used to infest a set of a resistant (IS-7471) sorghum, a susceptible (Swarna) sorghum and the other host which originally was infested. Results (Table 5) broadly indicated that *Striga* attacking sorghum, maize, sugarcane were not different from each other for their infectivity. However, very interestingly, in the pearl millet and sorghum contrast, the sorghum *Striga* was seen only on sorghum and not on pearl millet, while pearl millet, *Striga* was seen infesting both sorghum and pearl millet. This is being further studied.

6. SUMMARY

Among the several options like genetic, agronomic and biological methods being researched for Striga control in sorghum, breeding resistant varieties appears to be economically important as part of a Striga management strategy. Progress on breeding work, in the past as well as the work at ICRISAT indicate the availability of strong source lines and some converted source lines for use as breeding stocks. Low stimulant production screening has been a useful indicator of field resistance. Preliminary observations and studies have indicated that Striga is a very versatile species capable of adapting to other hosts. Hence, a careful monitoring of other plant hosts is required and breeding of varieties with stable resistance is stressed.

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Table 1. Proportions of field resistant lines in low and high stimulant breeding lines - 1980K

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	0.00	-	-	2	25.0	1	12.5
	Total:	31	16	51.6	12	38.7	6	19.4	-	-	12	38.7	5	16.1
3	Low	34	21	61.7	10	29.4	22	64.7	-	-	-	-	8	23.5
	High	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 2. Simple correlation coefficients between field resistance and stimulant production (Kharif 1981; advanced trial in checker board layout, 13 breeding lines).

Location	
Akola	0.910
Bhavanisagar	0.650
Bijapur	0.344

Table 3. Interlocation simple correlation coefficients for stimulant production and for field reactions to *Striga* (Kharif 1981; advanced trial in checker board layout, 13 breeding lines).

A. For Field Reactions

	Bijapur	Bhavanisagar
Akola	0.802**	0.473
Bijapur	-	0.664*

B. For Stimulant Production

	Bijapur	Bhavanisagar
Akola	0.166	0.904**
Bijapur	-	0.310

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No	SAR#	Orig n	Pedigree	ga counts %				
					Bh va ag	Bijapur	CS an	Average
1	SAR-1	53/1	(555 x 168)-H	6.07	5.21	1 27		4.18
2	SAR-2	53/2	(555 x 168)-16	6.81	16.61	0 00		6.81
3	SAR-3	53/3	(555 x 168)-23-1	26.00	19.89	1 35		15.75
4	SAR-4	53/4	(148 x 555)-bk	13.17	37.08	0 90		17.05
5	SAR-5	53/5	(148 x 555)	2.89	11.92	0 49		5.10
6	SAR-6	53/6	(148 x 555)-33-1-3	10.89	3.18	0 00		4.69
7	SAR-9	53/12	[SRN-4841 x (WABC x P-3)	8.95	15.96	5 57		10.16
8	SAR-10	53/13	[555 x (PD x CS-3541)-29 -5-2-1	3.33	29.74	2 04		11.70
9	SAR-11	52/16	(555 x Awash-1050)-2-2	3.10		4 70	7.60	7.70
0	SAR-12	52/27	(SRN-4841 x SPV-104)-17	7.20		0 10	8.30	8.30
11	SAR-13	52/32	(555 x 168)-1	2.10		4 00	9.50	5.40
2	SAR-14	52/47	(Framida x 148)-21-2-2-4	4.10		30	1.10	2.00
13	SAR-15	52/78	(555 x 168)-23-2-2-3-2	2.80		70	6.60	3.70
	SAR-16	52/79	(555 x 169)-19-2-7	5.00		30	18.90	9.30
	SAR-17	55/8	(N-13 x IS-269)-5-2	5.90			-	5.90
	SAR-18	55/15	1	7.90			-	7.90
			SH- Suscep check	00.00		00	00.00	00.00

Table 5. Results from cross infectivity studies (Kharif 1982; 75 day observations; wooden flats; 3 replications).

Host from which *Striga* seed was collected	Test host	
	Maize	Sorghum
A. Maize	+	+
Sorghum	+	+
	Sugarcane	Sorghum
B. Sugarcane	+	+
Sorghum	+	+
	Pearl Millet	Sorghum
C. Pearl Millet	+	+
Sorghum		

+ = *Striga* infestation seen

- = Striga infestation not seen.

AGRONOMIC AND CULTURAL METHODS USED FOR CONTROL OF STRIGA

M.M. Hosmani*

Many workers still believe that chemical control of *Striga* would be costly. Only feasible methods are evolving varieties which are resistant to *Striga* which is a time consuming process. In absence of this, alternate measures are agronomic methods of control of *Striga* by manipulating cultural practices, crop rotation, fertilizer management and water management.

Turning now to practical control measures, first severe infestation must be greatly reduced before susceptible crops can be profitably grown. The aim must be to reduce viable seed population as rapidly as possible. It is known that longevity of *Striga* seeds in the soil is such that even after several years of fallowing or cropping with non-susceptible crops, the infestation will not have died out. Many cultural operations and agronomic practices have been known to reduce the intensity of occurrence of witchweed. These practices viz., crop rotation, fertilizer management, effect of moisture, tillage and other practices on viability of striga seeds and minimising *Striga* incidence are discussed.

Crop Rotation: The value of using catch crop and trap crops to minimise or eradicate witchweed offers intriguing possibilities. Among its peculiariaties, is the necessacity for presence of chemical substance that initiates the germination. Some plants provide this material. A 'catch crop'

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is that crop with roots exuding the proper germination stimulus capable of parasitising the crop. The mature witchweed plants have to be destroyed before seed set. A 'trap crop' is a crop with roots that provides proper stimulating substance for germination of witchweed but the crop is not parasitised. Exhaustive list of catch crops and trap crops for each of the species of striga is available. Fortunately, there are for each species of *Striga*, a number of pseudo-hosts, which stimulate the germination of the parasite, yet cannot themselves be parasitised. For *Striga asiatica* - cotton, groundnut, cowpea, sunflower, linseed and castor act as pseudo-hosts. These trap crops have been main stay of striga control programme in many regions as they don't involve extra costly operations. In four-five years even very severe infestations can be brought under control (Luthra, 1921, Coleman, 1920, Andrews, 1945, Doggett, 1954, Narasimhamurthy *et al.*, 1957, Yaduraju, 1975).

An alternate to trap cropping is catch cropping, susceptible crop is grown closely to encourage maximum germination of *Striga* seed and is harvested before the weed has set seeds. Catch crops are fodder or green manuring crops. Sorghum for fodder purpose harvesting in about 70 days after sowing is used for the purpose (Annon., 1918, Timson, 1929, Last, 1961).

Efficiency of these trap and catch crops in stimulating *Striga* seeds can be assessed by using double pot technique, glass plate technique by raising seedlings in cotton wool in bell jar (Fig 1) (Hosmani and Parker, 1980; Reid and Parker, 1979, Krishnamurthy *et al.*, 1981). However, these techniques need to be standardised.

Fertilizers: Occurrence of witchweed in general, is considered exhaustion of soil. It has been known that *Striga* occurs in impoverished soil rather than fertile soils. Addition of fertilizers, particularly nitrogenous nutrient often reduces the severity of *Striga* attack and increase the yields of infested crops. Addition of nutrients increases the osmotic pressure of host tissue and reduces the osmotic pressure gradient toward the parasite, this gradient reduction decreases the ability of the parasite to survive. Several workers have observed lower incidence of *Striga* by application of heavy doses of nitrogen more than double the quantity of recommended dose for the crop and increased yields (Last, 1960; Mathur and Mathur, 1967, Egley, 1971, Prabhakar Setty, 1980, Guled, 1982).

Moisture: It is general experience that incidence of *Striga* is not uniform every year even in the fields artificially infested with *Striga* seeds. The germination of witchweed depends upon the age of seed and a combination of suitable moisture, temperature, light and physiological factors. It is generally observed that under excessive rainfall years, intensity of witchweed infestation is low compared to normal or drought years. Many workers have reported negative correlation with soil moisture and *Striga* incidence (Luthra, 1921, Uttaman, 1949, Govind Rao, 1953, Andrews, 1945; Nelson, 1958, Sreeramulu, 1959, Joglekar et al., 1959, Eplee, 1975, Murthy and Maheswar Reddy, 1976).

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Table 1. Effect of crop rotation with cotton on *Striga* population/ (Doggett, 1954)

Jowar Followed by cotton	1,160
Continuous jowar	4,010

Table 2. Influence of different crops on *Striga* seed germination - average of two years (Narasimhamurthy et al. 1957)

Crops	No. of *Striga* seeds germinated
Jowar	21
Cotton	65
Cowpea	10
Groundnut	1
Greengram	Nil
Safflower	1

Table 3. Effect of fertilizers on *Striga* population and yield of bajra (Mathur and Mathur, 1967).

Treatments	No. of *Striga*/ plot	Grain yield in kg/ha
Control	79	494
22kg N/ha	57	857
22kg P_2O_5/ha	54	551
22kg K_2O /ha	77	534
22kg each of NPK/ha	29	813

Table 4. Effect of 3 levels of mineral nutrition upon sorghum parasitised (P) by witchweed and non-parasitised (NP) (Egley 1972)

Sorghum parts	No Hougland		Hougland solution		Hougland solution double strength	
	NP	P	NP	P	NP	P
Entire plant	6.0	2.4	23.6	9.9	34.0	21.5
Shoot	3.9	0.8	16.5	3.4	24.0	13.1
Root	2.2	1.3	9.1	6.2	9.9	8.4
Grain	1.6	0.0	5.0	0.0	10.1	5.0

Table 5. Effect of nitrogen levels on *Striga* population/plot (Prabhakar Setty, 1980)

Nitrogen levels	*Striga* population/plot, Days after sowing			
	60	75	90	at harvest
0 kg N/ha	6.6	12.0	13.0	8.0
50 kg N/ha	0.0	1.6	7.6	4.0
100 kg N/ha	-	-	-	-
150 kg N/ha	-	-	5.0	4.0
200 kg N/ha	-	-	2.0	3.0

Table 6. Effect of nitrogen on striga population (Guled, 1982)

Treatments	*Striga* counts/plot, Days after sowing				
	50	60	70	90	at harvest
Control	153.5	148.2	166.5	166.2	165.2
100 kg N/ha	13.0	21.5	26.0	7.5	10.2
200 kg N/ha	12.0	19.5	20.2	6.2	5.5
300 kg N/ha	9.2	12.5	12.0	3.0	4.7

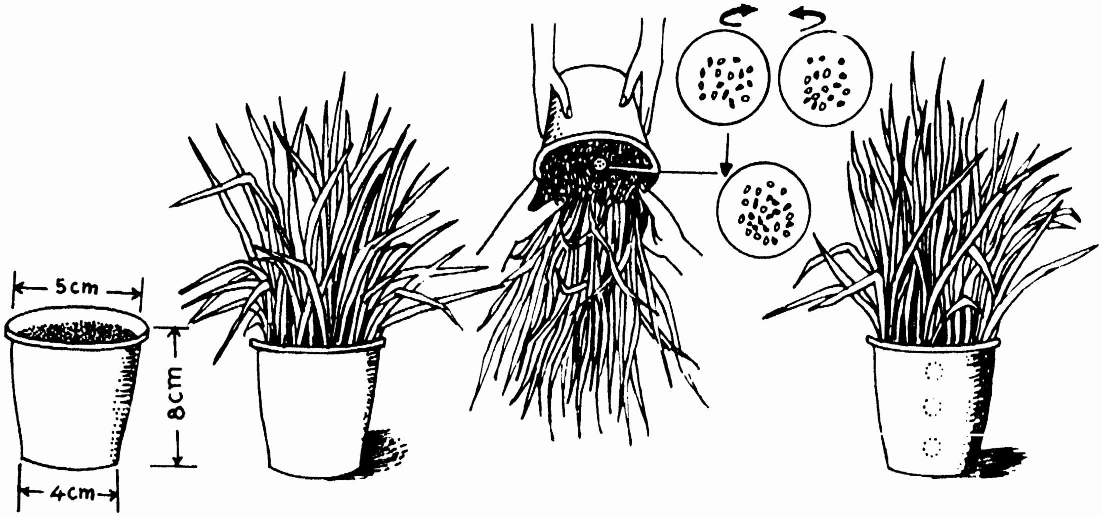
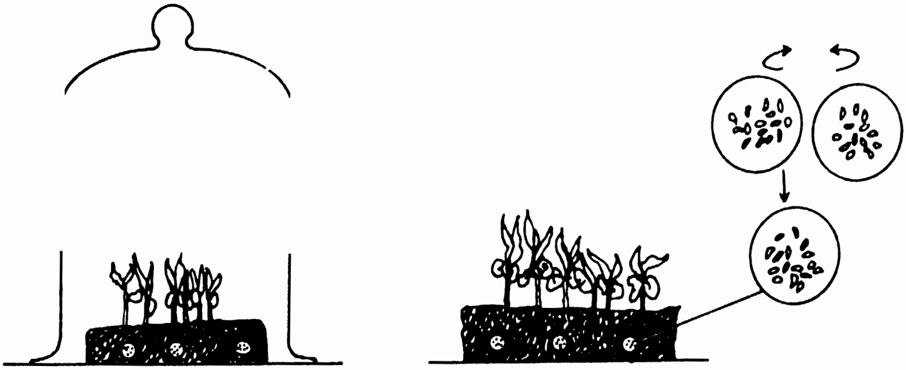


Fig. 1. Screening of crops for *Striga*.



CONTROL OF STRIGA BY CHEMICALS

M.M. Hosmani*

Various chemical treatments have been developed and used to eliminate manual weeding. Since the parasite emerges close to the base of the host, mechanical hoeing will leave number of them untouched. Moreover emergence of *Striga* usually takes place about 2 to 3 months after sowing of the crop by that time general hand weeding operations have been completed. Thus *Striga* control has to be attended to separately.

A number of chemicals have been used for control of this parasitic weed as pre-plant soil incorporation, pre-emergence spray and post-emergence spray. Recently stimulants and systemic herbicides have been successfully used. A brief review about the use of chemicals is described.

Pre-plant application. Pre-plant soil incorporation of Fenac (2,3,6 - trichlorophenyl acetic acid; at 2lb/acre followed by 2,4-D as a post-emergence treatment controlled *Striga* effectively. Fenac controlled all other weedy grasses in corn. (Dowler *et al.* 1963). Trifluralin (a, a, a-trifluoro 2,6-drinitro-N, N-dipropyl-P-toluidine) at 1-2 kg/ha and methyl bromide at 650 lb/acre as pre-plant application controlled all annual weeds and *Striga* very effectively. (Langston and Eplee, 1974).

Pre-emergence treatment. Pre-sowing hardening of sorghum seeds with vanillic acid, caffecic acid and ferulic acid at 25 ppm reduced the incidence of S. asiatica (Bharathalakshmi and Jayachandra, 1980). Controversial reports regarding control of *Striga* by atrazine, and 2,4-D have been reported. (Yaduraju, 1975, Bebawi and Farah, 1981) as preemergence spray in cereal crops.

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Post emergence treatment. Repeated application of 2,4-D or MCPA commencing from 3 weeks after sowing of crop but before emergence of Striga and also after emergence of *Striga* have successfully been used. But these herbicides were not effective against some grassy weeds which act as alternate host for *Striga*. After 1969, tank mixed 2,4-D and paraquat as a directed postemergence spray at 1 kg each per hectare have been extensively used for control of *Striga* in almost all the countries where there is *Striga* problem. Joglekar, et al 1969, Kurdikeri, 1972, Eplee and Langston, 1970, Yaduraju, 1975, Prabhakar Setty 1980).

Use of Stimulants. A major break through to eradicate *Striga* in USA was achieved when ethylene gas (C_2H_4) was found to be effective in stimulating germination of *Striga* seeds. Recently strigol analogues have shown a promise eradication of this weed. Ethylene gas is heavy and penetrates the soil to a depth of a meter below and a meter wide from the point of application. Ethylene gas stimulates pre-conditioned *Striga* seeds to germinate without host plants which is suicidal. Before ethylene gas injection *Striga* seeds should be moist at least for two weeks and soil temperature above 25°C. These pre-conditions have been over come by use strigol analogues recently. Strigol analogues GR 7 stimulates the *Striga* seeds even under dry conditions. Both ethylene gas and strigol analogues are being used at about 1 kg per hectare. (Egley and Dale, 1970, Chancellor, 1971, Eplee, 1975, Eplee and Langston, 1970, Prabhakar Setty, 1980, Johnson et al 1976, 1981; Babiker, and Hamdoun, 1982).

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PROSPECTS OF BIOLOGICAL CONTROL OF STRIGA BY MYCOPARASITES

V. Ravindra Nath*

The concept of successful biological control of a weed utilizing fungi and fungal diseases with prospects of successful and far reaching benefits to agricultural production is very rudimentary. While many fungal diseases of food crops have hyperparasites affecting the pathogenic fungi such as Darluca filum (B.V. Bern. ex Fr.) Cast. on many rusts of food and other crops, Cercospora leaf spot disease of groundnut; Tuberculina costaricana Syd. on rust pustules of groundnut rust etc. the indications of such possibilities are just hinted but never taken seriously.

The phanerogamic parasite *Striga* has been an inconspicuous host for study by mycologists and pathologists perhaps because of its restricted distribution especially in India and more so since it is dependent on certain host plants for survival. The plant itself has a poor stature except as a root parasite on Sorghum, Italian millet, maize, arhar, tobacco, sweet potato and Dolichos etc.
The importance of *Striga* as an economic danger has been realized only now since late seventies since all high yielding cultivars of sorghum are found harbouring the parasite.

When we scan our attention to the studies of *Striga* conducted with taxonomic as well as symptomological aspect of the fungi involved it is observed that there are only eleven mycologists who have contributed to this field and upto 1966 it consisted of only fungal reports on *Striga*. The first serious effort was made by Nagraj (1966), Nagraj and Ponnappa (1970) from India; Meister and Eplee (1971) from North Carolina and Zummo (1977) from West Africa. All these investigators reported pathogenic fungi or fungi which were facultative parasites. In addition there were three other fungi where Koch's postulates were not studied. These fungi are listed in Table 1 and 2.

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Scope for biological control

Speculation on the possibility of biological control of *Striga* started only in 1971 by Meister and Eplee followed by Zummo in 1977, even though a couple of workers studied the diseases on Striga to a considerable depth from 1966 (nagraj 1966; Nagraj and Ponnappa 1970). Meister and Eplee isolated four fungi from drying and dead plants of *S. lutea* and from the surrounding soil. They were *Curvularia jeniculata*, *Fusarium solani*, *Fusarium roseum*, *Rhizoctonia solani* and *Sclerotium rolfsii* from North Carolina. In artificial testing against 10-week old *Striga lutea* plants all the fungi except *Sclerotium rolfsii* were pathogenic only if the RH in the soil was maintained beyond 90% for more than 4 days and therefore it appeared that the fungi might limit the *Striga* numbers. *Fusarium solani* killed many seeds also. This raises doubts of practical utility since it would be practically difficult to maintain such high humidity in farmers' fields and in addition *Fusarium solani* is a good saprophyte on sorghum also. It is interesting to note that in their study the isolate of *Sclerotium rolfsii* was highly pathogenic. At that time itself Meister and Eplee (1971) opined that the wide host range of *S. rolfsii* as a disease causing agent on many hosts would preclude any extensive use of this fungus for biological control and on the other hand it could be used to eradicate the same within limited areas where the importance of this fungus could be tolerated. In India so far *Sclerotium rolfsii* is not a serious pathogen on sorghum even though it is observed to cause sheath rot of cultivars such as CSH-6 and there was considerable loss of plants in the delta regions of Andhra Pradesh (Ravindranath and Balasubramanian, unpublished 1979). Sorghum is susceptible to this fungus in various other parts of the world also. Since both *S. rolfsii* and *Fusarium roseum* are common soil dwellers and since they can be a threat to sorghum itself such situations of encouraging their spread could be risky under intensive cultivation methods.

Another interesting possibility was expressed by Meister and Eplee (1971) regarding *Rhizoctonia solani* causing death of *Striga lutea* in the presence of high humidity. The same fungus was earlier reported on *Striga asiatica* by King (1966). Subsequent investigations have indicated that *Rhizoctonia solani* caused a severe stalk rot disease in India and many varieties have been found susceptible including 168 (100%), CS 3541 (48%), 302 (25%), 604 (15%) (Raghavendra Rao and Pavgi 1975). It is reported pathogenic from many other parts of the world (Leukel, 1951, Quebral and Gibe 1958, Tarr 1962).

From West Africa Zummo (1977) spotted 3 fungi, all pathogenic to *Striga hermonthica* and whose potential as agents to control *Striga* seemed nil or abscure since from the same area he came across a strain of gram - ve bacterium which was antagonistic to all the three isolates of fungi and commonly associated with them. There is no information at present whether those fungi are pathogenic to sorghum or not.

An earnest attempt was made in India in 1966 when a PL 480 project for "Survey of natural enemies of witch-weed and water hyacinth and other aquatic weeds affecting waterways in India" facilitated survey of naturally occurring pathogens of *Striga*, the diseases they cause etc. (Nagraj, 1966). These studies indicated seven fungi out of which six were always associated with various diseases of *Striga lutea* and *S. densiflora* in the regions of Karnataka and Gujarat. They were Cercospora sp. (leaf spot, leaf blight and stem infection), *Oidium* sp. (defoliation and death of plants), *Phoma* sp. (Leaf spots and spots on stem), *Alternaria* sp. (leaf spot); *Macrophoma* sp. (Leaf infection, twig blight and death of plant). These species are not reported harmful to sorghum.

It is of special interest to note that Macrophomina phaseoli has been obtained as a parasite of *Striga* from Ranibennur region of Karnataka causing leaf spot and extensive twig blight (Nagraj, 1966). This is the same fungus which is the causative agent of charcoal rot of sorghum, a serious disease of the latter. This fungus is soil borne and there is no physiological specialization in it and at present it seems that there is no scope of utilizing this fungus for biological control without affecting or helping the spread of charcoal rot of sorghum.

Recently two fungi Leptosphaerulina australis and Phaeosphaeria eustoma have been reported on *Striga* from Kerala (India) (Ponnappa 1975). The detailed information on their effect on *Striga* and sorghum are not known.

Need of further work

1. Intensive work to test the fungi reported as pathogenic to *Striga* to understand whether they are harmful to sorghum.
2. Survey and exploration of new fungi indigenous or exotic and their effect on *Striga* and sorghum.

Summary

From the meagre work carried out in India and elsewhere it is obvious that attention to parasites of *Striga* is still in its infancy. A couple of fungi which are pathogenic to *Striga* ie., Sclerotium rolfsii, Rhizoctonia solani, Macrophomina phaseoli are also pathogenic to sorghum and have no real chance of being considered for *Striga* control. Further they are abundantly available in India and are omnivorous. Some fungi while being harmless at present to sorghum are lethal to *Striga* but only under conditions of high RH of 90% or more for a considerable length of time in sorghum field which is rather too much to expect in sorghum fields. The work carried out so far does not indicate that we are ready for biological control using mycoparasites.

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Table 1. Fungi Whose Pathogenicity was not Studied or which did not cause any Disease on *Striga*.

S.No.	Fungi	Host	Damage/Symposium on the host	Location	Reference
1.	*Pythium ultimum* Trow.	*Striga* sp.		S. Africa	Wagu (1940)
2.	*Phoma* sp.	*S.asiatica* (L.) Kuntze		Southern Rhodesia	Staples (1958)
3.	*Cercospora* sp.	-do-		-do-	-do-
4.	*Myrothecium roridum* Tode ex Fr.	*S. densiflora*	On twigs	Bardoli (India)	Nagraj & Ponnappa (1970)
5.	*Sphaerotheca fuligena* Schlecht ex Fr.	-do-	?	Bangalore (India)	-do-
6.	*Urohendersonia mysorensis* Nagraj & Kendrick	*S. lutea* Lour	Dead stem	-do-	-do-
7.	*Leptosphaerulina australis* McAlpine	*S. densiflora* Benth	?	Chaliyam (India)	Ponnappa (1975)
8.	*Phaeosphaeria eustoma* (Fuckell) L. Holm.	*S. lutea* Lour	?	Bodhan (India)	-do-

Table 2. FUNGI CAUSING DISEASES OF *STRIGA*

S.No.	Fungi	Host	Symptoms	Location	Reference
1.	*Cercospora* sp.	*S. lutea* Lour. *S. densiflora* Benth.	Blight of leaves, twigs and capsules and ultimately death of the plants. Stem infection more devastating than leaf infection *S. lutea* more susceptible than *S. densiflora*	Hanumana mitti (S.I.) Harihar Devanagere (S.d.) Rudroor (S.sp) (India)	Nagraj 1966
2.	*Oidium* sp.	*S. lutea* *S. densiflora*	Defoliation, stem infection, death of plants. *S. densiflora* more susceptible than *S. lutea*.	Hanumana mitti (S.I.) Harihar (S.d.)	-do-
3.	*Phoma* sp.	*S. lutea* *S. densiflora*	Spots on leaves and stems	Hanumana mitti (S.I.) Harihar (S.d.)	-do-
4.	*Alternaria* sp.	*Striga* sp.	Leaf spots	Rudroor (India)	-do-
5.	*Macrophoma* sp.	*S. lutea*	Leaf infection, extensive twig blight and death of plants	Arasikere (India)	-do-
6.	*Macrophomina phaseoli* (Maubl.) Ashby	*S. densiflora*	Leaf spots and extensive twig blight	Ranibennur (India)	-do-
7.	*Curvularia jeniculata* (Tracy & Earle) Boed.	*S. lutea*	Isolated from dead and dying plants and surrounding soils. Kills the plants if RH is more than 90%.	North Carolina	Meister and Eplee 1971

contd......

contd....

S.No.	Fungi	Host	Symptoms	Location	Reference
8.	*Fusarium solani* (Mart.) Appel & Wr.	*S. lutea*	Isolated from dead and dying plants and surrounding soils. Kills the plants if RH is more than 90%	North Carolina	Meister and Eplee 1971
9.	*F. roseum* Lk. emend Snyd. and Hans	-do-	-do-	-do-	-do-
10.	*Rhizoctonia solani* Kuehn	-do-	-do-	-do-	-do-
11.	*Sclerotium rolfsii* Sacc.	-do-	Quick death of plant	-do-	-do-
12.	*Rhizoctonia solani* Kuehn	*S. asiatica*	Root rot	?	King 1966
13.	*Cercospora* sp.	*S. hermonthica* (Del.) Benth.	Leaf spot	West Africa	Zummo 1977
14.	*Fusarium equiseti* (Corda) Saccardo	-do-	Vascular wilt and death of plant	-do-	-do-
15.	*Phoma* sp.	-do-	Stem lesion	-do-	-do-

BIOLOGICAL CONTROL METHODS OF STRIGA SPP

V.V. Thobbi* & B.U. Singh

1. Current status on the available biocontrol agents to check *Striga*

The persistent abundance of *Striga* during the past several years has increased efforts to achieve a more comprehensive understanding of the ecology of *Striga* so that effective monitoring and control strategies can be developed.

Witchweed Spp. (Striga densiflora, Striga asiatica, and Striga euphrasioides) are common root parasites of graminaceous crop in India. The roots of *Striga* get attached to the root of the host sorghum through haustoria and parasitize the host plant and most of the damage is done to the crop by the time parasite emerges above the ground.

2. Review of the reported Natural enemies and damages (types and extent) caused by them

Information concerning the way the biological control agents affect the development and further spread of *Striga* is essential if these natural mortality agents are to become significant components in an integrated pest management programme. The initial step of attaining this objective is to classify and define the distribution of Bio-Control agents associated with *Striga* (Table 1).

3. Future possibilities of the use of bio-control measures

a) Clean cultivation, removal of *Striga* before it sets seed so as to avoid further seeding and crop rotation using trap crops which stimulate *Striga* seed to germinate but do not provide a host are the best agronomic measures.

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b) Mass-rearing and releases of the weevil, Smicronyx albovariegatus Fst., which causes galls on root, stem and branches without affecting the reproductive potential of the host plant of sorghum.

c) Efforts should be made to mass-produce and inundations of indigenous noctuid larvae of Eulocastra argentisparsa Hmps., which feed on the ripening seeds in fruiting pods of *Striga* plant.

d) A thorough study on the available natural enemies is required before promising species like exotic agromyzid stem and root miner, Ophiomya strigalis Spencer could be introduced into India from East Africa.

Table 1. Natural enemies associated with *Striga*.

S.No.	Scientific Name	Nature of damage	Country Reported
		COLEOPTERA	
1.	Smicronyx albovariegatus Fst.	Larvae make galls on roots, stems and seed pods	India, East Africa, Nigeria, Uganda
		HYMENOPTERA	
2.	Eurytoma spp.	Adults make galls on stem	Kenya
		DIPTERA	
3.	Ophiomya strigalis Spencer	Larvae mine the leaves and stems of Striga	Kenya
4.	Chyliza sp.		
5.	Pachylophus proximus		
6.	Meromyza capensis		
7.	Atherigona spp.		
		LEPIDOPTERA	
8.	Diacrisia investigatorum	Larvae eat leaves and flowers	Africa
9.	Estigmene unipunctata	Larvae eat leaves and flowers	Tanzania

Table 1. (contd..)

S.No.	Scientific Name	Nature of damage	Country Reported
	LEPIDOPTERA (contd..)		
10.	Spodoptera litteralis	Larvae eat leaves and flowers	India & Tanzania
11.	Spodoptera exigua	-do-	Africa
12.	Heliothis armigera Hub.	-do-	India & Tanzania
13.	Eulocastra argentisparsa Hmps.	Larvae devour seed	India (AP & Karnataka)
14.	Gunonia orithya	Defoliate *Striga* plant	India
15.	Lobesia aeolopa	Defoliate *Striga* plant	East Africa & Uganda
16.	Platyptilia spp.	Defoliate *Striga* plant	India, Tanzania, & Uganda
17.	Syngamia abruptalis	Defoliate *Striga* plant	Uganda & Tanzania
	HEMIPTERA		
18.	Antestia cincticollis	Suck plant sap	Uganda
19.	Veterna patula	Suck plant sap	Uganda
20.	Poophilus castalis	Suck plant sap	Uganda

SESSION III

SPECIAL TOPICS

Chairman: S.Z. Mukuru

Rapporteur: N.K. Sangh

STRIGA - AN EXPERIENCE IN THE FARMERS' FIELDS[1]

N.K. Sanghi and T. Vishnu Murthy[2]

SUMMARY

Hybrid sorghum technology is the most significant contribution for improving the productivity of drylands in India. The problem of *Striga* has, however, upset the farmers as well as scientists, particularly to those who are associated with sorghum programme in red soils. There is an urgent need, therefore, to give high priority for carrying out research on *Striga* control. Until resistant genotypes are evolved, an integrated approach to the problem is essential. The following aspects appear promising for managing *Striga* on sorghum in the red soils of Hyderabad region.

I. Preventing seed multiplication of striga during first year of hybrid programme:
   - through a combination of hand weeding and post harvest tillage in situations where labour and draft availability is not a major constraint,
   - through institutional support/custom hiring for use of herbicides like 2,4-D.

II. Adoption of improved intercropping system, with 2:1 row proportion of sorghum and redgram, to achieve better compensation of yield in case where sorghum fails due to *Striga*.

III. Adoption of alternate crop of pearl millet instead of sorghum in *Striga*-sick plots.

INTRODUCTION

It is well recognized that *Striga* has flared up in the farmers' fields after the introduction of hybrids of sorghum. However, there has been a general difficulty in quantifying the severity of the problem and magnitude of the losses caused by this parasitic weed.

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[1] Paper presented in the working group meeting on *Striga*, jointly organized by AICSIP and ICRISAT during September - 30th to October - 1st, 1982.

[2] Operational Research Project, AICRPDA, Hyderabad.

This is due to the fact that the incidence of *Striga* varies, in an unpredictable manner, from field to field and also from year to year within the same field.

Low incidence during early years

It has been a common experience that *Striga* incidence occurs in patches, and is usually low during initial years of the hybrid programme. A detailed survey was conducted during 1982 about *Striga* infestation in 61 fields of Mankhal village, Ranga Reddy district. All these fields were planted with hybrid sorghum and were having shallow red soils. Fifty one of the fields were almost free from *Striga* (few *Striga* plants were seen in some of these fields). Out of the remaining 10 fields, only five were found to be severely infested with *Striga* (i.e. an average of about 15-20 per cent of the area was affected in these fields).

Multiplication of *Striga* problem

The long term experience at Manimuthyalamma Kunta (another red soil village in Ranga Reddy district) has been very revealing. In this village, improved genotypes of sorghum were introduced during 1976. There was a gradual increase in area under hybrid sorghum upto 1979. Afterwards, a sharp decline in the adoption occurred and at present, not even a single farmer is interested in adopting hybrid sorghum at his own cost.

In a micro-watershed, of about 10 ha, (which has continuously been used for trials-cum-demonstrations in Manimuthyalamma Kunta), the problem of *Striga* was negligible during 1976. An average of 25-30 q/ha grain yield was obtained upto 1979 by the five participants of the above watershed. However, over the period of 6 years (which includes only three crops of hybrid sorghum in rotation with castor) the entire watershed has now become almost like a *Striga*-sick block*. In the hybrid plots during this year, even cost of inputs may not be recovered.

Attempts to control *Striga*.

During the last three years, attempts were made to study the farmers' reaction to *Striga* problem and to identify simple management approaches for minimizing the above problem.

i. Preventing multiplication of *Striga* seed: It was recognized that one of the promising approaches to deal with *Striga* could be to prevent the seed multiplication during initial years (when the problem is insignificant and can be managed easily). The farmers of different villages reacted very differently to this approach.

In manimuthylamma Kunta village, (which is located nearer to Hyderabad city, and is having higher percentage of irrigation), farmers did not continue their interest in sorghum technology inspite of intensive efforts by the ORP scientists. The approach of hand weeding of *Striga* , for preventing the seed multiplication did not attract their attention and they preferred to concentrate their efforts in alternate activities like wet land paddy, milch production etc.

A different kind of experience was gained in Harshiguda village which is located away from the town and is having less area under irrigation. The farmers' response to sorghum technology is gradually increasing over the last three years. By now, 100 out of 110 farmers have already adopted the use of hybrid sorghum and fertilizer at their own cost (with a total of Rs. 30,000 from the rural bank). The problem of *Striga* is also under tolerable limits due to intensive weeding (which is possible to follow by these farmers due to sufficient labour for dryland activities).

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* A distinction must be made between the management level at research station and in the farmers' fields. *Striga* multiplies at a much faster rate in the farmers' fields due to less intensive hand weeding.

The above experience clearly brings out that in red soils of Hyderabad region, the existing sorghum technology, is suitable only for those villages/farmers where alternate opportunities like wet land farming, milch production etc. are limited. For situations where such alternatives are available, the control of *Striga*, through hand weeding method, does not excite the farmers. Under such conditions, it may be worthwhile to explore whether institutional support could be provided for herbicide use against *Striga*. After all, the cost involved towards spraying of 2,4-D is not high as only 1-2 per cent of the total area under hybrid programme is required to be sprayed if the problem is tackled in the first year itself.

ii. Improved intercropping system for better compensation: Intercropping of sorghum + redgram is a common feature in the farmers' fields. Traditionally, the intercrop of redgram crop is grown after every 4-6 rows of sorghum. The improved system, in which redgram is put after every 2 rows of sorghum, provides not only overall high productivity, but also helps in better compensation of yield in situations where sorghum is affected due to unpredictable problem, like *Striga*.

Compensation through redgram intercrop in *Striga*-sick plot, ORP, Hyderabad-1980

	*Grain yield q/ha		
Type of plot	Sorghum	+	redgram
Normal	29.7	+	2.2
Striga-sick	12.5	+	4.0

* Avg. of four farmers in each case

iii. Pearl millet instead of sorghum in *Striga* sick fields: It has been consistantly observed that BJ-104 pearl millet is completely resistant to the local species of *Striga* in the red soils of Hyderabad region.

Comparison of sorghum and pearl millet in *Striga*-sick plots, ORP, Hyderabad

Crop	Variety	Grain yield (q/ha)			*Striga** count (No/sq.m)
		1980	1981	Avg.	
Sorghum	CSH-5	5.4	4.8	5.1	19.1
	Local	10.8	12.4	11.6	6.5
Pearl millet	BJ-104	17.2	17.5	17.4	0.0

* Based upon the observation during 1980

Under *Striga* free situations, however, the sorghum CSH-5 gave on an average, nearly 50 percent higher yield as compared to local sorghum and about 25 percent higher yield as compared to pearl millet.

In *Striga*-sick plots, therefore, it is advisable to either switch over to pearl millet instead of sorghum or introduce it as an additional crop in the existing rotation of sorghum-castor.

The farmers of Nalgonda district, have readily accepted the choice of pearl millet as it is one of the existing crops in that region. However, greater efforts are required, through proper education, before this practice would be acceptable to farmers in Ranga Reddy district.

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STUDIES ON HERBICIDAL CONTROL OF *STRIGA*[1]

G.R. Korwar*

Introduction

Striga menace in sorghum has become serious in recent years. It is a well known fact that hybrid sorghums are more susceptible to *Striga* and in some cases the yield loss due to *Striga* is total including fodder yield. Once a field is infested with *Striga* it persists over years because of the long period of viability of its seeds. Cultivars resistant to *Striga* are not likely to be available soon, hence there is a need to work out suitable agronomic practices to control the problem immediately.

Past Research on Herbicidal Control

Post-emergence application of 2,4-D and paraquat is widely reported in literature. Similarly urea spray and control by hand pulling of *Striga* is also reported. But in all the above cases the treatment is useful essentially to prevent the seed multiplication without much yield advantage to the existing sorghum crop (as *Striga* causes major damage to the sorghum crop while it is underground).

Present Approach

An experiment is in progress since 1980 at Hayatnagar Research Farm of Dryland Agriculture Research Project, Hyderabad to evolve an effective method of *Striga* management. CSH-6 hybrid sorghum was grown on a *Striga*-sick red sandy loam soil during kharif seasons under Dryland conditions.

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1 Paper presented at the Working Group Meeting on *Striga* to be held at ICRISAT from September 30 to October 1, 1982.

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Among the various treatments tested, application of 2,4-D sodium salt @ 2 kg a.i./ha 4 weeks after sowing of sorghum crop has reduced *Striga* emergence, resulting in increases in sorghum grain yields (Table 1).

Table 1. Grain yield and *Striga* population as influenced by various treatments.

Sl. No.	Treatment	1980-81		1981-82	
		Grain yield a/ha	No. of *Striga* plants/m^2	Grain yield q/ha	No. of *Striga* plants/m^2
1.	Control	19.2	450	0.4	540
2.	Hand pulling of *Striga*	11.1	687	3.9	432
3.	Ethephon @ 1Kg ai/ha presowing	23.1	275	0.7	515
4.	Atraxine @ 1kg ai/ha 4 weeks after sowing	22.3	207	6.4	368
5.	2,4-D @ 2kg ai/ha 4 weeks after sowing	35.3	51	21.2	80
6.	2,4-D @ 2kg ai/ha spray post-emergence to *Striga*	23.0	10	11.3	62
	Urea (10%) spray post-emergence to *Striga*	28.5	119	3.5	273
	Ammonium sulfate (10%) spray post-emergence to *Striga*	27.8	214	5.6	331
	Common salt (10%) spray post-emergence to *Striga*	27.8	72	3.2	178
	C.D. at (P=0.05)	10.8		5.6	

Striga count taken 2 weeks after post-emergence application of treatments to *Striga*. (Spraying was done with high volume sprayer fitted with floodjet type of nozzle and hood using 500 litres of spray mixture per hectare. Spraying was directed towards soil surface. The treatments of post-emergence sprays to *Striga* and hand pulling of *Striga* were applied at flowering stage of *Striga*).

It appears that the 2,4-D applied at the 4 week stage killed striga soon after its germination, while it was still underground and before it started damaging sorghum crop and thus reduced its emergence and increased sorghum yields.

2,4-D applied post-emergence to *Striga* has helped in killing the emerged *Striga* plants and thus checking its seed multiplication. It has resulted in some yield increase, but not as much as in the earlier case.

The other post-emergence treatments like urea, ammonium sulfate and common salt have helped to reduce the *Striga* population to some extent. The yield increase over control in 1980-81 seen in these treatments is probably to due to low infestation in these plots as this was not seen in the subsequent year.

Practical Relevance

The application of 2,4-D@ 2kg a.i./ha 4 weeks after sowing can be used in the *Striga*-sick fields where *Striga* incidence is expected or in such cases where the *Striga* infestation for the first time is detected at initial stages (which is often possible, by noticing temporary wilting symptoms in sorghum plants even when the soil moisture is adequate and by observing small tiny *Striga* on the roots of uprooted sorghum plant). The herbicide 2,4-D applied at this stage would also control other weeds and thus save the money on second intercultivation and hand weeding.

The treatment of 2,4-D post-emergence spray to *Striga* can be used in such fields, where its infestation could not be detected early and is known only after its emergence. This would help in preventing further seed multiplication in *Striga*

The practices like urea spray and hand-pulling of *Striga* can be used in such cases where the herbicide is not available or the infestation is sporadic. In these practices repeated treatments are required as regeneration was noticed after some period of time.

Experience with Phenolic Acids under Field Conditions

Based on the laboratory studies at Bangalore ,a field experiment is under progress at the Hayatnagar Research Farm on pre-sowing seed hardening of sorghum with 25 ppm caffeic, ferulic and vanillic acids in combination with supplemental spray of these phenolic acids one month after sowing. Under field conditions phenolic acids did not contribute to any yield advantage or reduction in *Striga* emergence. There is need to understand the reasons for variations in the performance of phenolic acids under laboratory and field conditions.

Future Needs

The herbicide 2,4-D can be used only in situations where pure cropping of sorghum is practiced. However, in majority of situations pigeonpea is grown as an intercrop with sorghum. There is need to identify suitable herbicide for intercropping system of sorghum and pigeonpea as 2,4-D is injurious to pulse crops.

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STRIGA - EXPERIENCE FROM FARMING SYSTEMS RESEARCH AT ICRISAT[1]

S.V.R. Shetty and M.M. Sharma[2]

ICRISAT's Farming Systems Research is aimed at developing and evaluating alternate and improved farming systems suited to agro-climatic and socio-economic situations of the semi-arid tropics. The focal concept has been on resource management to extend cropping from the onset of monsoon to as far as possible into post-rainy season so as to improve the productivity of the farming systems on an 'year-round' basis. By investigating all facets of resource conservation and utilisation it has been possible to develop a few alternate improved systems that are biologically feasible and economically viable in the semi-arid tropics. At ICRISAT, since 1973 all components of improved farming systems are being tested and integrated on an operational scale under the watershed based management system. Though we did not have any specific field trial on *Striga*, we have been closely monitoring *Striga* situation in all these operational scale trials on the watersheds within ICRISAT. For the past 8 years, though we have observed a few *Striga* patches in some watersheds, we did not observe any significant number in any of the watersheds. Further, there was no clear trend of *Striga* incidence over these years. However, when we initiated our 'on-farm' research phase to evaluate the technology options involving improved soil, water and crop management technologies under real-world situations, we encountered severe *Striga* infestation. A brief account of our experience with *Striga* in two of our 'on-farm' research sites is presented below:

The objectives of our 'on-farm' research initiated during 1980 were:

1) To test the performance of new technologies on farmer's fields
2) To evaluate the economic implications of these technologies, and
3) To involve farmers in the technology development

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[1] A note prepared for AICSIP/ICRISAT working group meeting on *Striga* Research, ICRISAT, September 30 - October 1, 1982.

[2] Farming Systems Research Program, ICRISAT, Patancheru P.O., 502 324, India.

Small watersheds involving a number of farmers were developed on which the improved farming systems technologies were tested in these villages. As was expected we encountered rather different and newer problems in the 'on-farm' situation. With regard to weeds, we found different weed composition and increased infestation levels.

In Aurepalli (near Mahabubnagar, A.P.) which represented shallow to medium Alfisols with average rainfall of 650 mm, the improved technology harboured higher weed infestation when compared to traditional systems. Cynodon dactylon, Cyperus rotundus, and Celosia argentea were the major weeds. After first hand weeding and interculture (25 days after crop emergence) during 1980 a few plots of sorghum were severely infested with *Striga*. Two hand weedings to control *Striga* were not effective. Clipping *Striga* at the soil surface resulted in sprouting of new plants within a week. The infestation was not in patches but along the sorghum lines on the broadbeds. Sorghum growth was stunted and the effected crop looked pale green to yellowish. The average sorghum yields of CSH-6 in the fields with *Striga* infestation was about 10.5 q/ha while those without *Striga* produced about 16.5 q/ha (Fig.1). In a nearby field where CSH-5 was grown, the crops failed to produce any grain due to heavy *Striga* infestation while the field without *Striga* produced about 30 q/ha (according to farmer). It was interesting to note that in the lower part of the watershed where pearl millet was grown there was no *Striga* in the pearl millet. In another 'on-farm' research location, Taddanpalli (near Sanga Reddy, A.P.) which although has quite a different agro-climatic situations, the experience was similar. Taddanpalli has deep vertisols with traditional kharif fallowing, followed by rabi sorghum cropping. During the rainy season of 1981 sorghum and maize were planted with improved system of farming. Both the crops were severely infested by *Striga*. The infestation varied in its severity from negligible to heavy in different plots of the watershed. Farmers indicated that they were aware of *Striga* but their local cultivars, grown mainly in rabi, were moderately tolerant to *Striga*.

Two species, S. asiatica and S. densiflora were noticed abundantly in the watershed (Vasudeva Rao, Personal communication). Sorghum was infested mainly by S. asiatica while maize with mixed population of both the species. Im the postrainy season sorghum S. densiflora was more common than S.' asiatica. Fields were systematically surveyed for *Striga* infestation and yields of each field was recorded seperately. Sorghum yields were severely affected by *Striga* infestation (Fig.1). Minimum yield of 13.6 q/ha was obtained in heavily infested plots where as in *Striga* free plots the yield was about 32 q/ha. Maize also suffered some damage in patches, though not as much as sorghum.

Herbicide application in Taddanpalli watershed was not considered. However, in one plot directed urea spray was attempted on sorghum. It was observed that higher concentration (20%) of urea could control about 90% *Striga* plants (Fig.2). We are continuing our monitoring for *Striga* infestation during the present cropping season also.

Conclusions

Striga has only been occasionally seen to infest sorghum at ICRISAT Center watersheds and has never attained a status to be a problem weed so far. However, when the same farming systems technology was introduced to 'on-farm' situation severe infestation levels were observed in both Alfisol and Vertisol situations. It is evident that these soils in the farmers field already harbour a large *Striga* seed reserve. Because of less intensive cultivation and continuously growing of similar crops *Striga* seemed to have built up over the years. Because of prolonged dormancy, *Striga* seeds could remain viable when moderately tolerant local sorghums were planted during these years. The imtroduction of high yielding sorghum hybrids with improved farming systems technology provided an ideal environment for *Striga* to emerge in large numbers. Susceptible cultivars, improved soil management (particularly drainage) and crop management (particularly weed free situation seemed to have favoured *Striga* emergence in the farmers' fields.

Future Agronomic research needs

It has been increasingly felt that *Striga* is going to be a serious problem in the future. We now believe that any improved farming systems technology should be combined with improved *Striga* management techniques, if it is to succeed. All aspects of agronomic manipulation to prevent yield losses due to *Striga* need to be considered and incorporated. Following specific issues need further investigation.

1. Cultural practices
    - a) Effects of primary and secondary tillage, depth of cultivation, minimum tillage, conventional strip tillage (as done on broadbeds) and deep tillage on the *Striga* emergence
    - b) Effect of time of weeding on *Striga* emergence
    - c) Influence of farmyard manure and compost on the incidence of *Striga*
    - d) Interaction between N levels and *Striga* emergence
    - e) Influence of top dressing in the form of urea spray on the control of *Striga* and crop yields
    - f) Effect of land management treatment (broadbeds) on striga emergence.

2. Cropping systems/Trap and Catch crops
    - a) Effect of various intercrop combinations on the incidence of *Striga*
    - b) Influence of "smother cropping" systems on the emergence of *Striga*
    - c) Crop rotations involving catch and trap crops and their productivity.

3. Herbicides
    - a) Role of pre-emergence herbicides which are particularly safer under intercrop situation in preventing *Striga* emergence
    - b) Efficacy of post-emergence herbicides particularly as directed and spot application

Agronomic research on *Striga* should aim at identification and quantification of the factors favouring *Striga* build up and factors which reduce *Striga* incidence. Both these approaches are useful in artificially creating sick fields for *Striga* research as well as to develop control measures. Management techniques for both presently available but susceptible high yielding cultivars and new, *Striga* tolerant breeders' material need to be designed and evaluated in an organized way across different agro-climatic situations of the country to develop appropriate control measures. Such coordinated trials need inputs from both breeders and agronomists. ICRISAT Farming Systems Research Program is eager to participate in such coordinated agronomic trials.

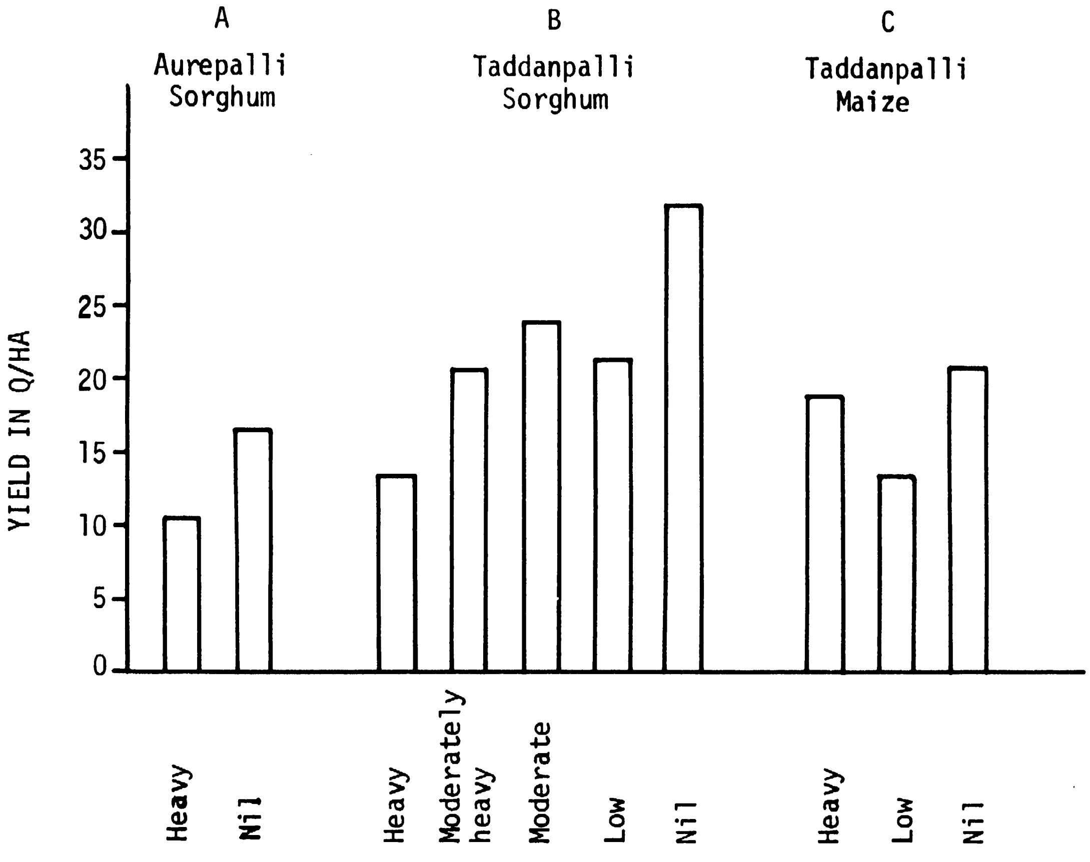

Fig. 1. Effect of Striga infestation levels on grain yield of Sorghum and maize at Aurepalli (Alfisols, 1980-81) and Taddanpalli (Vertisols, 1981-82).

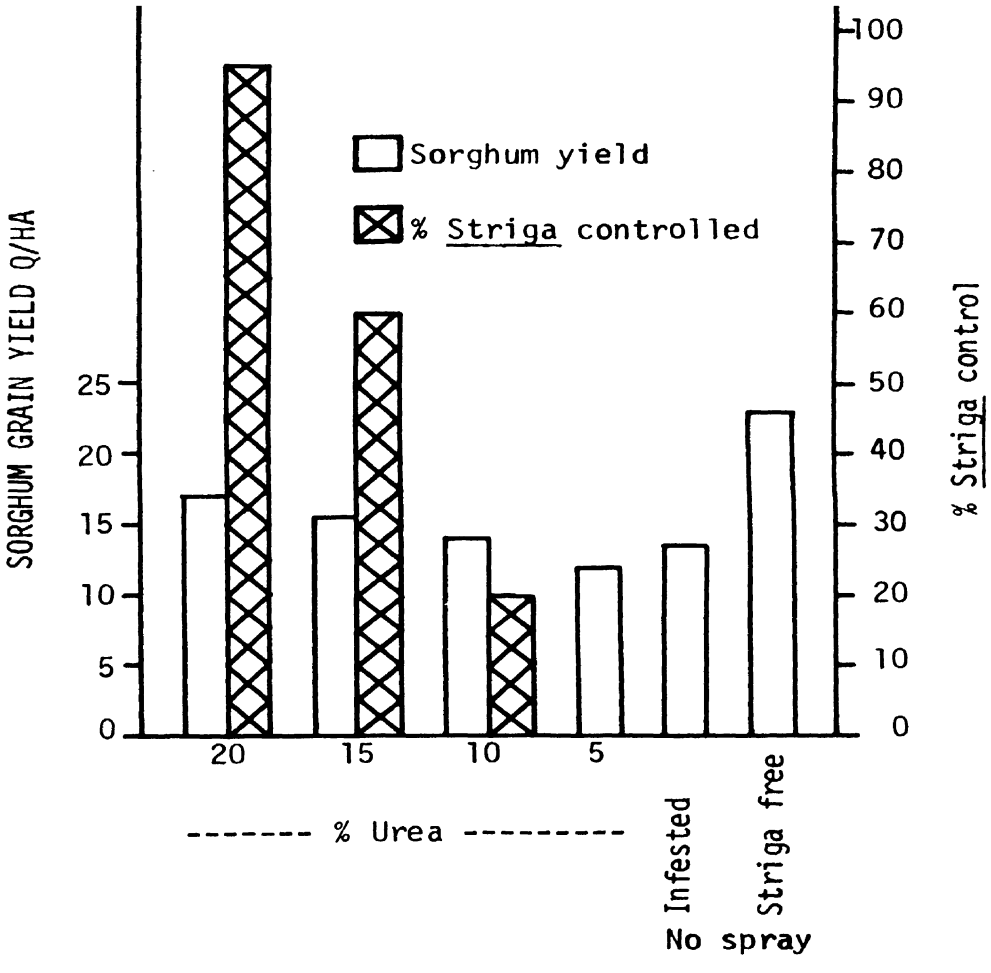

Fig. 2. Effect of urea spray on Striga control and Sorghum yields.

CONTROL OF *STRIGA* - RESULTS FROM PUNJABRAO KRISHI VIDYAPEETH, AKOLA, MAHARASHTRA, INDIA

S.T. Khade[1]

In Vidarbha region of Maharashtra where Punjabrao Krishi Vidyapeeth, Akola is located more than 50% area is under sorghum hybrids all of which are susceptible to *Striga* Heavy infestation of *Striga* can result in complete loss of the sorghum crop in lighter type of soils. Therefore, the control of *Striga* in sorghum is very essential.

Since 1976-77 to 1981-82 research on control of *Striga* was conducted at Akola with the financial aid of PL-480 on the following aspects:

I) Evaluation of *Striga* resistant/tolerant sorghum strains,
II) Use of herbicides and
III) Management practices.

I. Evaluation of *Striga* Resistant/Tolerant Sorghum Strains

Seven hundred sorghum strains were screened for resistance/tolerance to *Striga* in the field against the susceptible check CSH-1. From the data it is seen that one strain, BO-1, is immune, two strains (IS-5603 and IS-5118) are resistant and seven strains (IS-6942, IS-5218, N-13, IS-9985, IS-4242, IS-4202 and SRN-4882B) are tolerant to *Striga* (Table 1). However, all these strains are tall, late and low grain yielders than the susceptible check CSH-1. These resistant sources are being utilized in breeding program and the material is under evaluation.

II. Use of Herbicides

An experiment with different herbicides and urea was tried for the control of *Striga* on CSH-5. From the data it is clear that post emergence

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[1] Sorghum Breeder (*Striga*), Punjabrao Krishi Vidyapeeth, Akola, Maharashtra, India.

sprays of these chemicals on *Striga* plants controlled *Striga* (Table 2). Secondly, two applications are more effective than one application. However, two applications of herbicides like Gramoxohe, Fernoxone and 2,4-D (ethyl ester), are more effective than urea 20% solution. There is negligible increase in grain yield though the *Striga* is controlled by use of different herbicides and urea.

In another experiment the herbicide Treflan was tried for the control of *Striga* in the hybrid CSH-1. From the data it is clear that pre-emergence application of Treflan controls *Striga* very effectively (Table 3). However, Treflan is harmful to sorghum seed as it results in poor germination.

III. Management Practices

The effect of different intercrops in CSH -1 was studied for the control of *Striga*. From the data it is clear that the intercrops like groundnut, green gram, black gram, cotton and coriander controlled the *Striga* (Table 4). But the intercrops like groundnut and green gram controlled the *Striga* more effectively than others. The monetary returns per hectare is very high from these intercrops than the sole crop of sorghum.

In addition to the above research some filler trials were conducted for the control of *Striga*. It was observed that there was no effect on control of *Striga* due to sorghum seed fortification, soaking of sorghum seeds in coriander seed extracts (water soluble) and sorghum seed pelleting with insecticides like Phosalone, Monocrotophos, Bendiocarb and Chlorpyriphos.

Table 1. *Striga* reaction of sorghum strains (1976-77 to 1981-82)

S.No.	Sorghum strain	50% flowering of sorghum (days)	Height of sorghum plant (cm)	Sorghum grain yield(Q/Ha)	Ratio of *Striga* plants / 100 sorghum plants	No. of *Striga* (%CSH-1)	Reaction category
1	CSH-1 (check)	65	106.2	13.27	2344.56	100.00	Susceptible
2	BO-1	90	276.3	9.45	0.00	0.00	Immune
3	IS-5603	82	284.2	6.06	5.44	0.23	Resistant
4	IS-5118	90	275.8	5.15	10.24	0.43	Resistant
5	IS-6942	90	224.4	8.19	57.77	2.46	Tolerant
6	IS-5218	90	293.8	8.88	59.76	2.54	Tolerant
7	N-13	87	260.6	9.45	65.38	2.78	Tolerant
8	IS-9985	85	250.9	13.41	101.17	4.31	Tolerant
9	IS-4242	83	239.2	13.21	131.94	5.65	Tolerant
10	IS-4202	89	227.8	10.29	135.42	5.77	Tolerant
11	SRN-4882B	90	162.9	6.10	147.20	6.27	Tolerant

Table 2. *Striga* mortality and grain yield of CSH-5

S.No.	Treatment	*Striga* mortality (percentage)	Sorghum grain yield (Q/ha)
1	Gramoxone @ 1.5 lit/ha ... once	44.68	28.32
2	Gramoxone @ 1.5 lit/ha ... twice	57.07	26.62
3	Fernoxone @ 2.0 kg/ha ... once	30.70	29.19
4	Fernoxone @ 2.0 kg/ha ... twice	63.36	27.55
5	2,4-D (Ethyl ester) @ 3 lit/ha ... once	32.52	27.05
6	2,4-D (Ethyl ester) @ 3 lit/ha ... twice	56.93	29.45
7	Urea 20% solution ... once	28.03	25.86
8	Urea 20% solution ... twice	40.80	26.81
9	Control (no spray)	0.00	25.14

Note: The above chemicals were applied as post emergence sprays on *Striga* plants before flowering

Table 3. Herbicide treflan and *Striga* infestation in CSH-1

S.No.	Treatment	Germination of sorghum (percentage)	No. of *Striga*/ plot	*Striga* infestation (percentage)
1	Treflan @ 4.70 lit/ha	23.50	15	9.67
2	Treflan @ 6.25 lit/ha	20.52	13	8.38
3	Treflan @ 7.81 lit/ha	19.40	12	7.74
4	Treflan @ 9.40 lit/ha	11.56	8	5.14
5	Control (no Treflan)	80.22	155	100.00

Note: 1. All the treflan treatments were given as soil application (7 to 10 cm deep) one day before sowing of sorghum seeds. The sorghum seeds were sown in the same row and also in between the rows where treflan was applied.

2. Three attempts were made by resowing of sorghum seeds but in all the attempts there was very poor germination of sorghum seeds in treflan treated plots.

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Table 4. Intercrops and *Striga* infestation in CSH-1

S.No.	Treatment	No. of *Striga* plants/plot	*Striga* infestation (percentage)	Yield in quintals/ha			Monetary returns in Rs/ha
				Sorghum	+	Intercrop	
1	Sorghum sole crop (check)	8514	100.00	14.07	+	-	1407.39
2	Sorghum + groundnut	2097	24.63	9.37	+	12.55	5954.69
3	Sorghum + green gram	2351	27.61	9.85	+	8.33	4152.23
4	Sorghum + black gram	4126	48.45	7.62	+	10.83	3790.09
5	Sorghum + coriander	5373	63.10	9.50	+	0.46	1135.79
6	Sorghum + cotton	3280	38.52	6.68	+	6.95	3798.32

Note: Sorghum + intercrop were sown in 1:1 row ratio.

STRIGA STUDIES AT THE REGIONAL AGRICULTURAL RESEARCH STATION, NANDYAL

N. Ranganadhacharyulu[1]

Striga infestation is severe in sorghum fields in Rayalaseema area and the damage in some years goes upto 70%. *Striga* incidence is more swvere in drought years . Both *Striga asiatica* and *Striga densiflora* are found to attack sorghum in Andhra Pradesh (Sree Ramulu, 1959).

A brief review of the agronomical, chemical and plant breeding studies to control *Striga* at the Research Station, Nandyal in the ICAR Scheme which was in operation from 1949-59 and the work in progress afterwards, is presented in this paper.

I. AGRONOMICAL METHODS

i) Trap cropping: This trial was conducted with the object of finding out the number of trap crops of sorghum required to exterminate *Striga* in a heavily infested field. This method was found to be not economical and feasible for adoption under rainfed conditions, though it had some beneficial effect in reducing *Striga* intensity.

ii) Catch crop: To identify a green manure crop which could serve as catch crop, stimulating the germination of *Striga* seeds without serving as a host, the following crops were tried.

1. Pillipesara (*Phaseolus trilobus*)
2. Patchapesara(*Phaseolus aurous*)
3. Medapesara (*Phaseolus* sp.)
4. Field bean (*Dolichos lab lab*)
5. Cowpea (*Vigna unguiunculata*)
6. Sunnhemp (*Crotolaria juncea*)
7. Cotton (*Gossypium arboreum*)

All the pulse/green manure crops were ploughed *in situ*, and the cotton plants were removed by uprooting after the specified period of 44 days. Sorghum was sown after an interval of 17 days. It was

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[1] Sorghum Breeder (NARP), APAU, ARS, Nandyal

of the entire dose of nitrogen in the control plot. Delay in the emergence of Striga was observed in the treated plot, as compared to the check plot. But there was no difference either in the incidence of Striga or in the yield of the varieties.

II. CHEMICAL METHODS

i) Soil application of Fernoxone and lime: Preliminary experiments conducted to determine the interval between the soil treatment with chemicals and sowing of sorghum revealed that 2½ to 3 months interval was necessary in the case of Fernoxone to avoid toxic effects on sorghum and no interval is required in the case of lime. Regular trials were conducted later applying Fernoxone at 10, 20, 30 lb/acre duly observing the above interval and lime at 10 and 20 CWT/acre with the variety N-1. The treatments failed to significantly increase the yield over the untreated plots, though the *Striga* incidence was less in the treated plots. The cost of chemical was prohibitive and not economical for a dryland crop like sorghum. During years of low rainfall the toxicity of Fernoxone persisted for a longer period adversely affecting the germination of sorghum.

ii) Combined experiment for hand weeding and spraying chemicals: This experiment was conducted to study the decrease in the intensity of *Striga* infestation by hand weeding and to determine the number of weedings necessary for complete eradication of *Striga* in an infested field and also to study the effect of spraying chemicals on *Striga* during the crop period. Spraying the *Striga* plants after their emergence from the ground with Agroxone and Fernoxone in doses of one gallon of 10% liquid of the former in 100 gallons of water and 1¼ pound of the latter in 100 gallons of water per acre were tried. The chemicals were used as many times as was necessary and the treatments were compared with hand weeding and control plots. The results proved that the effect of hand weeding was as good in reducing *Striga* as the treatment with chemicals, which is less costly, safe and within the reach of the cultivators.

iii) Soil application of Fenac: An observation trial was laidout with N1 during 1966-67 on the effect of a pre-emergence herbicide 'Fenac' on the incidence of *Striga*. Four treatments, viz., 1,2,3 and 4 kg of the chemical/acre were included. *Striga* incidence was progressively reduced with the increase in the dosage of herbicide. But the differences among the treatments and control in respect of yield were not significant.

iv) Soil application of Maleic hydrazide: An observation trial was laid out with three treatments of 2%, 4% and 8% Maleic hydrazide on N-1 during 1966-67. Crop growth was stunted in all the treatment plots. Though the *Striga* incidence was very much reduced in the treated plots, grain yield gradually reduced with the increase in the dosage.

v) Effect of MC 1488 herbicide: This experiment was laidout with N-1 during 1971-72. The herbicide was applied at 16 lb/acre (equivalent to one lb. active ingredient/acre) - (i) at the time of final thinning of sorghum and (ii) at the time of emergence of *Striga* plants. The *Striga* incidence was poor in the treatments but the differences in yield were not significant.

vi) Effect of Atrazine: An observation trial was laid out with CSH-5 during 1974-75, using Atrazine as a pre-emergence spray at (i) 0.50 kg a.i./ha. Though there was reduction in *Striga* incidence in the treatments, the yield difference among the treatments and the control were not significant.

vii) Effect of synthetic analogues GR 7 and GR 28: The trial was conducted on CSH-1 during 1977-78 with two synthetic analogues (GR 7 and GR 28) which were received from Sussex University (UK) in collaboration with ICRISAT. They were applied to the soil at the concentrations of 1,5 and 10 PPM each prior to the sowing of sorghum. The results showed that both the compounds were not effective.

III. PLANT BREEDING METHODS

i) Selection: With the object of isolating *Striga* resistant types of sorghum that might exist in nature, a thorough survey of the tract was done in early fifties and single plants which were free from *Striga* attack were collected from badly infested fields in cultivators' holdings. These selections were compared for the yield of grain and straw with their respective local parents and for *Striga* resistance with Bonganhilo (S. caudatum), a *Striga* resistant variety from Africa. After continuous selection, 109 - a pure line selection from local Cherukupatcha jonna was isolated which was found to exhibit not only superior grain yields but also higher resistance to *Striga* attack than the existing strain N-1. It was superior to Bonganhilo for *Striga* resistance. The average yield of grain and straw and percentage of *Striga* infestation recorded by 109, in comparison with N-1 and Bonganhilo (AS 4003) on the station are presented below.

Table 1. Performance of selection 109 (N-13) in comparison with other selections at the time of release

Selection No.	Pedigree	*Striga* infestation		Grain yield		Straw yield	
		% of infestation	% of control	in kg/ha	% of N-1	in kg/ha	% of N-1
109(N13)	Pureline from Cherukupatcha jonna	1.5	12.5	437	125	1436	132
167	-do-	5.0	41.7	350	100	1158	107
187/6	N-1xAS 4003	6.0	50.0	331	95	1219	112
187/8	-do-	6.0	50.0	322	92	1181	109
AS 4003	Bonganhilo	4.0	33.3	211	60	1158	107
N-1	Control	12.0	100.0	350	100	1085	100

Selection 109 was released as N-13 in the year 1966 after establishing its superiority on clutivators fields. It is understood that N-13 proved its *Striga* tolerance at ICRISAT and also in some

ii) Screening: Germplasm on the station and the material received from ICRISAT are being screened in the *Striga* sick plot. Reaction of some important entries screened for *Striga* incidence at Nandyal are presented hereunder.

Table 2. *Striga* reaction of some important sorghum entries tested at RARS, Nandyal

Tolerant/Resistant entries		
E-3	AS 4003	IS 1473
E-8	148	IS 5118
E-9	168	IS 5218
E-17	CS 3541	N-13
E-24	Serena	NJ 1428
SRN 4841	BC 9	NJ 1515
ISRN 357	IS 555	NJ 1943
ISRN 359	IS 815	NJ 2048

iii) Hybridization: Hybridization was taken up to evolve *Striga* tolerant/resistant types, by using Bonganhilo and other standard yellow and white grain types.

Efforts in this program resulted in the evolution of cultures like 187/6 from N-1xAS 4003, 194/1 from N2 x AS 4003 and many others which were *Striga* tolerant. But most of them did not combine productivity and grain quality. Intensive efforts are being continued to combine *Striga* tolerance without sacrificing yield and grain quality, utilising the *Striga* tolerant material available in the International *Striga* Resistant Nursery (ISRN) material supplied by ICRISAT and also the available tolerent material in the germplasm. Some of the most important material so developed and undergoing tests in various generations are sampled below .

Table 3. Some of the *Striga* tolerant crosses under test in various generations at RARS, Nandyal

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F1 Generation

N 13xColln. 110 (Yellow grain)
N 13xColln. 122 (")
N 13xIS 1136 (")
N 13xIS 1147 (")
N 13xIS 1580 (")
N 13xIS 3508 (")
N 13xIS 15203 (")
N 13xIS 15563 (")
N 13xIS 15571
SPV 384xISRN357 (White grain)
SPV 385 x ISRN 359 (White grain)
SPV 385 x NJ 2048 (")
SPV 385 x 187 (")
IS 3541 x NJ 2048 (")
NJ 2048 x 12-1 (")

F2 Generation

IS 555xNJ 2044 (White)
IS 555xSPV 86 (")
IS 555xSPV 50 (")
NJ 1428 x IS 5118 (Yellow)

F3 Generation

M35-1 x BC 9(White)
BC 9 x BJ 2044 (")
BC 9 x NJ 1944 (")
SPV 86 x BC 9 (")
NJ 2009 x NJ 1031 (yellow)

Future lines of work

i) Intensive screening of germplasm.

ii) More emphasis on hybridization programme involving new *Striga* tolerant lines identified, besides the existing ones.

iii) Testing all the four cultivated species of Gossypium as rotation crop in stimulating *Striga* population. Only G. arboreum was tested earlier and was found to stimulate *Striga* germination without acting as a host.

iv) Testing of deep sowing of jowar with plough in comparison with gorru sowing, since earlier laboratory tests indicated that *Striga* seed which were 5 cm. above jowar seed did not germinate.

v) To test the efficacy and economics of some more chemical control methods.

Summary

Studies made for the control of *Striga* on sorghum in the striga sick plot at the Regional Agricultural Research Station, Nandyal, both in the scheme financed by the ICAR which was in operation from 1949-59, and the work during the later period are reviewed.

Agronomical methods like trap cropping, catch cropping, rotation cropping, cultural methods, deep ploughing and effect of top dressing of nitrogen were all found to be ineffective. Cotton as a rotation crop reduced *Striga* incidence in the succeeding sorghum crop.

Chemicals like Fernoxone, Agroxone, Lime, Fenac, Maleic hydrazide, MC 1488, Atrazine, Synthetic analogues GR 7 and GR 28 were tried. Some of them reduced the *Striga* incidence, but failed to increase the yields of jowar. Hand weeding was found to be equally effective as chemical methods, besides being less costly and safe.

N-13 released from Nandyal is found to be tolerant to *Striga* infestation at many places. Intensive hybridization programme utilising tolerant lines from ISRN material supplied with the courtesy of ICRISAT and from the germplasm available on the station is in progress.

Reaction of some of the important entries for *Striga* infestation, and *Striga* resistant/tolerant material generated which is undergoing tests in various stages are listed. Future lines of work have been indicated.

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METHODOLOGY FOR *STRIGA* RESEARCH[1]

M.J. Vasudeva Rao, B. Raghavender, V.L. Chidley and L.R. House[2]

1. Introduction

Precise and valid research methodology is a prerequisite for significant progress in any branch of science. A study of past efforts in breeding for *Striga* resistance indicates that progress has not been commensurate with the inputs invested. The main reason for slow progress is the absence of a reliable screening system. In this paper, we describe the research methodology used currently for *Striga* resistance breeding and discuss some newly proposed systems.

2. The Prevailing Screening Systems

The influence of the host roots on the parasite occurs in three stages of the parasite's development, viz., seed germination, haustorial establishment, and the final growth and establishment of *Striga*. Three mechanisms conferring resistance have been recorded, viz., low stimulant production, mechanical barriers to haustorial establishment (ICRISAT 1977) and antibiosis (Doggett 1970). Field resistance to *Striga* is the combined expression of one or more of these and possibly other mechanisms.

The existing screening systems could be understood in three groups - laboratory, pot, and field screening techniques.

2.1 Laboratory techniques. Several laboratory screening techniques are available like the double pot technique, Pasteur pipette technique, root slope technique, sandwich techniques, 'Eplee bag'

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[1] A working paper presented in the ICRISAT-ICAR working group meeting on *Striga* control, Sept 30-Oct 1, 1982, ICRISAT, Patancheru.

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technique, anti-haustorial factor screening etc. Though laboratory techniques have several advantages, they are often not well correlated with field screening results possibly for two reasons: first, the field resistance to striga cannot be explained by any single mechanism; and second, there are strong environmental interactions influencing the field results which are not allowed to act in laboratory techniques. Recently Parker and Dixon (1982) have proposed a 'polybag' technique for screening which they report to be useful. Though several laboratory screening technique are available, a technique which can screen for more than one mechanism on a single plant basis, is not yet available.

2.2 Pot screening technique. 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 counting the *Striga* that emerge above the ground. Although the pot techniques are not completely reliable, they could be useful since the *Striga* infestation in pots is more definite than in artificially infested fields.

2.3 Field screening technique. Growing sorghum lines in a field which is naturally or artificially infested with *Striga* and screening for field reaction has been a very common technique. Field screening is often not reliable because of various uncontrollable factors, most important among them being ununiform *Striga* infestation. 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 coefficients of variability in the experiments, reducing the chance of finding significant differences between treatments.

3. Efficiency Requirements of the Screening Techniques

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

i) land races from germplasm

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

iii) advanced generation lines.

The land races and advanced generation lines, are almost homozygous and need maximum efficiency in screening. If available, the screening must be able to identify absolute resistance. The testing has to be adequately replicated. Screening of F_2 progeny must be undertaken on a single plant basis while from the F_3 onwards, screening could be undertaken on a family basis, however, single plant screening would still be advisable.

4. Double Pot Screening Technique

This technique was originally developed at Weed Research Organization (WRO), Oxford, and is very useful for screening a large number of pure lines of sorghum. The technique in brief consists of: 1) raising sorghum seedlings in an ice-cream cup in sand culture and extracting the root exudate after one week, 2) pre-conditioning *Striga* seeds at optimum temperature (25°C) and moisture for 10-14 days to break dormancy, and 3) germinating the pre-conditoned *Striga* seeds with the root exudate at 33°C for 24 hours and counting % *Striga* seed germination. The experiment is replicated twice; the variety 'Swarna' is used as a susceptible standard and distilled water is used as a check. This technique has been extensively used at the ICRISAT Center to screen a large number of germplasm and breeding lines. Low stimulant screening will be a useful technique only if the low stimulant lines are resistant in the field. The first effort to correlate low stimulant production and field resistance indicated a low correlation. However, further work has indicated that the proportion of field resistant types was higher in the low stimulant than the high stimulant category.

5. The Seed Pan Technique

A 'Seed pan' technique is developed at the ICRISAT Center to screen single plants for *Striga* resistance. This is a modification of the pot screening procedure. The details of this procedure were first described in a paper presented to the All India Sorghum Workshop at Navsari in May, 1981 (Vasudeva Rao et al. 1981).

Two experiments conducted to verify the usefulness of the seed pan technique are described below:

5.1 Experiment 1. Comparison between resistant and susceptible cultivars.

Two susceptibles, CSH-1 (a hybrid) and Swarna (a variety), and a resistant variety N-13, were compared using the seed pan technique. Comparisons were made over four normal sorghum growing seasons at ICRISAT Center, Patancheru with at least six replications for each observation. 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 (Table 1 and Figure 1). The experiments were independently analyzed 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 2). Variation between blocks (pans) was nonsignificant in all the seasons. Table 1 and Figure 1 indicated that rainy and summer seasons are the best seasons for conducting the experiments. In the postrainy season the differences, though statistically significant, were not pronounced probably due to the low temperatures prevailing during the period of *Striga* establishment.

5.2 Experiment 2. Comparison of 25 sorghum lines. This experiment was conducted using 21 resistant and four susceptible sorghum lines during the summer of 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 count of subterranian *Striga* (Figure 2). The resistant and susceptible groups differed significantly from each other.

Another very important use of the seed pan technique is the screening of single plants in the presence of a stimulant. In this type of screening, the plants are grown as described earlier. Bulk quantities of stimulant collected from 'Swarna' stocks are applied on 5,10,15,20 and 25 days after sowing of sorghum. The subterranian *Striga* are counted 55 days after planting sorghum. A preliminary study indicated useful differences between sorghum lines demonstrating the presence of resistance mechanisms other than low stimulant production.

6. Field Screening Methodology

A three-stage field screening methodology was first proposed and presented at the AICSIP workshop held at Navsari in May, 1981. Further details of this methodology and the procedures for data collection, analysis and interpretation were presented at the AICSIP workshop held at Pune in May 1982 (Vasudeva Rao et al. 1982)

The three stages of this methodology are presented below:

6.1 Observation nursery. This stage consists of an unreplicated trial of a large number of test entries with a frequently repeated susceptible check. Test entries may be grown in a two or three row plot. It may be a multilocation nursery or at one location only.

6.2 Preliminary screening. This is the second stage of testing and includes those entries from the observation nursery which were agronomically good and on which *Striga* infestation was low or did not appear. The entries are tested in 3 row plots and 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. 3).

6.3 Advance screening. This is the third and final stage of testing in which the selected entries from the preliminary screening will be tested in larger plots with a susceptible check plot all around the test entry (Fig. 4). Each plot would be at least a five row plot so that yield estimates and *Striga* reactions are obtained from fairly reliable plot sizes; and further, the border effects are minimized. The entire trial is covered on all the four sides with a strip of the susceptible check.

7. Measurement of *Striga* Reaction

Measuring *Striga* reaction has always been very difficult. Doggett (1965) was the first to give some thought about the proper measurement of host reaction to *Striga*. He analyzed the relation between the number of subterranian and emerged *Striga* plants.

Striga reaction of varieties could best be measured by the numbers of striga plants that appear above ground and the loss to yield it causes. Yield loss measurements are like the measurement of any other yield reducing factors. A comparison of yield in a *Striga* sick field and striga free field is a good measure. Varieties where the yield loss is least could be a more resistant or tolerant variety.

Data on *Striga* numbers have been reported in different ways.

i) *Striga* score - Scoring on a 0 to 5 scale is useful when it is not possible to physically count the many *Striga* plants that emerge.

ii) *Striga* counts - Counting the number of *Striga* plants that emerge above ground, at one, two, or three stages of crop growth, with or without uprooting the *Striga* plants during counting has been a very appropriate way of representing the *Striga* reactions of varieties.

iii) *Striga* index - *Striga* index (Hanumanth Rao, 1982) is weighted average of *Striga* counts and the height of *Striga* plants; weights being the frequency of *Striga* plants in each height category. Though the height measurements of *Striga* plants is a laborious process, and also the heights change with time, *Striga* index could however be a measurement when studying relative growths of *Striga* in different varieties or where treatment effects result in differential growth of *Striga*.

In order to account for the non normality of *Striga* count data, various transformations like log, $\sin^{-1}$, square root $\sqrt{x+1}$ have also been used by different people. The log transformation resulted in near normality of striga counts data (Vasudeva Rao et al. 1982).

Future Research Required on Methodology

Most research efforts in the past have addressed themselves to the problem of ununiformity of infestation in fields used for screening purposes. However, more effort is required to improve the infestation level itself. This requires the identification of factors favourable for *Striga* development and deployment of these favourable factor in a *Striga* sick field. Specific research methodology are also required for agronomic or cultural control research. The efficiency in breeding would greatly be improved if new techniques are established which can sort out single plant differences for *Striga* resistance. However, the results of these techniques must correlate well with field tests.

We also need a technique for reliably screening a large number of entries as part of the effort to develop agronomically elite varieties and hybrids with resistance to striga.

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Table 1. Mean subterranian *Striga* counts on resistant and susceptible sorghum cultivars in seed pans

Season	Date of sowing	Cultivar	Host age (days)				
			27	29	31	35	49
Rainy	8 Jul 80	CSH-1	2.0	4.0	4.7	8.6	7.6
		Swarna	3.0	3.0	5.0	4.2	12.3
		N-13	0.5	0.3	0.0	0.2	0.0
			20	25	32	40	50
Postrainy	24 Oct 80	CSH-1	0.0	0.3	1.2	0.7	1.2
		Swarna	0.0	0.5	1.4	2.5	4.3
		N-13	0.0	0.3	0.7	0.0	0.0
			22	28	32	42	52
Summer	23 Feb 81	CSH-1	0.0	0.2	0.4	7.0	10.5
		Swarna	0.0	0.0	0.4	2.9	7.1
		N-13	0.0	0.2	0.0	0.5	0.3
			20	25	30	40	50
Rainy	17 Jun 81	CSH-1	0.2	1.2	3.0	10.2	13.0
		Swarna	0.3	1.2	3.0	9.5	11.0
		N-13	0.0	0.0	0.0	0.2	0.5

Table 2. Analysis of variance for subterranian *Striga* counts in seed pan over three seasons

Source of variation	Postrainy 80		Summer 81		Rainy 81	
	DF	MS	DF	MS	DF	MS
Blocks	5	1.55	7	7.24	5	3.29
Main plots (days)	4	8.93*	4	171.28**	4	218.18**
Error (A)	20	2.53	28	5.97	20	8.83
Subplots (cultivars)	2	16.53**	2	115.90**	2	243.38**
Main x sub	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

* Significant at $P < 0.05$ ** Significant at $P < 0.01$

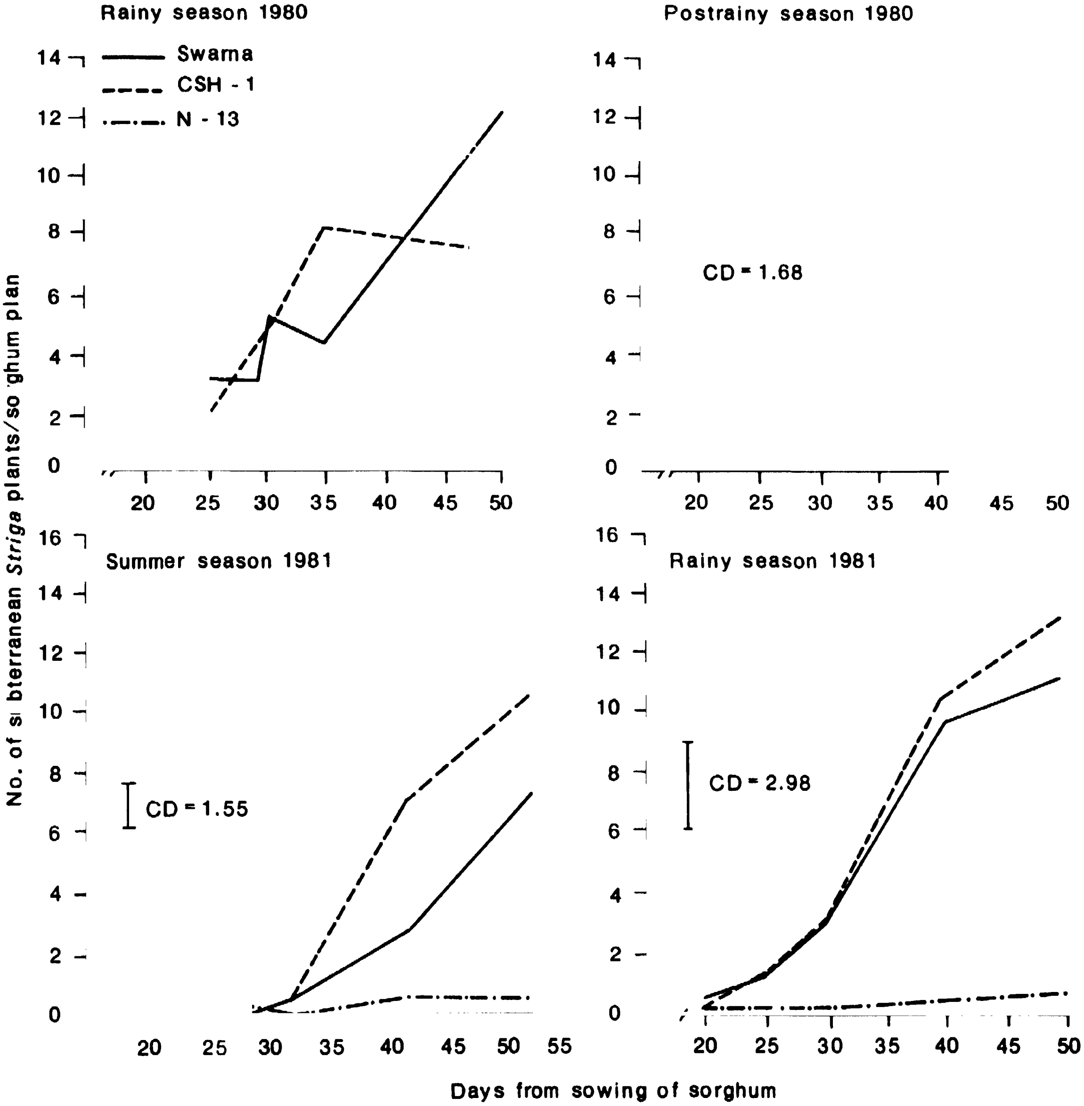


Figure 1. Subterranean Striga *counts on the roots of resistant and susceptible cultivars of sorghum.*

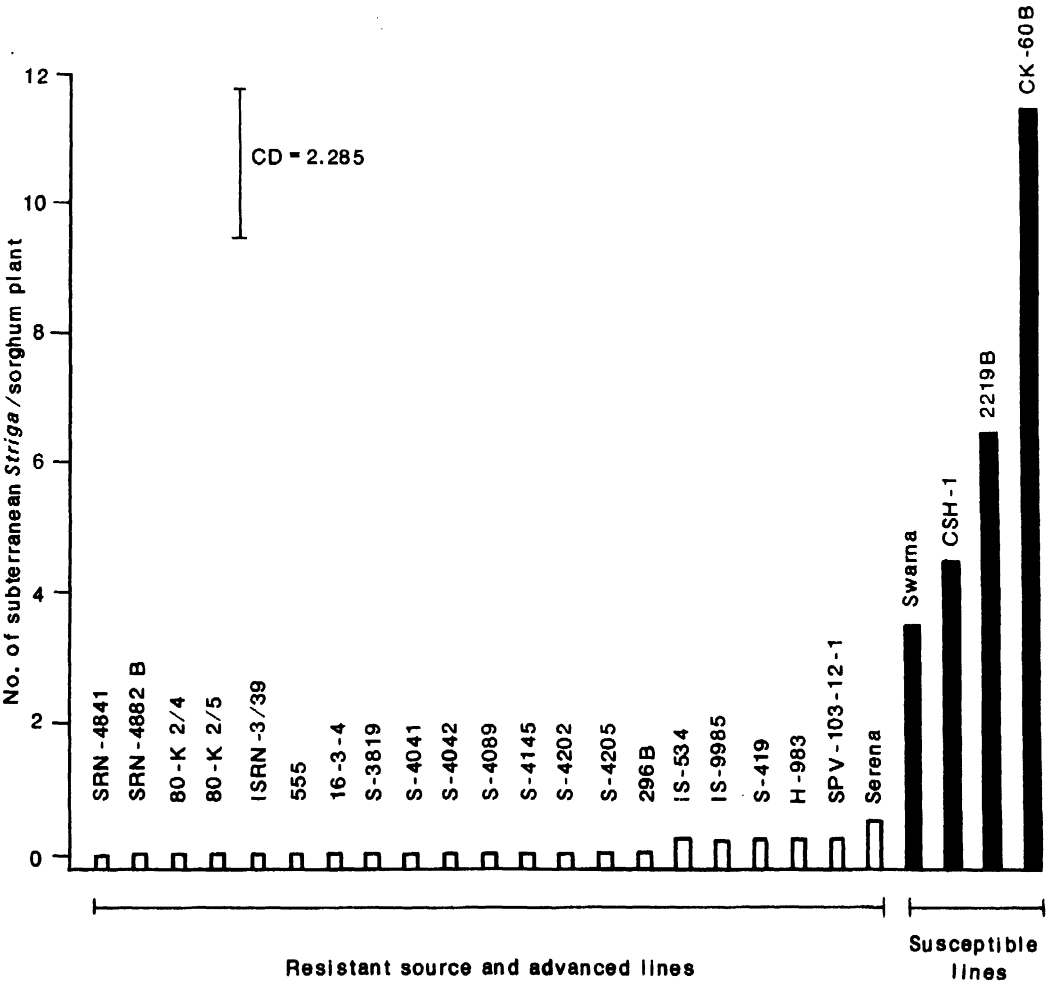
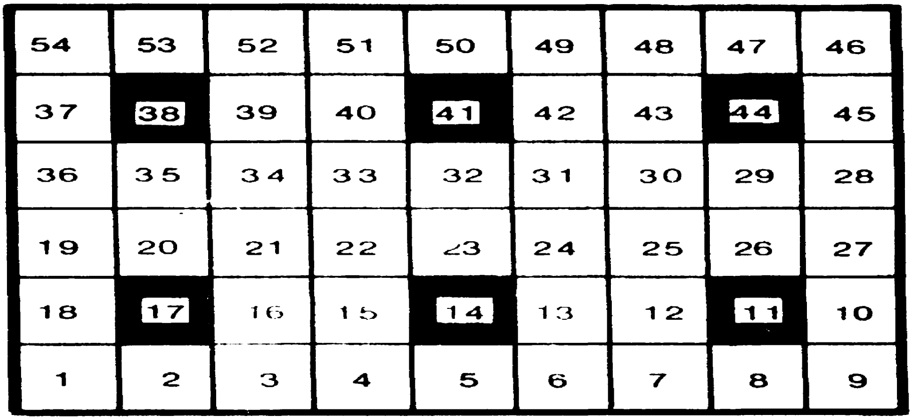


Figure 2. Subterranean Striga *counts of 25 sorghum lines in seed pans. (55-day counts) (D/S : 30.1.81).*

☐ Test entry

■ Susceptible check



54	53	52	51	50	49	48	47	46
37	38	39	40	41	42	43	44	45
36	35	34	33	32	31	30	29	28
19	20	21	22	23	24	25	26	27
18	17	16	15	14	13	12	11	10
1	2	3	4	5	6	7	8	9

Figure 3. Field layout in the preliminary screening stage for Striga *resistance.*

☐ Test entry

■ Susceptible check plots

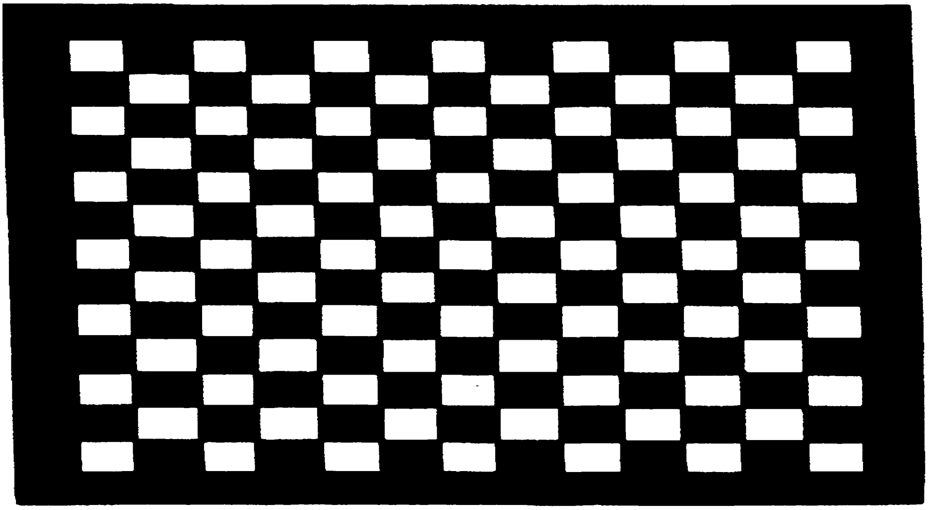


Figure 4. Checkerboard layout for advanced screening in Striga *resistance breeding.*

SELECTION FOR *STRIGA* TOLERANCE IN SORGHUM

C. Hanumantha Rao[1] and B.S. Rana[2]

Striga asiatica is a root parasite of sorghum and reduces the grain and fodder yields drastically under endemic situation. Though its incidence is reported long back, its appearance has recently become more prominent after the introduction of new hybrids and varieties. Therefore, a program was initiated in 1978 to select tolerant lines from recently developed AICSIP high yielding varieties.

1. SCREENING TECHNIQUE

The varieties/hybrids were screened in a sickplot. The sickplot was developed at Hayatnagar Research Farm by growing the susceptible hybrids continuously over years, by allowing the *Striga* to flower and shed the seed and by spreading *Striga* seed collected from other fields in the month of May. Since the *Striga* incidence is not uniform over large area (Table 1), testing entries in the large plots in a traditional way was not found useful. Therefore, a small plot consisting of 3 rows of 3 m length was adopted. On either side of the test variety, a susceptible check (CSH-1 or CSH-6) was grown as an indicator of *Striga* infestation in that particular spot.

The varieties were replicated four times and randomized within each block. The incidence of *Striga* on a test variety was in relation to the *Striga* population on the bordering check entry (guard rows) The damage on the check entry was expected proportional to the intensity of striga emergence (Table 2).

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2. PARAMETERS OF FIELD RESISTANCE

2.1 *Striga*/sorghum plant. When *Striga* population effectively suppressed the flowering of susceptible check at both the sides, was considered sufficient for evaluating the test variety directly in terms of *Striga*/ sorghum plant.

2.2 Percent *Striga* incidence. In case of variability in *Striga* population on both sides of guard rows, the counts of *Striga* on test variety was expressed in terms of % *Striga* counts on susceptible check planted as guard rows.

2.3 *Striga* index. *Striga* not only varies in its population (intensity) on various varieties but also differs in its emergence. *Striga* index, as an additional parameter, was computed in order to account for both intensity of incidence and differences in the emergence. *Striga* counts per meter row length were taken on the middle row of the test variety as well on the guard rows at the 55 days crop growth stage. The differences in *Striga* emergence were measured in terms of height (growth differential) of *Striga* at 55 days. *Striga*'s height, classified with a class interval of 5 cm eg., 1-5, 6-10, 11-15, 16-20 cm, and count in each class were recorded. Geometric mean of sum of the product of midclass value x *Striga* count was defined as the *Striga* index. The *Striga* index of the test variety was also expressed in terms of % *Striga* index of the susceptible check as follows:

$$S.I.(\%) = \frac{\textit{Striga}\text{ index of the test variety}}{\text{Average }\textit{Striga}\text{ index of both guard rows}} \times 100$$

Evaluation of a variety was dropped when *Striga* incidence on susceptible check was not sufficient.

3. TOLERANCE MECHANISMS

In absence of complete resistance in highly yielding varieties and available germplasm, the varieties can be classified into three different tolerant groups. (i) Varieties (N-13 and IS-2203) supporting constantly less number of *Striga* plants and keeping normal plant growth,show high degree of tolerance. (ii) Some varieties such as 3962 x WABC 1022 and IS-4242 delay the *Striga* germination upto flowering and make up sufficient vegetative growth before *Striga* emergence. (iii) The varieties which tolerate some degree of *Striga* infestation at the expense of its growth and still make up some grain yield as happens in case of PJ8K local variety. The varieties which fail to flower under normal striga incidence can certainly be regarded as susceptible varieties. Differences in the degree of tolerance is expected due to different threshhold levels determined by the combination of various biochemical and mechanical parameters of sorghum root and intensity of *Striga* infestation.

4. EFFECT OF *STRIGA* ON THE PLANT GROWTH UNDER DRYLAND AGRICULTURE

Drought is more often and severe in shallow soils. Parasitism of *Striga* further escalates the drought effects and consequently wilting. Wilting caused by drought and by *Striga* are difficult to distinguish at the seedling stage. Though the germinating *Striga* on sorghum roots can be identified on uprooted seedlings, the differential recovery of seedlings after a shower distinguishes between physiological and *Striga* stress. The wilting seedlings which recover quickly after a shower indicate the physiological stress and those which do not recover elucidate the underground *Striga* stress. *Striga* damage is fairly severe on young seedlings before its emergence above the ground. It is due to heterotropic nature and complete dependence of *Striga* on the sorghum plant. Depending upon the intensity of *Striga* and rainfall, a susceptible variety can fail to flower or produce some yield (Table 2). As the *Striga* incidence increases, plant height, number of leaves and stem girth decrease.

5. SELECTION FOR VARIETAL TOLERANCE

The screening of released, prereleased varieties and hybrids, promising breeding materials and known resistant germplasm was carried out in sickplot. The surviving plants were selected each year and advanced to next year testing.

5.1. Selection from Basic Stocks

It was observed that none of the varieties possessed absolute resistance but there was varying degrees of tolerance among known "resistant" varieties (Table 3). *Striga* emergence in IS-2203 and N-13 remained low throughout the growth period but was initially low in other varieties (3692 x WABC 1022 and IS-4242) which increased at the time of flowering. IS-3924 was also a promising entry. While IS-2203 and IS-5218 were photosensitive, IS-3924 was photoinsensitive, early maturing and more desirable for plant breeding work.

5.2. Selection from High Yielding Varieties

Among the high yielding varieties, CSV-5 (168), SPV-103, SPV-104, SPV-109 and SPV-221 showed satisfactory tolerance to *Striga* at Hyderabad (Table 3). Their tolerance level was confirmed at Nandyal also (Venkateswarlu 1979). The single plants which matured in presence of *Striga* were selected and advanced for further testing. The tolerance level could not be substantially enhanced after two cycles of selection probably due to absence of residual genetic variability.

5.3. Selection from Local Variety

The local variety, PJ8K comprised white, yellow and red grains. Three pure line selections were made. The isolated red grain selection showed more tolerance to *Striga*, early maturity and improvement in productivity (Table 4). Under moisture stress condition, the yield potential of red selection was equal to high yielding varieties like SPV-221 and SPV-245 but lower than CSH-6 (Table 5). The red selection was multiplied and being tested in 25 *Striga* sick farmers' fields in Gadwal region of Andhra Pradesh.

5.4. Hybridization and Selection

Five tolerant varieties, viz., SPV-103, SPV-104, SPV-221, IS-3924 and N-13 were crossed with some high yielding varieties. Selections were made for earliness, grain yield and tolerance to *Striga* from segregating generations. Some of these crosses are now in F_5 generation.

Emphasis is given to combine drought and *Striga* resistances with higher grain yield so that resulting variety or parental line yields better under physiological and *Striga* stresses.

Table 1. *Striga* incidence in sickplot

Year	N	No. of *Striga* plants per one meter row length			CV%
		Range	Mean	S.D.	
1979	745	0 - 245	54.5	45.4	83.3
1980	192	26 - 690	260.8	111.5	42.7

Table 2. *Striga* incidence and damge caused to CSH-1 sorghum (kharif 1980)

Stage of plant growtn	*Striga* index	No. of *Striga* plants per one meter row length			CSH-1					
					Height (cm)		No. of leaves		Stem girth (cm)	
		Average	Median	S.D.	Avg.	S.D.	Avg.	S.D.	Avg.	S.D.
Flowering	28.3	145	120	73.3	120.1	12.8	9.1	0.52	1.26	0.14
Boot leaf	30.0	161	133	62.1	65.8	14.9	8.9	0.76	1.10	0.11
Vegetative	32.8	202	179	75.2	43.3	9.9	8.3	0.98	0.99	0.20
Dried plant	35.3	220	203	96.9	32.3	6.9	7.5	0.96	0.88	0.13

Table 3. Varietal tolerance to *Striga* and their yield potential under *Striga* stress

Entry	*Striga* incidence over control		% of Cob bearing plants		Fodder yield t/ha		Grain yield q/ha
	79	80	79	80	79	80	80
Resistant source							
IS-2203	16.2	18.0	71.3	52.5	6.23	6.76	0.00
IS-5218	39.0	10.0	62.0	0.0	8.83	12.09	0.00
N-13	4.9	62.0	65.0	11.0	5.97	8.37	0.00
IS 3924	-	30.0	-	100.0	-	3.07	4.02
High Yielding Varieties							
CSV-5 (168)	36.1	44.0	50.5	41.3	1.45	5.73	4.96
SPV-103	36.3	-	33.3	-	3.34	-	-
SPV-103-5	-	44.0	-	55.5	-	9.26	2.67
SPV-221	55.2	62.0	45.0	70.5	3.08	3.04	6.22
CSV-3 (370)	27.9	72.0	43.0	91.0	0.90	3.11	7.85
SPV-109	68.3	40.0	20.7	42.3	2.31	6.07	11.58
SPV-107	47.7	63.0	28.7	14.3	2.21	3.90	6.35
SPV-86	146.3	-	30.7	-	4.13	-	-
SPV-86-S	-	7.0	-	78.7	-	7.67	8.99
Local							
PJ8K	61.3	59.0	36.7	31.0	1.58	2.07	4.78

Table 4. Effect of pure line selection on *Striga* tolerance

Entry	*Striga* index	%ear bearing plants
Local red (pure line)	3.94	70.8
Local PJ8K(bulk)	10.79	27.6
IS-3924(Res.Check)	4.21	78.6

Table 5. Comparative yield potential of local red pure line in *Striga* free plot

Entry	Grain yield(kg/ha)	50% flowering (days)
Local red (pure line)	2392	63
Local PJ8K (bulk)	1259	71
CSH-6 (hybrid)	3671	60
SPV-245	2412	75
SPV-221	2100	70
CD (0.05)	6.16	

'GENETICS OF *STRIGA* RESISTANCE IN SORGHUM

V.K. Shinde and N. Kulkarni*

Striga has become a major constraint in stabilizing sorghum production. Two species are reported to be prevelent in India, S. asiatica and S. densiflora. S. asiatica is of common occurrence in sorghum growing areas of India while S. densiflora in Ahmednagar district of Maharashtra. Yield reduction caused by *Striga* can be very serious with heavy infestations occassionally killing plants before heading. Different control methods have been tried with varying success. This includes hand weeding, trap cropping, high fertility levels, use of herbicides and host resistance. However, it is recognized that utilization of genetic resistance in sorghum would be the most economic way to combat this problem. Three resistance mechanisms are generally reported in the literature, viz., the mechanical resistance, low stimulant production by host roots which is required for *Striga* seed germination, and antibiosis factors (Doggett, 1970 and Maiti et al., 1977).

Saunders (1933) identified mechanical blockage for establishment of *Striga* in three resistant varieties. Three different root tissues were identified as sites where invasion by haustoria of the parasite was curtailed - cortical cells, endodermal cells and xylem vessels. When crosses of these varieties were made with susceptible variety, inheritance of resistance was found to be complex and different for the three strains. Doggett (1965) reported that the variety Dobbs possessed a certain amount of mechanical resistance. Kumar (1940) reported two varieties of sorghum with low stimulant production ie. Bilichigan and Muddinandyal. Rao (1948)

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reported similar type of resistance in variety Bonganhilo from Tanzania. This variety was used by Shanmugasundaram and Venkataraman (1964) in India to develop a resistant strain Co 20. Later, Williams (1959) also reported a low stimulant line, Framida.

Nelson and Rogers (1959) demonstrated that a variety which is resistant to a given species of *Striga* at one location may not show resistance to same species or different species at another location. Five sorghum varieties which were considered to be immune to S. asiatica in South Africa were found susceptible to same species when tested in U.S.A.

Genetic variability for resistance

Most of the earlier work in India is an attempt made to screen varieties for *Striga* resistance and identification of resistant sources. Rao et al. (1967) reported that the variety N 13 was resistant to *Striga*. Chopde et al. (1973) screened varieties for resistance and reported that PS 13, Bonganhilo, PJ 16K and Khedi 2-2-10 showed considerable tolerance below 10% level of infestation. Rao and Jotwani (1974) reported *Striga* resistance in agronomically desirable variety 168 (CSV-5). Maiti et al. (1977) found that both N 13 and 168 were stimulant positive but resistant to infection In N 13 the resistance was attributed to the mechanical barriers (highly thickened endodermal cells and 2-3 layers of thick walled pericyclic sclerenchyma), where as in 168 it was due to presence of large amount of silica in the endodermal cells. Field resistance of N 13 and 168 to *Striga* was confirmed by many workers (Murty et al., 1974 and Bapat et al., 1975). Murty and Rao (1975) found that the varieties CS 3541, IS 6928, both zera zera types were free from *Striga* infestation. They found that Karad local and Aispuri were good donors of *Striga* resistance; and hybrids with 148 were *Striga* tolerant.

Hanumanth Rao et al. (1980) observed that there is no absolute resistance even in N 13, Bo-1 and M 35-1. Among the high yielding cultivars SPV 103, SPV 109, SPV 104 and SPV 221 have field resistance.

Vasudeva Rao (1981), based on multilocation field experiments conducted from 1977-80, concluded that there is no absolute resistance and the best low susceptible source lines are viz., N 13, 555, Serena, IS 2203, IS 4202, etc. These appear to be reasonably stable and promising as low susceptible sources to S. asiatica.

Desai (1972) studied the stability of yield in resistant varieties under *Striga* infestation. The variety BC 9 had lower mean with less than unit regression and they showed resistance even under heavy infestation.

Genetics of Resistance

1. Field resistance: Field resistance is the combined effect of the three mechanisms of resistance described earlier. Therefore, in field screening the final manifestation of individual mechanisms is assessed in the host lines. Webster (1972) advocated testing of the crosses involving local x exotic varieties on the land infested with *Striga* for their tolerance. Tarr (1962)from the crosses between resistant and susceptible strains reported that inheritance was complex, susceptibility being partially dominant in two such crosses and resistance incompletely dominant in the third. Some segregates were much more susceptible than the original susceptible parents. He observed that the most of the resistant sorghums had red rather than white seed but in crossing experiments seed colour and *Striga* reaction segregated independently in the F_3 generation.

At ICRISAT, the preliminary studies indicated that the field resistance was under the control of few genes, however no critical data was published.

Shinde and Kulkarni (1982) from their studies on 42 possible F_1 crosses involving resistant and susceptible lines reported that the field resistance was under the control of both additive and non-additive gene action. They observed higher magnitude of additive gene action than non-additive gene action and suggested the effectiveness of straight selection for field resistance. They reported that the genotypes N 13, CSV-5 and S 1841 were good combiners contributing favourable genes for striga resistance.

2. Stimulant production: It was reported from ICRISAT that the low stimulant production is controlled by a single recessive gene in a set of low and high stimulant sorghum line crosses. Vasudeva Rao et al (1981) reported preponderance of additive genetic variance for stimulant production and that the variety IS 2221 was a good combiner. Shinde and Kulkarni (1982) also reported higher magnitude of additive variance. They found that the reciprocal differences were significant and emphasized the need to account this source of variation in breeding for low stimulant production. They found S 1841 and SPV 86 to be good combiners for low stimulant production.

3. Mechanical resistance: The genetics of this type of resistance is not satisfactorily understood. Saunders (1933) reported that the inheritance of resistance is rather complex. Therefore, in a programme to develop a *Striga* resistant variety first step would be to identify lines with low stimulant activity to several strains. Next step would be to combine this character with mechanical barriers which would result in a high degree of resistance and would not readily break down.

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GENETICS OF RESISTANCE TO STRIGA ASIATICA IN SORGHUM[1]

V.K. Shinde and Narendra Kulkarni[2]

The information on the genetics of *Striga* resistance in sorghum is very limited. Incorporation of *Striga* resistance into agronomically elite background in the past has met with little success. Basic information on the inheritance of resistance is required to plan a systematic breeding programme to develop resistant varieties. It is with this objective the present studies were initiated at Sorghum Research Station, Parbhani. Preliminary work on *Striga* has identified tolerant/resistant sources. Seven parental lines comprising four known resistant sources, viz., N 13, CSV 8R, S 1841, CSV 5 and three susceptible lines, viz., CK 60B, 2077B and 2219B were crossed in all possible combinations and 42 crosses including reciprocals were produced and evaluated to know the genetics of *Striga* resistance.

1. Genetics of field resistance:

The seven parental lines and their 42 possible crosses with their corresponding F_2s were sown in two sets, one consisting of parents and crosses and another parents and F_2s during kharif 1981 in R.B.D. with three replications. A systematic check (CSH-1) was sown after every three test entries. Mateiral was grown in a *Striga* sick field. Artificial inoculation of soil with *Striga* seeds was also done 10 days before sowing. There was uniform and heavy *Striga* infestation during the season. The *Striga* counts were log transformed and expressed as percentage of the check to adjust for the variability. The parents and corsses were also analysed for stimulant production and different source groups were identified.

The mean *Striga* count on different source groups such as strigol negative (SN), mechanical resistant (MR) and susceptibles were recorded (Table 1). Both strigol negative and mechanical resistant parents contributed to the field resistance.

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[1] Part of Ph.D. work carriedout by Shri Narendra Kulkarni. Paper presented at ICRISAT IN a working group meeting held on Sept. 30 to October 1, 1982

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As regards hybrids, the crosses between SN x SN or SN x MR and their reciprocals exhibited very low *Striga* count. The crosses between strigol negative parents like S-1841 and CSV-8R expressed differential reaction to *Striga*. When S 1841 was used as female it could give moderage *Striga* count but when CSV 8R was used as female, the *Striga* infestation was high. These results indicates that there is differential reaction of different cytoplasmic sources for field resistance.

N 13 variety has been identified long back as a mechanical resistant parent. When this was crossed with susceptible lines, *Striga* count in F_1 was very high. However, CSV 5 which is another mechanical resistant line, when crossed with susceptible lines reduced the striga count to 50%.

Susceptible x susceptible crosses exhibited higher degree of susceptibility in the hybrid generation as compared to their parents. Thus, the dominance or recessiveness of the character varied in different types of crosses and depends on the type of female parent used in crossing programme. Apparantly it seems that the crosses between SN x SN., SN x MR., and MR x MR would be more useful for developing *Striga* resistant varieties in future breeding programme.

The genetic analysis for *Striga* count indicated that the field resistance was under the control of polygenes where both additive and non-additive gene actions were significant (Table 2). However, the magnitude of additive gene action was more than non-additive gene action. Hence, straight selection for field resistance would be more effective.

Gca effects on parental lines indicated that N 13, CSV 5, S 1841 and CSV 8R contributed maximum favourable genes for *Striga* resistance in that order both in F_1 and F_2. These varieties, therefore, will be useful in conventional breeding programme. The parental lines 2219B, 2077B and CK-60B were highly susceptible to *Striga* as was evident from their high gca values.

2. Genetics of field tolerance:

Field tolerance can be defined as the capability of sorghum plants to produce an acceptable yields when parasitised with *Striga*. The pattern of inheritance was similar to that of field resistance. The gca effects of parental lines in both F_1 and F_2 (Table 3) indicated that S 1841 and CSV 5 had significant desirable effects for grain yield. These cultivars, therefore, can be used for direct introductions in *Striga* endemic areas till some other resistant sources are made available.

3. Genetics of stimulant production:

The 42 crosses and their parents were screened against two *Striga* sources viz., Parbhani and Patancheru for their stimulant production at ICRISAT. Both additive and non-additive gene actions were important in the inheritance of stimulant production. The reciprocal differences were also significant. This indicated that the low stimulant lines could be used as female parent in breeding for low stimulant production lines. The cultivars CSV 8R and S 1841 showed high gca for low stimulant production for Parbhani *Striga* source while S 1841, CSV 5 and 2077B for Patancheru *Striga* source. The variety N 13 was strigol positive and contributed more favourable genes for strigol production. It's field resistance is therefore, attributed to mechanical barriers.

The analysis of variance and variance components (Table 4) showed that the differences due to genotypes were significant. The magnitude of $\sigma^2 g$ was larger. The genotype x *Striga* source interaction was significant indicating variation between sorghum genotypes for stimulant production. This implies that the resistance of sorghum genotype to any one *Striga* source does not necessarily show it's resistance to other *Striga* source. Thus the virulance of *Striga* source differ with sorghum genotypes. The varieties CSV 8R, CSV 5 and 2077B had the differential response to the different *Striga* strains of the same species as seen from their gca effects

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Table 1. Cytoplasmic Differences for Field Resistance to *Striga*

Source	Parents/Crosses	Mean *Striga* count	% Log (STC)
A. <u>Parents</u>			
1. Strigol negative	S-1841, CSV-8R	10.17	50.95
2. Mechanical resistance	N-13, CSV-5	11.67	46.58
3. Susceptible	CK-60B, 2077B, 2219B	138.89	102.23
B. <u>Crosses</u>			
1. SN x SN	S-1841xCSV-8R CSV-8RxS-1841	16.83	65.74
2. SN x MR	S-1841xN-13 S-1841xCSV-5	17.50	58.45
3. MR x SN	N-13xS-1841 CSV-5xS-1841	16.83	57.82
4. SN x Susc.	S-1841xCK-60B S-1841x2077B S-1841x2219B	59.89	79.57
	CSV-8RxCK-60B CSV-8Rx2077B CSV-8Rx2219B	145.55	95.02
5. Sucep. x SN	CK-60BxS-1841 2077BxS-1841 2219BxS-1841	67.11	83.67
	CK-60BxCSV-8R 2077BxCSV-8R 2219BxCSV-8R	151.66	96.11
6. MR x MR	N-13xCSV-5 CSV-5xN-13	15.00	55.28
7. MR x Suscep.		127.56	95.52
8. Suscep. x MR		132.67	98.26
9. Suscep. x Suscep.		194.28	103.36

Table 2. Analysis of Variance for Combining Ability for Field Resistance (*Striga* Count), Field Tolerance (Grain Yield), and Stimulant Production

Source	d.f	Field Resistance		Field Tolerance		Stimulant Production	
		F_1	F_2	F_1	F_2	Parbhani source	Patancheru source
GCA	6	2179.06**	1993.25**	386.140**	128.426**	173.616**	180.084**
SCA	21	166.468*	109.12**	233.531**	49.410**	67.186**	63.034**
Reciprocal	21	2.949	0.862	10.776**	1.004	54.988**	41.500**
1. Maternal effects	6	6.641	0.856	19.006**	1.483	-	-
2. Non - maternal effects	15	1.472	0.864	7.484*	0.811	-	-
Error	96	3.176	4.41	3.522	2.263	3.570	4.274
GCA/SCA		13.1	18.3	1.6	2.6	2.6	2.9
$\sigma^2 g$		144.028	134.755	11.283	5.722	7.707	8.458
$\sigma^2 s$		93.027	59.653	131.035	26.859	36.242	33.475
$\sigma^2 r$		-0.114	-1.774	3.627	-0.629	25.709	18.613
$\sigma^2 g/\sigma^2 s$		1.6	2.3	0.08	0.213	0.21	0.25

*, ** Significant at 5% and 1%

Table 3. General Combining Ability Effects of the Parental Lines

Parental line	Field Resistance		Field Tolerance		Stimulant Production	
	F_1	F_2	F_1	F_2	Parbhani	Patancheru
			(Grain Yield)			
N-13	-10.00**	-11.963**	-1.343**	1.047**	5.211**	5.404**
CSV-8R	- 3.55**	- 3.008**	4.793**	3.806**	-5.568**	-0.035
S-1841	-12.181**	- 7.704**	7.676**	3.614**	-3.022**	-4.117**
CSV-5	-12.962**	-13.682	0.346	0.207	-0.764	-3.058**
CK-60B	11.483**	11.453**	-2.218**	-2.016**	2.012**	4.117**
2077B	12.412**	9.791**	-0.508	-3.556**	1.391**	-2.041**
2219B	14.798**	15.114**	-8.745**	-3.103**	0.743	-0.209
S.E. (gi) ±	0.440	0.520	0.464	0.372	1.336	1.461

** Significant at 1%

Table 4. Analysis of Variance and Variance Components for Stimulant Production

Source	d.f.	M.S.S
Genotype	48	235.159**
Striga source	1	52.09
Replications/locations	1	11.39
Genotype x *Striga* source	48	51.636**
Error	48	14.605
$\sigma^2 g$		45.881
$\sigma^2 g \times s$		18.515
$\sigma^2 e$		7.302
$\sigma^2 g / \sigma^2 gs$		2.478

** Significant at 1%

MECHANISMS OF *STRIGA* RESISTANCE IN SORGHUM*

R.K. Maiti and L.R. House

Striga belonging to the family Scrophulariaceae is a noxious root parasite attacking graminaceous crops such as sorghum, millet, maize etc.; and crops like cowpea, tobacco and sunflower are also attacked by other species. A severe attack by this parasite sometimes causes total crop failure. In India, sorghum is attacked by *Striga*. Control measures to eradicate *Striga* such as application of ethylene has been developed (Dale et al;1970)and different control measures have been reported by Hosmani 1978 , but as very high costs are involved, this method is not feasible. A disadvantage of other methods is that the crop cannot be saved from damage already done by the parasite prior to emergence above the ground. Hence breeding resistant cultivars appears to be a useful approach to solve the problem.

There are several mechanisms operating in plants for *Striga* resistance. The association between the parasitic plants and the hosts is accomplished through a specialized contact organ, the haustorium and the infestation of host depends on the successful penetration of haustoria into the vascular bundles of the host root. Three different host resistance mechanisms to *Striga* are reported by the previous workers viz., i) low stimulant production (Kumar 1940; Rao 1948 and Williams 1959), ii) mechanical barriers (Saunders 1933), and iii) antibiosis or physiological obstruction (Saunders 1942). However, studies on the last two mechanisms are limited.

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A review of literature on different aspects of research on *Striga* follows: Parker 1965 has discussed the problem of *Striga*. A comprehensive review dealing with the physiological concepts of the association between parasitic angiosperms and their hosts has been discussed by Tsivion (1978). The transfer of water and solutes of the xylem sap takes place mainly by osmotic flow through the xylem bridge of the haustorium. Other physiological processes involve morphogenetic interactions caused by hormonal factors which culminate in the development of the haustorium. Several studies have been made to investigate the mode of parasitization of the susceptible host by *Striga*. These include studies by Stephens (1912), Saunders (1933), Uttaman (1950) and Rogers and Nelson (1962) on Striga asiatica by Musselman and Dickinson (1975) on various parasitic Scrophulariaceae (including Striga asiatica), by Okonkwo (1966) on Striga senegalensis and by Okonkwo and Nwoke (1978) on Striga gesnerioides.

Attempts have been made to study the histochemistry of the haustorium of Striga hermonthica on millets. The presence of phosphatase enzymes at the contact zone between the host and the parasite indicate that these enzymes were involved in the penetration mechanism and perhaps provide active support (Tidiane Ba 1979). Chances in growth regulating substances have also been reported in Sorghum bicolor infested by Striga hermonthica (Drennan and Hiweris 1979). In this study most tolerant variety showed the largest cytokinin content and the lowest content of gibberrelins and farnesol. With infestation there was reduction by 90-95% cytokinin and gibberelins by 30-80% in the xylem exudates of the host (Drenan and Hiweris 1979).

Renaudin (1975) found that Lathraea clandestina (Scrophulariaceae) haustoria was found only when a physical contact with the host root was made. The author has interpreted the presence of a limiting exogenous stimulus which triggered an endogenous stimulus leading to the haustorial initiation. Renaudin (1977) showed by histochemical techniqud the activity of cellulase in the haustorium of Lathraea clandestina in the regions adjacent to the host. No such information is available on *Striga* parasitization on sorghum root.

Research at ICRISAT

An investigation has been undertaken at ICRISAT to investigate the mode of haustorial development of Striga asiatica (L.) Kuntz and its penetration, and to learn more about the nature of mechanical barriers in sorghum cultivars (Maiti et al in press). Twenty-five sorghum cultivars were chosen to represent a wide geographic distribution and a range of susceptibility. Most of these lines had been field tested for resistance to Striga asiatica in Akola, India and against S. hermonthica in Sudan, Cameroun and Ethiopia. Based on their field performance over all these locations, they were grouped into resistant, moderately resistant and susceptible categories for assessing the variability of the haustorial development in the hosts.

The technique adopted for growing sorghum seedlings and the pretreatment of *Striga* seeds were similar to that of Parker et al (1979). After four weeks (by which time the *Striga* was well established on the roots of the susceptible cultivars), the seedlings were carefully removed from the cups. The roots were gently washed and the root regions with *Striga* attachments were fixed in a formalin propionic acid-alcohol mixture and finally processed for microtome sectioning following Johansen (1940). The sections were cut through the root regions with *Striga* attachment, processed and stained for permanent slide preparation. Observations were made under microscope on the degree of thickening of the inner endodermal cell walls, the frequency of silica crystals in the endodermal cells and the degree of thickening of the walls of the pericycle.

In order to understand whether the development of mechanical tissue differed in resistant and susceptible cultivars, a time-course study of the changes in root anatomy at different stages (7, 14, 21 and 28 days) were made on CSH-1, (susceptible) and N13 (resistant).

Parasitization of the susceptible and resistant roots

Germination began with the radicle making its way through the seed coat. The plumule grew very slowly at this stage, and still remained within the seed coat until the haustorium established its vascular contact with the host root. The bulbous haustorium formed at the tip of the radicle, made contacts with the epidermis of the host root and pressed against cortical cells. These became distorted and the haustorium penetrated to the cortex and ultimately came in contact with the endodermis.

The invasion of the host stele was by the tracheids developed from the axis of the young haustorium. These tracheids were characterised by the spiral thickenings as described by Rogers and Nelson (1962) and penetrated the xylem vessels either by dissolving the cell walls or by mechanically disrupting them. This made the host parasite vascular connections complete; at this stage the haustorium attained almost double the size of the host stele. In some cases the presence of a substance which stained dark green with toludine blue was noticed when the haustorium was in contact with the endodermis.

In the resistant cultivars the attachment to the root and the penetration of the cortex by the haustorium followed the same processes as in the susceptible cultivars. However, in the resistant cultivars most of the haustoria failed to penetrate the endodermis, in contrast to the susceptible cultivars in which most haustoria were successful in establishing the vascular connection with the host root.

Some resistant cultivars were found to have a thickening in the endodermal cell walls and pericycle cell walls and the endodermal cells were found to contain silica crystals. These were observed in the resistant cultivar N13 and in contrast to the susceptible CSH-1. The course of development of these thickenings on the two cultivars indicated that cell wall thickening in these two tissues as well as the presence of crystals was observed in N13 as early as 7 days after germination. CSH-1, in contrast, showed only insignificant thickening in the endodermis and contained no silica crystals as late as 14 days after germination. By 28 days, there was only a small increase in thickening in the endodermis and in the pericycle in CSH-1, whereas N13 had accumulated considerable thickening material, especially in the pericycle, by that time. Sorghum cultivars did show range of variability in the intensity of mechanical tissue.

In addition, several apparent responses to the invasion by the *Striga* haustorium were observed in certain resistant cultivars. One example of these reactions appeared to be extra lignification in the pericycle cells at the point of contact of the haustorium with the endodermis in N13 and IS 4202. As a result, the haustorium appeared to become distorted and failed to penetrate into the stele. In another resistant cultivar, (SRN 4841), a few haustoria did penetrate through the endodermis but on reaching the xylem vessel, tyloses-like occlusions were formed in the cavity of the xylem vessels.

Relationship of host root anatomy and host resistance

Host root anatomy of 25 selected cultivars could be grouped into three types of mechanical tissue; 1) the thickness of the inner tangential wall of the endodermis; 2) the degree of lignification of the pericycle, and 3) and the frequency and size of the crystals in the endodermal cells. Each genotype was scored as high, intermediate or low for each of these characteristics. The genotype with the high score representing the maximum expression of the character could be associated with resistance.

In the overall scoring more weightage is given to the intensity of mechanical tissue (sclerenchyma) in the pericycle and size of silica crystals in the endodermis. This mechanical tissue is assumed to offer resistance to the invading haustorium. Based on the overall score, it appears that all the cultivars in the resistant group have a high or intermediate rating for all the three characters. In case of IS 4202 and IS 5218, all the three characters were rated as intermediate but collectively might be regarded as strong enough to restrict haustorial penetration. Resistance mechanism of the different cultivars could not be explained only on the basis of mechanical barriers. It might be that the resistant cultivars may have in addition to these mechanical barriers some yet unknown factor(s) (enzymes or hormones) which together with the mechanical barriers confer field resistance.

Host parasite relationship

Saunders (1933) has identified three resistant cultivars in South Africa with particular reference to Striga lutea which had three different resistance mechanisms. In the first cultivar the obstruction of haustorium was by cortical cells with very little resistance from the endodermis and vascular cylinder; in the second cultivar, the inner walls of the endodermis and vascular cylinder both obstructed the penetration of haustoria fairly effectively; and in the third cultivar, the serious impediment to the haustorial penetration was the vascular cylinder itself rather than the endodermis.

In the investigation at ICRISAT N13 was found to have a resistance associated with the highly thickened endodermis and pericycle tissue, and, SRN 4841 was found to have resistance from a highly lignified pericycle. Extra lignification in pericycle cells at the point of contact of the haustorium was observed in N13 and IS 4202 resulting in failure of *Striga* haustoria to enter the stele.

There are several reports explaining the role of lignification to parasite resistance. Extra lignification as a response to a wound caused by invading hyphae of fungal pathogen is reported in wheat (Ride 1975). An extra lignification of the xylem vessels in sunflower cultivars resistant to *Orobanche cumune* in response to the *Orobanche* haustorium has been reported (Panchenko and Antonova 1974).

Lignification occurred around a fungal infection site in a resistant cucumber variety whereas in the susceptible lines there was no lignification (Hijwegen 1963). He concluded that lignification could be part of an active resistance mechanism inhibiting the parasite in its progress.

The study at ICRISAT on the haustorial development of *Striga* on a wide range of sorghum cultivars also corroborate the finding of Saunders (1933), on parasitism of *Striga lutea* in that some sorghum cultivars offered mechanical barriers to the invading haustoria. The collapsing of haustoria in the cortex and the deposition of dark staining materials could be the impact on a physiological obstruction as reported by Saunders (1942). The deposition of dark green substance stained with toludine blue could be a chemical substance reported to be produced by the advancing haustorial cells in *Striga asiatica* (Saunders 1933) and *S. gesneriodes* (Okonkwo and Nwoko 1978). They reported that this chemical substance softened or dissolved the cell wall of host tissue. The chemical substances has not been identified but the tests for cellulase were reported to be negative (Rogers and Nelson 1962).

In this study no direct comparisons have been made to relate the presence of mechanical tissue with field resistance but studies were undertaken with an objective to investigate haustorial development on some sorghum genotypes. The field resistance of some of the genotypes is known. Although no clear cut conclusions could be made regarding the relation between the field resistance, and mechanical barriers, there are indications that some of the resistant lines like N13, IS 4202 produced more mechanical barrier while many of the susceptible lines showed less mechanical barrier.

However, this study contributes some evidences that the mechanical resistance does seem to be an important, if not exclusive, mechanism of host plant resistance to *Striga* in stimulant cultivars.

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PHYSIOLOGY OF SORGHUM - *STRIGA* INTERACTIONS

S.R. Parvatikar[1]

Striga has been appropriately named as withchweed because of its deceptive nature of doing the harm even before being detected. It is a root parasite establishing itself directly in the vascular systems of the host plant and drains off water and nutrients, resulting in yield losses of 15 to 75% depending on the severity of infection. *Striga* has strong survival mechanism like dormancy, long period of viability, and prolific seed production capacity. Removal of *Striga* shoots, when seen above ground, is not much useful since the shoots resprout soon from their crown-buds which are located upto 15 cm below the soil.

About 60 *Striga* species have been reported in the world. *Striga asiatica* (L) Kuntze, is the most widely occuring species in India (Hosmani, 1978). *Striga* seed measures about 0.4 mm in length and 0.2 mm in breadth, and consists of an undifferentiated embryo enclosed by an aleurone layer and seed coat. No endosperm is present between the aleurone layer and embryo. *Striga asiatica* grows to a height of 15-25 cm and has narrow, linear or lanceolate leaves measuring about 0.5 to 5 cm in length. It produces about 90,000 to 4,50,000 seeds per plant (Doggett, 1970). High humidity and temperature rapidly reduce the viability of the seeds, (Kust, 1963). Moisture induces dormancy and seeds are incapable of germination until dried. In dry soil the seeds are viable for a longer period, even upto 20-40 years.

Dormancy and Germination

In many species, seeds from the same harvest, or even the same flower may possess different dormancy characteristics, so that the period of germination is spread over many months or even several years. Dormancy may be due to immaturity of the embryo or the impermeability of the seed coat to gases and water. *Striga* seeds require an after-ripening period varying from a few months to several years before it can germinate in the presence of a stimulant. They germinate after undergoing a period of pre-conditioning and on getting a stimulant for triggering the germination.

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Striga seed germination takes place in two phases. During the first phase, moisture only is required but during the second phase a chemical stimulant must be present. The first phase takes place most rapidly at temperatures of 80°F to 90°F and requires from 5 to 20 days. The second phase which results in actual emergence of the radicle is completed in 24-48 hours. Absorption of stimulant occurs during the first 2 hours of the second phase of germination. Following germination, *Striga* root establish contact with the host root by means of haustorium which penetrates into the xylem vessels of the host roots and draw water and nutrients. Cook et al. (1966) isolated from cotton roots a crystalline germination stimulant strigol ($C_{19}H_{22}O_6$). D-xyloketose, cumarin derivatives and ethylene also stimulate germination of *Striga* seeds. Yoshikawa et al. (1978) reported that air dried seeds treated with kinetin at 1.2×10^{-4} M induced germination without any pre-conditioning. Even the shoot development of *Striga* was promoted. *Striga* seeds about 10 mm away from the host root can be stimulated and can made contact with the host root (Doggett, 1965). The radicle of the *Striga* seedlings apparently secrete enzymes, which assist the penetration of the host root by dissolution of the host cell walls. The *Striga* haustoria then establish connections with the vascular strands of the host (Rogers and Nelson, 1962).

The studies of Williams (1961) on the tropism and morphogenesis of *Striga* seedlings in the host rhizosphere indicated that the host root exerts a definite, positive chemotropic influence over the growth of the parasite radicle in the immediate vicinity of the host roots upto 4mm distance. Further, host roots also produce morphogenic factors which induce striking changes in the parasite seedlings. He reported that GA_3 (1-25 p.p.m) promoted shoot formation while kinetin (10 p.p.m) caused the development of root hairs.

Musselman (19?3) indicated that in Striga lutea root hairs are absent, although root hairs are commonly found in the vicinity of the hypocotyl, that the radicular apex is less organised with an early sloughing of cells, and that the root apex may form a primary haustorium upon contact with the host root. Germination and haustorium initiation are different and distinct processes mediated by seperate chemical controls.

After establishing on the host root, the parasite remains underground for about 3-6 weeks. Hence in its subterranian stage, *Striga* is a complete parasite and presumably obtains all its nutrients from the host plant. Large quantities of starch is stored in the young subterranian shoot of Striga asiatica (Saunders, 1933). However, the translocation of organic substances has not been understood because no phloem connections between the host and the parasite have been demonstrated. Stephens (1912) suggested that if the organic materials were obtained from the host, then they must be either the materials passed from the phloem to the xylem of the host, or what the haustoria may absorb from the cortex of the host.

After the *Striga* plant has produced substantial green shoot, it can synthesise organic compounds in its green tissues, and absorbs only mineral salts and water from the host (Saunders, 1933). However, some workers feel that certain species of *Striga* continue to take food material from their host even after producing green leaves. Rogers (1959) confirmed this by exposing leaves of maize to $^{14}CO_2$ in light and detecting activity in the attached green Striga asiatica after a period of time.

Using $^{14}CO_2$ and ^{14}C-urea it was seen that greater activity was detected in the parasite (aerial and subterranian) than in the host roots or stem on a dry weight basis. The activity in the subterranian parasites was double than that in the aerial portion of parts. Greater activity of ^{35}S was detected in the parasite when ^{35}S was applied to the host roots than when applied to the host leaf.

Translocation of ^{14}C did not occur appreciably from the parasite to the host. Saunders (1933) found that the osmotic pressure in the parasite haustorium was 2-3 times higher than the host. Some workers believe that bulk of the mineral salts needed by the parasite may be obtained from the host, though a small amount of independant absorption occurs by *Striga* roots. Increased nitrogen application to sorghum results in decreased osmotic pressure gradient towards the parasite which adversely effects its survival. Also nitrogen application reduces strigol production by sorghum plant.

Germination

The rate of germination of *Striga* seeds with different crop root exudates was studied by Prabhakar Setty (1980), and the results indicated that the maximum germination was within three days after the application of root exudates (Table 1).

The stimulation of *Striga* seed germination by different growth regulators were also studied (Table 2). Kinetin in combination with GA_3 and I.A.A. has given the highest germination and in 3 days time, maximum germination was observed.

Studies on the chlorophyll content of *Striga* plants by Prabhakar Setty (1980) have shown that the contents of both chlorophyll a and b was highest at 10 days after emergence (1.30 mg/g fresh Wt.). There was a general increasing trend from 5 days to 10 days and then it declined.

The ^{14}C photosynthetic rate revealed that there was progressive increase from 5 days after emergence, and a peak was attained at 20 days. It decreased at 25 and 30 days after emergence and the lowest rate was recorded at 30 days.

The activity of nitrate reductase was lowest at 5 days, went on increasing upto 20 days after emergence and then started decreasing. Even at 30 days after emergence N R activity was higher than at 15 days after emergence.

Studies on the total dry matter production by the *Striga* plant conducted upto 30 days after emergence (later the plant matures), showed an increase in D.M.A. upto 30 days.

Prabhakar Setty (1980) also studied the nutrient content of different elements and found that the N, P and K contents of *Striga* plants were highest at 5 days after emergence. They were 33.0, 58.0 and 47.4 mg/g dry weight of *Striga* respectively. The content of micronutrients like Ca, Mg, showed gradual increase with age upto about 15-20 days whereas Mn and Cu recorded highest content at 30 days after emergence.

Tolerance to *Striga* in some varieties might be correlated to the content of total sugars and aminoacids. Also higher cytokinin and low farnesol were found in tolerant varieties. The cytokinin, GA, ABA and Farnesol content is much lower in *Striga* than in sorghum but the nutrient content is higher in *Striga* than in sorghum.

The failure of *Striga* to parasitise tolerant crop varieties may be due to the inability of *Striga* to penetrate beyond the endodermis and make contact with the xylem vessels of the host roots. The inner walls of the endodermis are thicker in the tolerant types of sorghum. Further, the tolerant varieties may exude low amount of the stimulant by their roots.

Egley (1971) has shown that the grain yield of sorghum was severely affected under no-nutrition condition (low nutrition or poor soils) while there was only 50 per cent reduction in yield with double the level of nutrients and that the early-emerged parasites caused more damage to the host than the late-emerged ones.

CSH-1 and Swarna are highly susceptible to *Striga* and are used as susceptible checks in experiments. Rate of photosynthesis reduced upto 45% in CSH-1 and about 25% in Swarna due to infestation with *Striga*. Free proline content increased by 2 to 3 fold, N R activity, in both roots and leaf, increased substantially and water stress was more evident in sorghum plants infested with *Striga* as compared to the control. About 40% loss in grain yield was reported.

Table 1. Germination of *Striga* seeds by crop root exudates

Crop/Variety	Percentage germination of *Striga* seeds		
	After 24 hrs.	48 hrs.	72 hrs.
Sorghum			
CSH 1	22.03	31.45	32.95
CSH 5	15.27	25.28	25.63
Swarna	24.22	37.45	37.48
148	14.10	21.23	21.08
BH-4-1-4	11.87	20.23	25.80
Cotton	15.50 to 20.50	22.05 to 32.25	22.05 to 33.72
Groundnut (DH-330)	34.93	49.45	50.95
Redgram (Hy3C)	25.65	34.80	35.15

Table 2. *Striga* seed germination induced by different growth regulators

Treatment	Conc. (p.p.m)	Percentage of *Striga* seed germination After 24 hrs.	48 hrs.	72 hrs.
Etherol	20	0*	0	0
Kinetin	10	62.01	62.36	63.36
$G.A_3$	40	22.89	24.62	27.95
I.A.A.	10	20.90	21.08	21.17
$G.A_3$ + IAA	40+10	41.88	42.12	43.51
$G.A_3$+Kinetin	40+ 5	71.78	73.08	74.51
Kinetin + IAA	10+ 5	71.68	72.07	72.47
Kinetin+GA_3	10+20	77.02	77.58	78.73
Distilled Water	-	0	0	0

* Absence of germination could be due to improper pH during germination

PHYSIOLOGICAL BASIS OF 'HOST-PREFERENCE' IN STRIGA ASIATICA (L.) KUNTZE

Bharathalakshmi and Jayachandra[1]

Striga asiatica (L.) Kuntze is a wide spread root parasite attacking a large number of graminaceous and non-graminaceous species (Hosmani, 1978) The members of the species are reported to show different degrees of preference to the host(s) in any given area (Lewin, 1932). S. asiatica occurring on different hosts cultivated in different areas of Karnataka, are reported to be host-specific in their response to the root exudates of different host crops (Bharathalakshmi and Jayachandra, 1979). A survey of the cultivated fields of Kikkeri, Mandya district, Karnataka, India during 1977 and 1978 showed several cases of preferential attack of crops by Striga. Sorghum and Paspalum fields showed heavy infestations. In finger millet fields the incidence was negligible. Rice fields adjacent to the Striga - infested field of Paspalum was completely free though the former is also reported as a host to Striga (Hosmani, 1978). When finger millet/rice was grown with sorghum, only the sorghum plants were parasitized. These observations indicated host-specificity among the members of S. asiatica and hence detailed studies on the behaviour of the parasite at different stages of its growth as influenced by different characters of the hosts and the parasite were undertaken.

MATERIALS AND METHODS

The two samples of S. asiatica used in the present study were collected from the sorghum (CSH-1) and Paspalum fields at Kikkeri, Mandya district, Karnataka, India and are designated as S_K and P_K, respectively. The seed samples were stored for atleast six months for after-ripening, before being used. The grains of sorghum (Sorghum bicolor (L.) Moench) var. CSH-1 and Paspalum scrobiculatum L., were obtained respectively from the National Seeds Corporation, Bangalore, and from the cultivators in Kikkeri.

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1. Germination Response

The host root exudate from 10 day-old seedlings were obtained following the technique described by Parker et al., (1977). Germination of the pretreated seeds of the two samples of *Striga* was tested in the root exudate following Bharathalakshmi and Jayachandra (1979). Germination tests were also carried out by inoculating pretreated seeds of *Striga* on the roots of 10 day-old seedlings of both the hosts grown in filter paper rolls.

2. Penetration Response

The pretreated seeds of S_K and P_K samples were germinated in GR7 ($1\ \mu g\ ml^{-1}$) medium and the 'discs' with the germinated *Striga* seeds were inoculated on the seminal roots of 10 day-old seedlings of both the hosts. After allowing the seedlings to grow for ten more days, the number of parasite seeds germinated and the seedlings penetrating the host-root were counted.

3. Emergence

A set of 40 earthen pots (30 cm top dia. and 40 cm depth) was half-filled with a mixture of red soil:sand::1.0:1.5. The top 20 cm soil was thoroughly mixed with 150 mg seeds of *Striga.* Sorghum and *Paspalum* were sown in ten replicate pots for each *Striga* sample at the rate of five seeds per pot and were thinned to one seedling per. pot after emergence. *Striga* emergence was noted up to 130 days at intervals of ten days.

4. Biochemical analyses of the host-root exudate

a) Separation of 'Striga-germination-inducer'

Root exudate (2000 ml) from 10 day-old seedlings of the two hosts were collected as described by Parker et al. (1977) and was extracted twice with half the volume of petroleum ether to collect most of the inducers. This fraction was concentrated under reduced pressure, redissolved in chloroform and was subjected to TLC using silica gel G plates. The plates were developed in chloroform:methanol (40:2) system for one hour. The UV fluorescent spots were eluted in chloroform and concentrated to dryness. The residues were weighed and the UV spectra were recorded. The eluates were also tested for induction of germination of the pretreated Striga seeds.

b. Separation of total phenolics

The remainder of the root exudate after petroleum ether extraction was concentrated to 50 ml in a water bath and total phenolics were extracted in ether after hydrolysing with 4N NaOH (Harborne, 1973). Ether was evaporated, the phenolic residue was dissolved in methanol and subjected to two dimensional TLC on silica gel G plates using chloroform:acetic acid::90:10 and benzene: ethylacetate::55:45 as the first and second solvent systems, respectively (Harborne, 1975). The UV fluorescent spots were eluted with methanol, redissolve in ethanol and their UV spectra were recorded.

The eluates were also tested for Striga seed germination with and without GR7 (1 $\mu g\ ml^{-1}$) as the inducer.

c. Metabolites

The root exudate of sorghum (CSH-1) and Paspalum were analysed for reducing sugars following Clark (1964), amino acids following Moore and Stein (1948), proteins following Lowry et al. (1951) and total phenolics (A.O.A.C., 196

5. Analyses of the host-cell wall material

a) Biochemical analyses

Cell wall material from one gram root material of 10 day-old seedlings of sorghum and Paspalum, was extracted following the procedure described by Rogers and Perkins (1968). From 10 mg of the cell wall material, pectins, hemicelluloses and celluloses were separated, hydrolysed, neutralized and the reducing sugars were estimated following Clark (1964). For proteins, 10 mg of cell wall material was hydrolysed, neutralized and the amino acids were estimated following Moore and Stein (1948). From 10 mg of cell wall material, lignins were hydrolysed and their ionization difference spectra were recorded (Kimmins and Wuddah, 1977).

b) Histochemical analyses

4-5 day old, i.e. 2-4 cm behind the tip, root segments from the 10 day-old seedlings (based on daily markings) were fixed in F.A.A. for 24 hours and processed following the paraffin technique (Johansen, 1940). The 10µ sections were stained separately for the insoluble polysaccharides using periodic Acid Schiff's reagent (PAS) and for lignins with Schiff's reagent (Jensen, 1962). Camera-lucida drawings of the endodermal cells and metaxylem elements were prepared and the thickness of the parts stained for polysaccharides and lignins in the inner wall of the endodermis and the wall of the metaxylem elements, was measured.

6. Biochemical analyses of Striga seeds

10 mg unpretreated and pretreated (at 35°c for 10 days) seeds were analysed for reducing sugars, free amino acids, soluble proteins and total phenolics as stated in Exp.4C. RNA and DNA were also estimated (Plummer, 1979).

b) The ethylacetate extracts of 100 mg seeds of the S_K and P_K samples with and without pretreatment and of the pretreatment medium, were subjected to TLC on silica gel G plates using benzene:ethylacetate (55:45) system for 45 min. The iodine positive spots were marked. The spots that developed from the extracts of pretreated seeds were eluted in 5 ml of methanol, divided into two parts and concentrated to dryness on filter paper taken in petri dishes. The residue was dissolved in either water or GR7 (1 µg ml^{-1}) and tested on germination of the respective Striga samples.

7. Exoenzyme production by Striga seedlings

25 mg of the seeds of the S_K and P_K samples of Striga were pretreated and germinated in 2 ml of GR7 (1 µg ml^{-1}) medium in 4 cm dia. petri dishes in 5 replication and incubated for five days by which time the radicles grew to

about 4-5 mm. On the sixth day, the growth medium was assayed for pectinases and hemicellulases following Albershiem (1966) and King and Fullwer (1968), respectively and the reducing sugars so formed were estimated using DNS reagent (Clark, 1964). Cellulases following Pettersson and Porath (1966) and Proteases following Dhawan (1980) were also assayed.

The data of the above studies were analysed using student's t-test.

Results and Discussion:

The *Striga* sample, S_K germinated in the root exudate of both sorghum and *Paspalum* whereas P_K germinated only in the root exudate of *Paspalum* (Table 1). Germination of S_K with *Paspalum* was very poor (20.68%). The germination behaviour of the two samples in the direct - inoculation test was similar to that in the root exudate test. The penetration of the seedlings of the two samples of *Striga* was higher into the roots of their respective hosts (Table 2). Penetration of P_K into the roots of sorghum was higher than that of S_K into the roots of *Paspalum*. The sample S_K emerged with both sorghum and *Paspalum* but the per cent emergence with the latter was very poor (Table 3). P_K emerged only with *Paspalum*. These results strongly suggest the existence of host-preference in *S. asiatica*.

The host-preference at the germination stage could be related to several factors concerning the host root exudate and the seeds of the parasite. The *Striga*-germination-inducer isolated from the root exudate of sorghum could induce germination in S_K but not in P_K and the inducer from *Paspalum* was effective on both the samples of *Striga* (Fig.1). These results are in conformity with the root exudate and direct-inoculation tests. P_K being non-responsive to sorghum root exudate/roots could be due to the differences in the nature of the inducer as revealed by their UV characteristics (Table 4). The concentration as well as number of inducer spots in the root exudate of sorghum was higher than that of *Paspalum* (Figs. 1 and 2). This must have contributed to the higher germination of S_K than P_K; the low induction of S_K by the root exudate of *Paspalum* was also probably due to this cause. The results were also indicative of the adaptation of P_K to germinate at relatively low concentrations of the inducer(s). The phenolic spot C isolated from sorghum root exudate induced germination of both S_K and P_K (Table 5 and Fig.1). A very low concentration of this inducer and the interference by other phenolic components in the sorghum root exudate might have been responsible for its ineffectivenss on P_K in the root exudate/direct-inoculation test. The phenolic spots A and B in the root exudate of both the hosts inhibited the germination of Striga samples to different degrees. Presence of inhibitors, and the inducer/ inhibitor ratio in the root exudate also play an important role in regulating germination of the root parasites as pointed out in Orobanche (Whitney, 1979). In the present study, the inducer/phenolic ratio was higher in sorghum (0.197) than in Paspalum (0.046). This would also explain the low germination of S_K in the root exudate of Paspalum. It appears that P_K is adapted to a low inducer/inhibitor ratio.

The levels of reducing sugars, amino acids and proteins in the root exudate of Paspalum was higher than in sorghum (Fig.2). Certain sugars (Brown et al. 1949) and L-methionine (Worsham, 1961) are reported to be germination stimulants. But in the present study, no correlation between the sugar and amino acid contents in the root exudate and its ability to induce germination was evident.

The seeds of the sample S_K showed higher levels of reducing sugars, free amino acids and proteins and P_K showed higher levels of DNA and total phenolics (Fig.4). Subsequent to pretreatment, the level of amino acids increased and those of proteins and phenolics decreased in both the samples. S_K showed an increase in the level of other metabolites whereas P_K showed a decrease in the levels of sugars and RNA.

The TLC of ethylacetate extract of Striga seeds revealed 6 spots in S_K and 4 in P_K, and subsequent to pretreatment, the number decreased to 5 in the former but remained unchanged in the latter (Table 7). Four spots in S_K were promotory to germination in Striga and one was inhibitory. In P_K, two spots were ineffective and other two were inhibitory.

Though S_K appears to be adapted to a high inducer level or high inducer/ phenolic ratio in the root exudate of its host, it could germinate to some extent in the root exudate of Paspalum with a low inducer/phenolic ratio. The higher levels of sugars and amino acids, lower level of phenolics, presence of four stimulants and only one inhibitor in the pretreated seeds of this sample might have contributed to an increase in the final effective inducer/inhibitor ratio when its seeds were set for germination in the root exudate of Paspalum.

Thus the totality of the situation arising from the inducer/inhibitor level of the root exudate and that of the seeds of the parasite, and the supplementary role of other metabolites in the later, may be deemed as having determined the germination in the parasite.

The host-preference that was evident at the penetration stages could be correlated with the toughness of the host roots and the ability of the parasite seedlings to produce exoenzymes. The cell wall materials of roots were significantly higher in Paspalum than in sorghum (Fig.3). Histochemical analyses also showed that the inner walls of endodermis and the metaxylem walls in the roots were thicker in Paspalum than in sorghum (Table 6). The Striga sample P_K showed higher levels of all the exoenzymes studied than S_K (Table 8). It is clear from the results that P_K producing higher levels of the exoenzymes could penetrate to a higher degree into the roots of Paspalum, roots of which possess thicker cell walls. Penetration of Paspalum roots by S_K was lower than that of sorghum roots by P_K. The behaviour of the former is understandable on the light of the inverse relationship between the exoenzymes production in S_K and resistance in Paspalum root in terms of the quantities of wall components. But the lower penetration of P_K with higher enzyme production into sorghum with relatively low quantities of the wall components is surprising and this points to the involvement of some other factor of the host root in the haustorial penetration.

The host-preference of the Striga samples was evident in emergence studies. The lower and delayed emergence of S_K with Paspalum could be explained on the basis of inducer concentration in the root exudate of the latter. S_K requires higher inducer concentration or higher inducer/inhibitor ratio, as duscussed earlier. In Paspalum with low production of inducer, the period required for the production of the stimulant to levels high enough to induce germination in S_K, would be longer. The emergence of P_K with Paspalum occurred much later than that of S_K with sorghum, indicating the adaptation of the former Striga sample to the longer growth period of its host.

The host specificity among the strains of the parasite might find expression at different stages of growth of the parasite as discussed by Musselman (1980). The host-preference evident in the two Striga samples of the present study, is the expression of a degree of host specificity. The specificity of P_K Was at the germination stage and that of S_K was more at the penetration stage. The specificity at the germination stage seemed to be stronger than at the penetration stage as there was no emergence of P_K with sorghum but there was a low emergence of S_K Paspalum. The concentration and nature of the inducer/inhibitors in the root exudate of the host and of the stimulants/inhibitors/metabolites in the seeds of the parasite appear to determine the germination specificity of the samples. The ability of the parasite to produce exoenzymes and the host factors influencing haustorial development and penetration contribute to the host-specificity of the parasite at the post-germination stages.

Summary

A survey of the cultivated fields at Kikkeri (Mandya district, Karnataka, India) on the incidence of Striga asiatica (L.) Kuntze, a root parasite on different crops, indicated intraspecific 'host-preference' (host specificity). Laboratory and pot trails on germination, penetration and emergence of the S_K and P_K samples of the area, with sorghum and Paspalum confirmed this behaviour.

The S_K sample appeared to have adapted to a higher inducer/inhibitor ratio and the P_K to a lower inducer/inhibitor ratio. Higher levels of sugars and amino acids, lower level of phenolics and presence of germination stimulants in the seeds of the S_K sample might have permitted its low emergence with Paspalum.

Paspalum roots were tougher than those of sorghum in terms of amount of polysaccharides, proteins and lignins. The penetration of the two Striga samples with their respective hosts was in correlation with the toughness of their respective host roots and the ability of the parasite-seedlings to produce exoenzymes.

The host-specificity of the P_K sample was expressed strongly at the germination stage and that of the S_K sample more at the peneration stage.

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Table 1. Seed germination(%)in the two samples of *Striga asiatica* (L.) Kuntze with sorghum and *Paspalum*

	host	*Striga seed sample*	
		S_K	P_K
Root exudate test	Sorghum	67.96 (10.2)	0.0
	Paspalum	20.68 (2.5)	33.09* (5.1)
Direct inoculation test	Sorghum	62.19 (4.7)	0.0
	Paspalum	7.70 (0.8)	22.99* (5.5)

* Significant at 5% level

figures in parentheses are standard deviations

Table 2. Penetration (%) of the host-root by the two samples of *Striga asiatica* (L.) Kuntze

Host	*Striga* sample	
	S_K	P_K
Sorghum	18.23 (4.9)	9.70* (3.9)
Paspalum	7.50 (3.8)	19.19* (9.1)

* Significant at 5% level

Figures in parentheses refer to standard deviations

Table 3. Emergence of *Striga asiatica* (L.) Kuntze with the two hosts - sorghum and *Paspalum*

Host	Host-age (days)	Number of *Striga*/pot S_K	P_K
Sorghum	40	2.6 (2.6)	0.0
	90	3.6 (4.1)	0.0
	130	5.2 (6.3)	0.0
Paspalum	40	0.0	0.0
	90	0.0	1.2 (1.8)
	130	1.6 (1.7)	3.2 (3.4)

Figures in parentheses refer to standard deviations

Table 4. The *Striga*-germination inducer isolated from the root exudate of sorghum and *Paspalum*

Crop	R_f in chloroform: methanol (40:2)	Visible light	Color in UV	UV + NH_3	λ max
Sorghum	0.99	Yellow	Blue	Intense blue	225 274 280
Paspalum	0.97	Yellow	Blue	Intense blue	210 225 275

Table 5. Phenolics in the root exudate of sorghum and *Paspalum*

Crop	Chloroform:acetic acid (90:10)	R_f benzene:ethyl accetate (55:45)	λ Max
Sorghum			
Spot A	0.07	0.0	200,211
Spot B	0.88	0.89	212,235
Spot C	0.95	0.96	234,268
Paspalum			
Spot A	0.15	0.0	236,279
Spot B	0.97	0.89	235,257,275

Table 6. Thickness (μ)[1] of the endodermal and xylem walls in the roots of sorghum and *Paspalum*

Host	Inner endodermal wall		Metaxylem wall	
	PAS 2 reagent	Schiff's3 reagent	PAS 2 reagent	Schiff's 3 reagent
Sorghum	2.575 (0.18)	1.468 (0.2)	2.283 (0.47)	1.473 (0.14)
Paspalum	3.76 (0.29)	2.603 (0.48)	3.06 (0.29)	2.352 (0.57)

[1] based on the camera-lucida drawings

2 and 3 the thickness of parts stained for polysaccharides and lignin respectively

Figures in parentheses are standard deviations

Table 7. The TLC pattern (R_f) of the ethyl acetate extract of seeds of the two samples of *Striga asiatica* (L.) Kuntze before (J) and after (II) the pretreatment and of the pretreatment medium(III)

Striga sample					
S_K			P_K		
I	II	III	I	II	III
0.04	0.03 + 23	0.03	0.03	0.03 0.00	0.03
0.13	0.13 + 5	0.11	0.10	0.10 0.00	0.08
0.23	-	-	-	-	-
0.36	0.36* + 2				
0.80	0.84 - 15	0.76	0.84	0.84 - 7	0.81
0.95	0.95 + 32	0.95	0.95	0.95 - 30	0.95

Figures in the second line of each horizontal column refer to per cent promotion (+) or inhibition (-) of germination

* Spot intensified

Table 8. Activity of the exoenzymes from the 5 day-old seedlings of the two samples of *Striga asiatica* (L.) Kuntze

enzyme	*Striga* sample	
	S_K	P_K
Pectinase+	0.095	0.182
	(0.04)	(0.03)
Hemicellulase+	0.046	0.160
	(0.03)	(0.04)
Cellulase+	0.028	0.040
	(0.01)	(0.00)
Protease++	0.056	0.163
	(0.04)	(0.1)

+ μg reducing sugars formed mg^{-1} seeds minute^{-1}

++ μg amino acids fromed mg^{-1} seeds minute^{-1}

Figures in parentheses are standard deviations

Data significant at 5% level

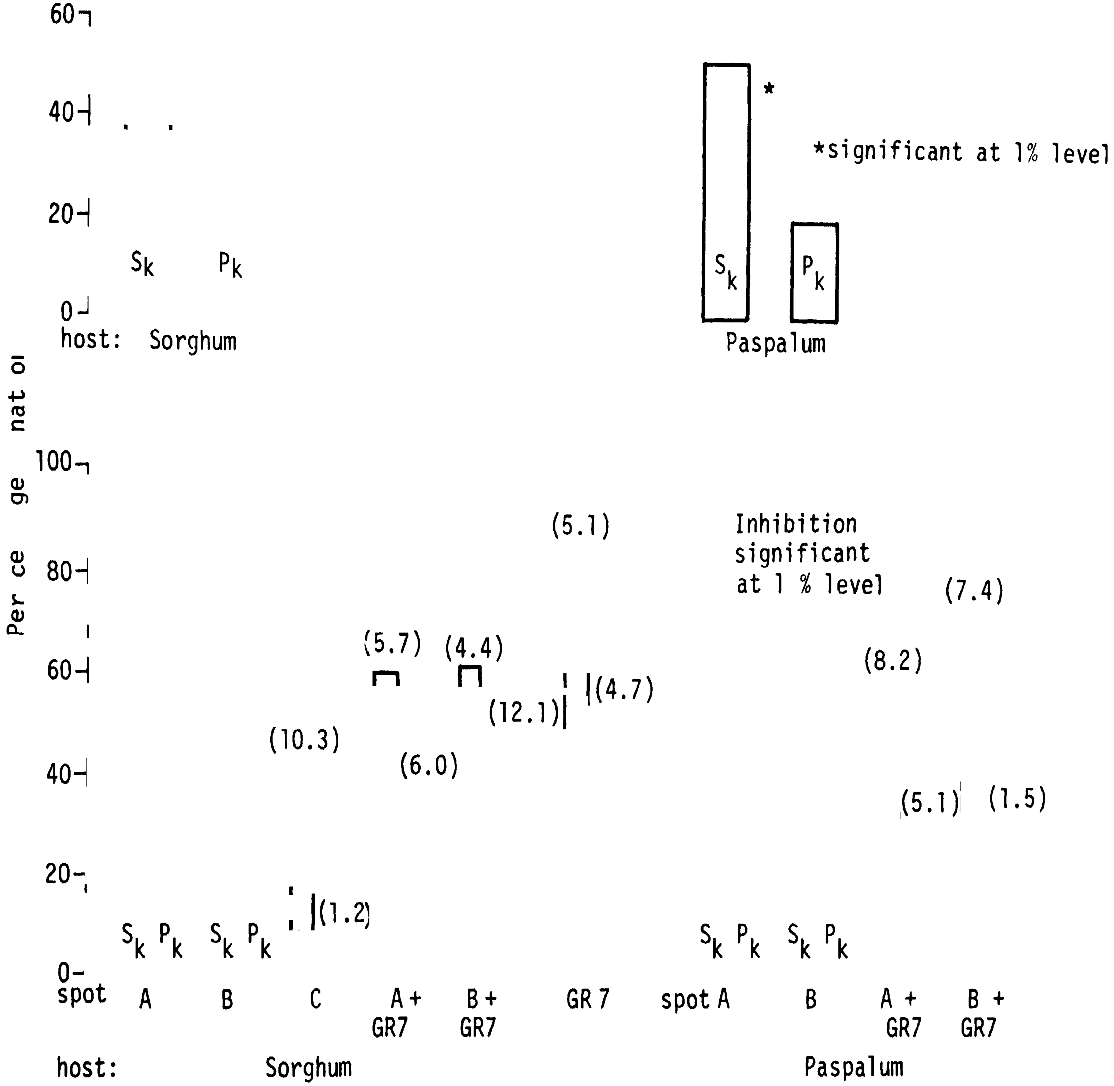
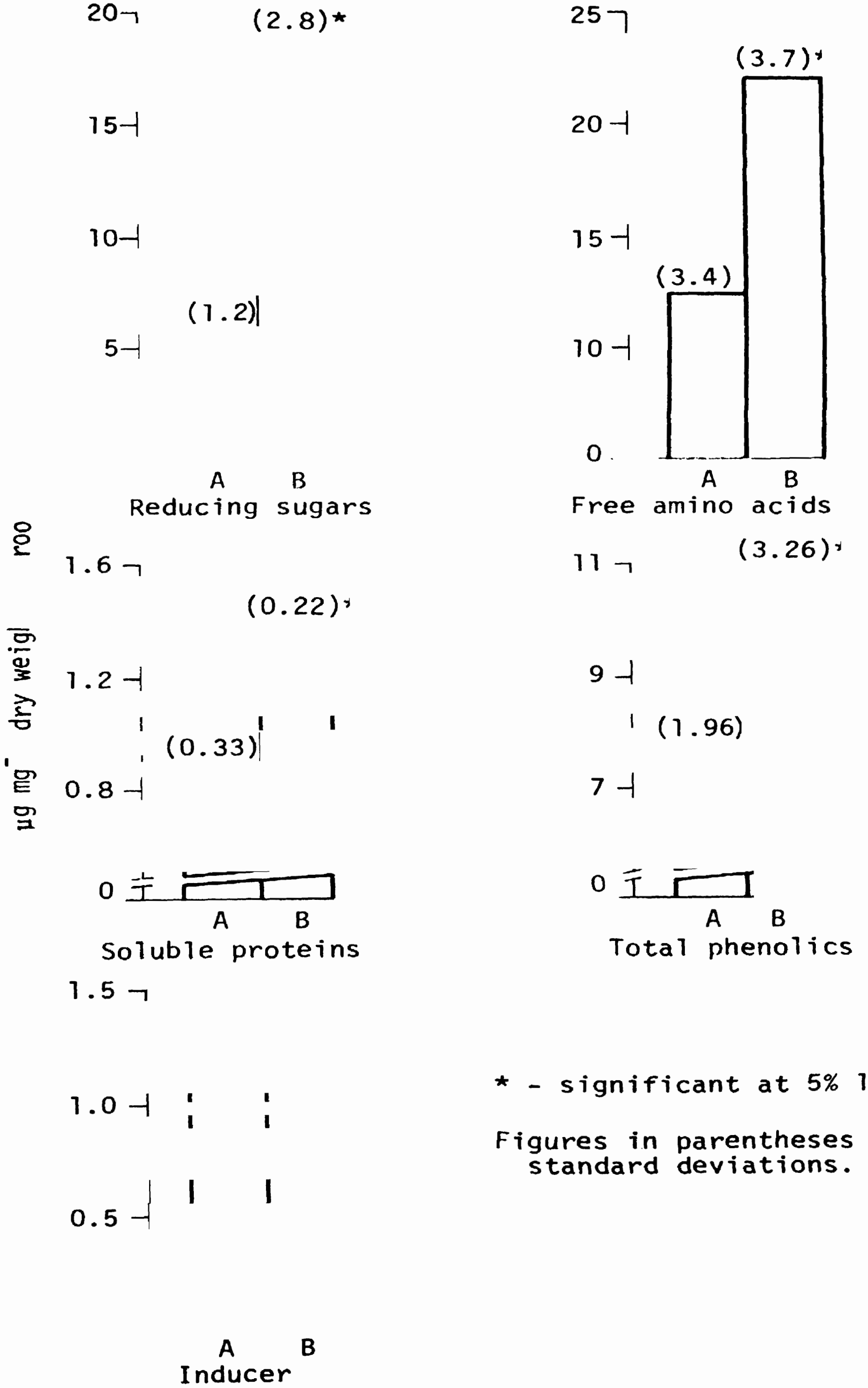


Fig. 1. Influence of the different fractions of the root exudates of sorghum and paspalum on seed germination in the two samples of *Striga*.

Top and bottom rows: respectively, petroleum ether and phenolic fractions.

A, B and C - phenolic spots referred in table 5.
Figures in parentheses are standard deviations.



* - significant at 5% level

Figures in parentheses are standard deviations.

Fig. 2. Metabolites and inducer in the root exudate of the two hosts.

A - Sorghum and B - Paspalum

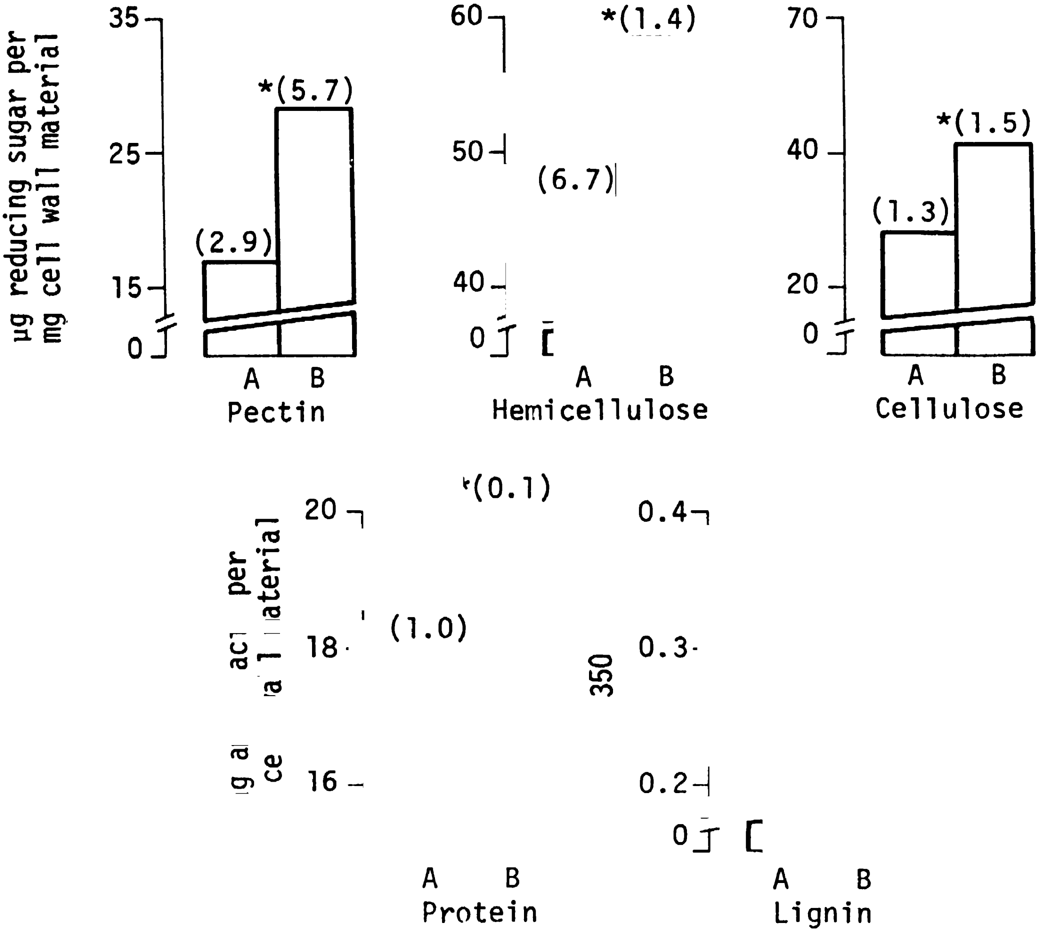


Fig. 3. Different components in the cell walls of the two hosts.

A - Sorghum and B - Paspalum.
*Significant at 5% level.
Figures in parentheses are standard deviations.

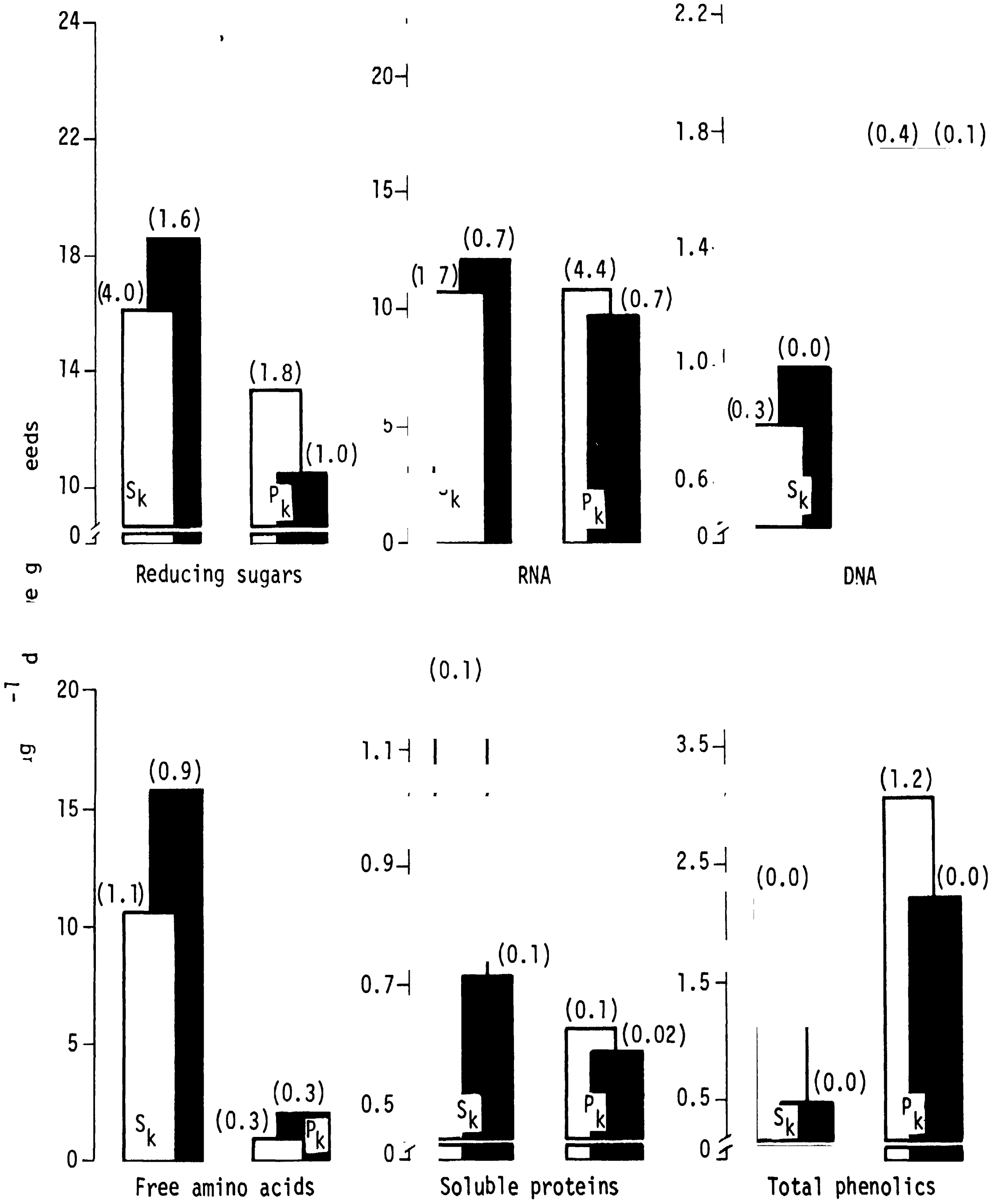


Fig. 4. Influence of pretreatment at 35°C for 10 days on seed metabolites in the S_k and P_k samples of *Striga asiatica* (L.) Kuntze.

☐ before ■ after the pretreatment

Figures in parentheses are standard deviations.

MECHANISM OF INDUCED *STRIGA*-RESISTANCE IN SORGHUM

Bharathalakshmi and Jayachandra[1]

Striga asiatica (L.) Kuntze, a parasite of cereals pose serious problem to the cultivation of several food crops in Asia, Africa and in some parts of USA (Hosmani, 1978). This menace is particularly felt with sorghum. Though India has the largest area under sorghum cultivation (Verma, 1980), the yield is very low and *Striga* infestation has been one of the major causes for this (Hosmani, 1978).

The literature on various measures to control *Striga* have been reviewed from time to time (Shaw et al. 1962; Parker, 1965; Porwal and Mathur, 1972; Eplee and Langston, 1976; Hosmani, 1978; Musselman, 1980). As seed germination and penetration of the host root are the two important stages in the successful establishment of *Striga*, any well directed interference with the host-parasite inter-relationship at these two stages should prove useful in controlling the weed. Presowing hardening of sorghum with some phenolic acids is reported to reduce its ability to induce germination of *Striga* insignificantly (Bharathalakshmi and Jayachandra, 1980). Hence studies were extended to examine if this novel method was effective in lowering the induction of seed germination, penetration and emergence of the parasite. An understanding of the biochemical and physiological effects of the treatment on the host crops has also been attempted.

Materials and Methods:

The grains of sorghum var. CSH-1 selected for hardening treatment were obtained from National Seeds Croporation, Bangalore. *Striga* seeds collected from the sorghum fields at Kikkeri (Mandya district) and Hagaribommanahalli (Bellary district) and referred to as 'S_K' and 'S_H' respectively in the following text, were stored for six months under laboratory conditions, before being used for the study.

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Among the phenolic acids used for hardening, caffeic acid and ferulic acid were from Koch-Light Laboratories, England and vanillic acid was from Fluca-Buchs, Switzerland.

The presowing hardening treatment with distilled water and phenolic acids was carried out as described previously (Bharathalakshmi and Jayachandra, 1980).

1. Host-hardening on Striga germination

The *Striga* samples were pretreated at 35°c for 10 days as described by Parker et al. (1977) and set for germination in the root exudate of 10 day-old seedlings of sorghum raised from the hardened and unhardened grains as described by Bharathalakshmi and Jayachandra (1980) The germination counts were taken after 24 hours.

2. Host-hardening on striga penetration

a) Five mg seeds of S_H, mixed with 100 g sterilized sand held in paper cups (6.5 cm dia. and 8 cm depth) were incubated in 25 replications at 28 ± 2°c for 10 days with the addition of 5 ml of distilled water daily to pretreat the seeds. Seedlings from the hardened and unhardened grains of sorghum were raised in these containers in five replications of five seedlings each, supplying 10 ml distilled water per container daily. The 20 day-old sorghum plants were carefully separated from the medium, roots washed and the number of *Striga* seedlings attached to the host root was recorded.

b) The upper half of the 30 cm deep sandy soil (red soil:sand::1.0:1.5) held in 50 polythene bags (22 cm. dia) was thoroughly mixed with S_H striga at the rate of 200 mg kg^{-1} soil. N, P and K were added to the soil at the rate of 150, 62.5 and 25 kg ha^{-1}, respectively based on the analysis.

The hardened and unhardened grains of sorghum were sown at the rate of three per bag in ten replications and thinned to one seedling per bag after emergence. The 40 day-old sorghum plants were carefully separated from the soil, roots washed and the number of *Striga* seedlings attached to the root system was recorded.

3. Host-hardening on striga incidence

a) Pot trial: Fifty earthen pots (30 cm top dia. and 40 cm depth) were filled with a mixture of red soil:sand::1.0:1.5. The top 20 cm was filled with soil thoroughly mixed with 50 mg seeds of S_H. The hardened and unhardened sorghum seeds were sown at the rate of three per pot and thinned to one seedling per pot after emergence. *Striga* emergence in these pots was noted up to 130 days at intervals of ten days.

b) Field trial: A sorghum field at Ittigi, a village near Hagaribommanahalli that showed heavy infestation of *Striga* was selected for the trial. Twenty five plots, each measuring 3.0 x 1.5 m with an interplot distance of 0.6 m were prepared. N, P and K were added at the rate of 125, 75 and 25 kg ha^{-1} following the initial addition of FYM at the rate of 7500 kg ha^{-1}, based on the soil analyses. The hardened and unhardened grains of sorghum were sown in three replicate plots in a completely randomized design. Each plot had 25 plants. The plots were irrigated periodically and kept free from other weeds allowing only *Striga* to grow.

4. Effect of phenolic acids on striga germination

The pretreated seeds of S_K were set for germination in four replications with four 'discs' in each as described by Bharathalakshmi and Jayachandra (1980) in Kinetin (50 $\mu g\ ml^{-1}$) with/without 25 and 100 $\mu g\ ml^{-1}$ of ferulic acid/caffeic acid/vanillic acid in the medium. The germination was recorded after 24 hours. The experiment was repeated using the root exudate of 10 day-old sorghum seedlings as the inducer (in place of kinetin) in five replications. In the control, the root exudate was mixed with equal quantity of distilled water instead of phenolic acid.

5. Influence of hardening on some components of the root exudate of sorghum

a) The '*Striga*-germination inducer': The seedlings of the hardened and unhardened grains of sorghum were raised in 100 replications for ten days and the inducer present in the root exudate was quantified as described by Bharathalakshmi and Jayachandra (1982).

b) Metabolites: The root exudate of 10 day-old seedlings was analysed for reducing sugars (Clark, 1964), free amino acids (Moore and Stein, 1948), Proteins (Lowry et al. 1951) and total phenolics (A.O.A.C.1960).

6. Influence of hardening on the cell wall components of sorghum root

Pectins, hemicelluloses, celluloses, proteins and lignins in the roots of 10 day-old seedlings of sorghum raised from hardened and unhardened grains were estimated and the thickness of the inner wall of the endodermis and wall of the metaxylem in the sorghum roots was measured as described by Bharathalakshmi and Jayachandra (1982).

The data of the above studies were analysed using F-test and two-way analysis of variance following the procedure described by Sokal and Rohlf (1973).

Results and Discussion

Presowing hardening of sorghum brought down the ability of its root exudate to induce germination in S_K by 13.0-49.2% and S_H by 14.8-18.3%

(Table 1). Phenolic acids were more effective than distilled water as hardening agent and among the three phenolic acids, vanillic acid was the most effective followed by caffeic acid and ferulic acid in S_K whereas, against S_H the three acids were almost equally effective but to a lower degree.

The number of *Striga* seedlings penetrating the host root in the hardened set was also reduced significantly (Fig.1). Penetration that was quite high in the unhardened set was almost complete at the 20 day-old stage of the host; but in the hardened set the penetration was delayed and extended up to 40 days. Even the final penetration per cent was 30-45% lower than in the unhardened. At 40 day-stage vanillic acid treatment ranked high followed by caffeic acid, distilled water and ferulic acid.

The effect of hardening persisted even at the advanced stages of host as evidenced by the data on the emergence of *Striga* in pot and field trials (Tables 2 and 3). The progress as well as total emergence of striga was significantly lower with the hardened set and considering the final emergence, ferulic acid was again the least effective.

Hardening brought down the exudation of the 'germination inducer' from the roots of sorghum (Table 4). Resistance to *Striga* in several varieties of sorghum has been attributed among other things, to the low level of inducer/s in their root exudates (Williams, 1959; Parker et al. 1977). In the present study, however there was no good correlation between the lowering of the inducer level and the decline in the ability to induce germination and hence, though the reduction in the inducer level in the root exudate was responsible for lowering the germination inducing ability of the host, it was not the exclusive cause.

Phenolic acids including caffeic, ferulic and vanillic acids are reported to be inhibitors of seed germination (Mayer and Poljakoff-Mayber, 1978). The germination of *Striga* was also brought down in the presence of these phenolic acids and with increase in concentration, the inhibition caused was greater (Fig.2). The phenolic acids at 25 $\mu g\ ml^{-1}$, brought down the kinetin-induced germination from 63% to 24-44% and at 100 $\mu g\ ml^{-1}$, the germination did not exceed 20%. The root exudate of sorghum induced 58% germination and addition of phenolic acids (25 $\mu g\ ml^{-1}$) brought down the per cent to varying degrees (32-52%). At 100 $\mu g\ ml^{-1}$ of the phenolic acids, the germination was only 15% with ferulic acid and was completely inhibited with the other two acids.

The hardening treatment with vanillic acid and caffeic acid increased the exudation of phenolics through roots (Table 4). Hence this factor has also contributed to the decline in the germination inducing ability of the host. The greater inhibition of germination in *Striga* due to the presence of caffeic acid and vanillic acid than ferulic acid in the medium compared well with the greater usefulness of the former two as hardening agents in this regard.

The inducer/phenolic ratio in the host root exudate was brought down to varying degrees (Table 5). The decline in the ratio was proportionate to the reduction in the induction of germination in *Striga*. The alteration in the ratio was attributable to the decline in the inducer level in ferulic acid and distilled water treatments, to a decrease in inducer and an increase in phenolic levels in the caffeic acid treatments and to a marked rise in the phenolic level attended with considerable decrease in the inducer concentration in the vanillic acid treatment.

Sugars (Brown et al. 1949) and L-methionine (Worsham, 1961) are reported to induce germination in *Striga* and their occurrence in the root exudates of several crops are on record (Rao, 1977). The sugar and amino acid levels were lower in the root exudate of the hardened set than that of the unhardened (Table 4). Excepting the sugar level in the caffeic acid hardened set, there was a good correlation between the magnitude of reduction of these metabolites in the root exudate and the decline in the host root exudate induced germination of *Striga*. Hence, the decreased levels of these metabolites must have also been responsible for the lowered induction of germination. The role of proteins in this regard remains to be investigated.

In *Striga* resistant varieties of sorghum the thicker endodermal walls are considered to act as barriers to the haustorial penetration (ICRISAT, 1981). In the varieties of sunflower that are immune to Orobanche, deposition of lignin in the root at the places of contact with the haustorium is considered as making it difficult for the parasite to penetrate the host tissue (Antonona, 1978).

In the present study, hardening brought about a quantitiative increase in the polysaccharides, proteins and lignins in the roots of sorghum except for the hemicellulose content in the distilled water set (Table 6). Obviously, the consequential toughening of the host root tissue probably caused the reduction in the number of *Striga* plants penetrating the host in the hardened set. The total increase in the wall material due to hardening (excepting ferulic acid treatment) could be correlated to the reduction in the per cent penetration.

The extent of increase in the deposition of wall material in the host root at the region of penetration should be viewed as of greater significance. The hardening treatment caused an increase in the thickness of inner endodermal wall and metaxylem wall at this region (Table 7). The total amount of deposition in the phenolic acid treatment correlated with their effectiveness in reducing penetration.

The reduction in the number of *Striga* seeds germinating, delayed penetration and lower number of seedlings of the parasite penetrating the host probably were responsible for the reduced incidence of *Striga* due to hardening as noted in pot and field trials.

Results of the present study show that presowing hardening of the host reduces *Striga* incidence, significantly affecting the two important stages in the establishment of the parasite, prompting further exploration of the potentialities of the treatment in influencing the host-parasite inter-relations. The information on the biochemical and physiological effects of hardening obtained from the present study would provide important clues regarding the usefulness of any other treatment with similar effects, against *Striga*.

Summary

The presowing hardening of sorghum with 25 $\mu g\ ml^{-1}$ of ferulic, caffeic and vanillic acids reduced the induction of seed germination in *Striga* by the host root exudate, lowered the number of the parasite seedlings penetrating the host root and also reduced the incidence of the parastite.

The treatment brought about a decline in the levels of *Striga* germination inducer, reducing sugars, free amino acids and proteins in the root exudate of sorghum. Hardening with caffeic acid and vanillic acid increased the phenolic level in the root exudate. The consequential lowering of the inducer/phenolic ratio probably caused the decline in the induction of *Striga* germination.

The hardening treatment also increased the levels of pectins, hemicelluloses, celluloses, proteins and lignins in the cell walls of sorghum root. The deposition of polysaccharides and lignins at the region of penetration of *Striga* was also higher in the treatment set. This toughnening of the host root must have hindered the penetration of the parasite.

Obviously, the decline in the germination and penetration of *Striga* brought down the incidence of the parasite with the crop.

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Table 1. Effect of hardening of the host with phenolic acids (25 ug/ml) on the ability of the root exudate from the 10 day-old plants of sorghum to induce seed germination in *Striga*

Treatment	S_K *Striga*		S_H *Striga*	
	% germination	%control	%germination	%control
Unhardened (control)	52.7 (2.3)	-	48.8 (9.9)	-
Hardened with				
distilled water	39.5 (11.9)	93.8	34.8 (2.1)	71.2
ferulic acid	31.9 (7.9)	60.6	30.6 (6.5)	62.7
caffeic acid	9.8 (3.4)	18.6	29.5 (9.5)	60.5
vanillic acid	3.5 (1.1)	6.6	30.3 (8.7)	62.0

LSD 5%	
between *Striga* samples	14.1
between seed treatments	9.98
interaction	9.98

Figures in parentheses are standard deviations

Table 2. Influence of presowing hardening of the host-sorghum on the emergence of *Striga*, in pot trial

Treatments	Number of *Striga*/pot		
	Host age (days)		
	40	90	130
Unhardened (control)	2.5 (3.1)	12.4 (7.8)	18.6 (9.4)
Hardened with			
distilled water	3.1 (4.5)	5.8 (5.0)	8.2 (4.4)
ferulic acid	2.4 (1.8)	9.4 (6.5)	11.7 (7.2)
caffeic acid	1.6 (1.4)	4.3 (5.6)	7.2 (5.9)
vanillic acid	2.3 (1.5)	6.3 (5.2)	7.3 (5.0)
LSD 5%			
between seed treatments		8.65	
between growth periods		6.10	
interaction		5.00	

Figures in parentheses are standard deviations

Table 3. Influence of presowing hardening of sorghum on the emergence of striga in the field trial

Treatment	Number of striga/pot	
	host age (days)	
	60	110
Unhardened	23.7 (10.1)	20.8 (10.1)
Hardened with		
distilled water	7.7 (1.5)	4.0 (3.0)
ferulic acid	9.3 (5.8)	7.0 (1.0)
caffeic acid	5.0 (3.0)	6.0 (5.0)
vanillic acid	5.3 (3.2)	6.3 (5.7)
CD 5%	10.7	10.5

Figures in parentheses are standard deviations

Table 4. Influence of pregermination seed hardening of sorghum on the levels of metabolites and inducer (µg mg^{-1} dry weight of root) in the root exudate

Treatment	Reducing sugars	Free amino acids	Soluble proteins	Total phenolics	Inducers
Unhardened (control)	5.8	13.3	0.87	7.70	1.52
	(1.2)	(3.4)	(0.33)	(2.0)	
<u>Hardended with</u>					
distilled water	4.7	6.4	0.38	7.17	1.00
	(1.3)	(0.9)	(0.05)	(0.1)	
ferulic acid	5.0	5.9	0.41	3.70	0.62
	(1.2)	(1.2)	(0.06)	(2.6)	
caffeic acid	5.5	4.8	0.39	11.68	0.70
	(1.2)	(1.1)	(0.15)	(2.6)	
vanillic acid	3.9	3.8	0.33	13.70	0.82
	(0.9)	(1.6)	(0.11)	(3.1)	
CD 5%	1.9	3.4	0.3	4.0	

Figures in parentheses are standard deviations

Table 5. Influence of pregermination hardening on the inducer/ phenolic levels* in the root exudate of the 10 day-old seedlings of sorghum

Treatment	Change in the level of				inducer/ phenolic ratio
	inducers		phenolics		
	**actual change	percent change	actual change	percent change	
Unhardened (control)	-	-	-	-	0.197
Hardened with					
distilled water	***-0.52	-34	-0.53	- 7	0.160
ferulic acid	-0.90	-59	-4.00	-51	0.103
caffeic acid	-0.82	-53	***+3.98	+51	0.060
vanillic acid	-0.70	-46	+6.00	+77	0.060

* based on the data on phenolics and inducers given in Table 4

** $\mu g\ mg^{-1}$ dry weight of root

*** + increase, - decrease

Table 6. Influence of pregermination hardening of sorghum with phenolic acids on the cell wall components

Treatment	Pectin*	Hemicellulose*	Cellulose*	Proteins**	Lignins***
Unhardened (control)	16.7 (5.7)	46.7 (6.7)	28.0 (1.3)	18.0 (1.0)	0.269
Hardened with					
distilled water	20.0 (0.0)	38.1 (3.5)	48.0 (2.7)	30.0 (1.0)	0.294
ferulic acid	28.3 (2.9)	49.3 (9.4)	66.7 (2.7)	27.6 (0.4)	0.391
caffeic acid	21.7 (4.6)	51.2 (0.0)	54.7 (4.0)	38.4 (1.0)	0.411
vanillic acid	26.7 (2.9)	54.6 (4.0)	61.3 (2.7)	25.2 (0.4)	0.346
CD 5%	6.1	10.3	6.1	1.5	

* ug reducing sugars released per mg cell wall material

** ug amino acids released per mg cell wall material

*** absorbance at 350 nm

Figures in parentheses are standard deviations

Table 7. Influence of presowing hardening on the thickness (μ*) of the endodermal and xylem walls in the roots of sorghum

Treatment	Inner endodermal wall		Metaxylem wall	
	PAS[1] reagent	Schiff's[2] reagent	PAS[1] reagent	Schiff's[2] reagent
Unhardened (control)	2.575 (0.18)	1.468 (0.2)	2.283 (0.47)	1.473 (0.14)
Hardened with				
distilled water	3.485 (1.87)	3.321 (0.22)	2.893 (0.18)	2.801 (0.41)
ferulic acid	3.060 (0.63)	2.470 (0.19)	3.630 (0.34)	1.923 (0.10)
caffeic acid	3.738 (0.83)	2.078 (0.44)	3.788 (0.75)	1.900 (0.21)
vanillic acid	3.735 (0.44)	3.129 (0.15)	3.300 (0.18)	2.486 (0.26)
CD 5%	0.55	0.25	0.23	0.4

* based on the camera-lucida drawings

1 and 2 give respectively, the thickness of parts stained for polysaccharides and lignin

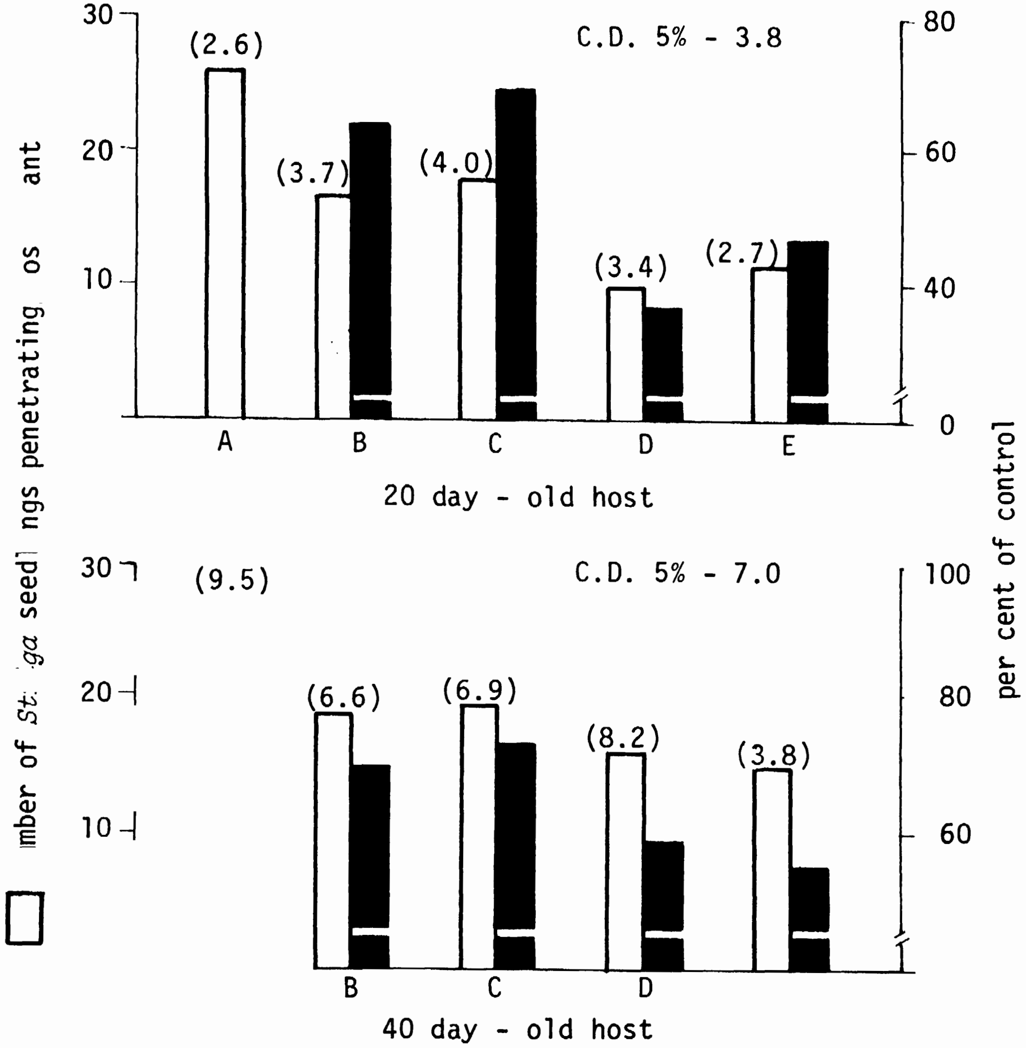

Fig. 1. Effect of presowing hardening of the host-sorghum on the penetration by the parasite - *Striga*.

A - unhardened, B to E - hardened with distilled water and 25 ug ml^{-1} ferulic, caffeic and vanillic acids, respectively.

figures in parentheses are standard deviations.

Phenolic acid (µg ml^{-1})	CD 5%	
	Kinetin	Root exudate
25	10.9	11.7
100	7.1	-

+ - Significantly different from a_1 at 5% level.

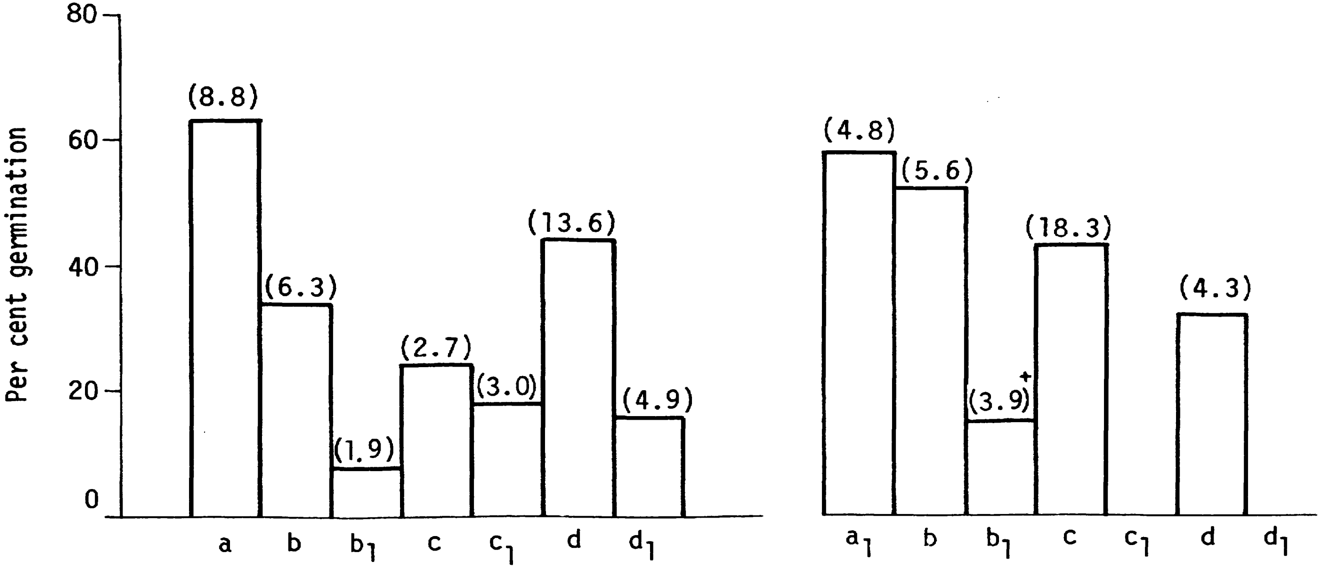

Fig. 2. Effect of phenolic acids in the medium on seed germination in the S_k sample of *Striga*.

Kinetin (50 µg ml^{-1})/root exudate of sorghum alone -a/a_1 and with 25 and 100 µg ml^{-1} of ferulic acid (b, b_1), caffeic acid (c, c_1) and vanillic acid (d, d_1).

Figures in parentheses are standard deviations.

SESSION IV

CONCLUDING SESSION

Chairman: **D.R. Bapat** **Rapporteur:** **P.P. Tarhalkar**

FUTURE RESEARCH GOALS FOR COMBATING *STRIGA* ON SORGHUM

D.R. Bapat*

Witchweeds are important parasites of sorghum and literature on this parasite has been well reviewed (Williams; 1958, Tarr, 1962 and Doggett, 1970). S. asiatica is common in parts of India, Burma, Southern and Eastern Africa and is also the species which occurs in North and South Carolina (U.S.A). S. hermonthica is confined to the African continent where it generally predominates in areas north of equator. In India five species of *Striga* are known to occur, of which Striga asiatica and Striga angustifolia are known to attack economically important plant species causing heavy crop losses. The species that usually attack sorghum are S. asiatica and S. densiflora.

Striga can cause serious yield reductions with heavy infestations occasionally killing plants before heading. Reported losses range from 25-85% in bajra (Mathur and Mathur, 1966), 53% in sorghum (Younis and Agabawi, 1965). Several methods of control have been tried with varying degree of success. These include hand weeding (Ogborn, 1968), trap cropping with soyabean and field peas (Robinson and Dowler, 1966), Sudan grass grown for five weeks (Last, 1961), high fertility levels-80kg N/ha (Ogborn 1970; Agabawi and Younis, 1965), herbicides like 2,4 D, paraquat, Methyl bromide, 2,4 D + MCPA (Eplee and Langston, 1968; 1970, 1971, and Ogborn, 1969) have given satisfactory control in different countries.

Genetic resistance in sorghum to *Striga* is recognised as the most economic way to combat this parasite. Two forms of resistance are generally discussed in the literature. One of these involves resistance based on barriers to successful establishment on the host root, and the other involves resistance based on low production of the stimulant by the host which is required for *Striga* seed germination.

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Kuijt (1969) has made interesting observations regarding origin and function of the haustorium and the nutritional relationship with the host (i) the absence of any direct contact between phloem tissues of the host and parasite; the natural bridge for transport of both water and organic and inorganic nutrients being the xylem, (ii) transpiration rates are invariably high, presumably leading to maximum transfer of nutrients from host to parasite (iii) host specificity is normally quite wide.

Several workers have reported resistance to *Striga* in sorghum. Saunders (1933) working in South Africa met with some success in identifying and developing resistance based on mechanical blockage of establishment by *S. asiatica* haustorium. In three resistant strains, three different root tissues viz., cortical cells, endodermal cells and xylem vessels were identified as sites where invasion by haustoria of the parasite was curtailed. Inheritance of resistance was found to be complex and different for the three strains. Doggett (1965) reported that the variety 'Dobbs' possessed a certain amount of mechanical resistance. Sorghums which have resistance based on low stimulant production have been reported in two varieties, Bilchigan and Muddinandyal from India (Kumar, 1940) and Bonganhilo from Tanzania (Rao, 1948). Bonganhilo was used to develop resistant variety Co 20 (Shanmugasundaram and Venkatraman, 1964). Framida also has resistance based on low stimulant production.

However, research efforts to incorporate *Striga* resistance into an agronomically elite background in the past have met with little success. At ICRISAT during past five years considerable progress has been made in identifying *Striga* resistant sources and transfer of this character into good agronomic background. The resulted indicated that *Striga* resistance in sorghum is a function of three independent mechanisms viz., low stimulant production by the host roots, mechanical barriers to the establishment of *Striga* and antibiosis factor. About 14000 germplasm entries were screened and 640 low stimulant lines were identified. Generally the results indicate that not all low stimulant lines are resistant in field, though a good number of them turned out to be field resistant. In advanced generation progenies also out of the 23 field resistant lines, 18 were observed to be low stimulant producers. Proportion of field resistance in the low stimulant category was higher than the proportion of field resistance in the high stimulant category. The process of selection for *Striga* resistance and other desirable traits has shown that though several resistant sources are available not all of them are "good breeding"stocks.

Screening methodology for resistance breeding is also being standardised at ICRISAT and Research Project for Dryland Agriculture at Hyderabad. For screening sorghum lines for genetic resistance to *Striga*, laboratory, pot and field screening techniques have been used in the past. Laboratory techniques have several advantages but they have not been found useful for breeding field resistance. This lacuna arises from the basic fact field resistance cannot be explained by any one mechanism and there are strong environmental interactions which influence the field reactions. Pot tests were more reliable than field screening for obtaining attack by *Striga*. The problems that are encountered in field screening are (i) variability in occurence of *Striga* through years in the same field (ii) absence of any control on levels of infestation (iii) ununiform *Striga* distribution in the field (iv) total dependence on environment for *Striga* infestation (v) high CV's in the experiments making the conclusions unreliable. A three stage improved field screening methodology was therefore proposed involving an observation nursery, a preliminary screening and an advanced screening (Vasudeva Rao et al., 1981). Further, they reported the details on the method of analysis of *Striga* data collected on three stage methodology in 1982 (Vasudeva Rao, et al., 1982). They further reported that logarthmic transformations coupled with NEPLOT analysis, originally described by Papadakis (1937), was found useful in reducing the coefficients of variability in advanced trials to acceptable levels.

Soil type, rainfall and fertility are some of the factors which affect the incidence of *Striga*., and make research involved with identification and manipulation of host resistance difficult. Such work is further complicated by the existence of pathogenic strains. It has also been reported that sorghums which are resistant to a given species of *Striga* at a given location may not necessarily be resistant to the same species or a different species at another location.

Variation in the emergence of *Striga* plant appears to be mainly due to soil moisture, (Andrews, 1945; Wilson Jones, 1953). Similarly the condition of the surface layer of soil is also critical for *Striga* emergence. In areas where cereal crops are established during short early rains, the crop has to endure a dry period later which favour the development of *Striga*. This explains the ununiform pattern of *Striga* appearance in different years.

From the foregoing discussions it is apparent that research on resistance breeding needs to be strengthend. Since any one resistance mechanism may not remain stable over environments, it is advisable to pyramid the different mechanisms into one variety. The stability of different mechanisms be also studied, to isolate factors which distrub the resistance mechanism. Physiological races in different species if any be identified, so as to test breeding material critically, since this may also be one of the factors for not getting stable resistance. Genetical studies on *Striga* resistance appear to be meagre and hence it is necessary to study the genetics of the three mechanisms, so as to adopt suitable breeding methods to incorporate these characters in agronomically desirable genotypes.

Laboratory and pot studies are certainly useful for screening germplasm. However, since field screening appears to be inevitable, *Striga* sick plots in different soil types need to be established, in major sorghum growing areas by infesting with local *Striga* seed. This would also help to identify physiological races and study *Striga* emergence in different soils and seasons. Advantage of these plots be also taken to correlate soil moisture, temperature relations with emergence of *Striga*. It is generally observed that if long breaks in rain during August and September are experienced, *Striga* emergence is more. In some pockets of Maharashtra *Striga* menace becomes alarming in some years, especially where hybrids like CSH-1, CSH-5, CSH-6 and other are planted every year.

Suitable trap cropping, intercropping experiments need to be conducted to isolate suitable cropping pattern which would reduce the *Striga* seed populations in the soil by inducing suicidal germination (Robinson and Dowler, 1966).

Chemical control of *Striga* by spraying 2,4 D and other weed killers though effective, involves lot of expenditure and risk if dicots are grown around and as such this method is not extensively followed. It is therefore, suggested to find out cheaper and less harmful chemicals, so that in endemic pockets, pilot projects could be taken up to control this parasite. Okonkwo (1966) has reported that the pattern of translocation of photosynthates and minerals from host to parasite suggests a possible use of selective weedkillers applied as a spray to the host leaves for controlling the parasite. Such method will be more effective, as it would kill parasite before it does much harm to the host plant.

There are favourable reports of effect of nitrogen application on *Striga* control. It is reported that N application delays the emergence *Striga*. This aspect needs further probe, as at present farmers use very little N for raising a sorghum crop and striga incidence is usually more in unfertilised fields.

Insects like Smicronyx, Ophiomyla, Eulocastra argentispora etc. have been reported to attack *Striga*. Similarly fungal pathogens of witchweed like Curvularia geniculata, Fusarium solani, F. roseum, Rhizoctonia solani, have been reported. Work on biological control of witchweed is also meagre and needs further investigation to develop an effective method of biological control.

Thus it could be summarised that work on resistance breeding coupled with agronomic manipulations and biological control would go a long way to erradicate this plant parasite and thus help enhance sorghum production of the semi-arid tropics.

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DISCUSSION 1: STRATEGIES FOR BREEDING SORGHUM VARIETIES RESISTANT TO *STRIGA*

B.S. Rana[1], C. Hanumantha Rao[2], V.J.M. Rao[1] and B.B. Reddy[1]

Sorghum and *Striga* are dynamic biological systems. Therefore, resistance to *Striga* in sorghum is to be viewed in its totality as a complete ecological system. Systematic information on host-parasite-environment interactions would help to combine resistance in desirable agronomic background and to develop suitable *Striga* management practices. We have to resort to some cultural and chemical control measures to suppress *Striga* population in endemic areas but ultimately the most economical solution lies in developing resistant varieties. Some cheap control measures such as systemic herbicides, biological control, trap cropping, crop rotation and seed treatment by some phenolic acids are reported but they should be further worked out with particular reference to a variety, environment and soil type.

The information on screening technique, sources and mechanisms of resistance, host-parasite interaction and nature of gene action are prerequisite of any breeding programme.

1. Screening techniques:

Striga being a very deceptive parasite, a sound and reliable field screening technique is essential to distinguish between resistant and susceptible progenies. Growing of susceptible entry and allowing the *Striga* to shed the seed or by adding *Striga* seeds collected from other fields one to two months prior to sowing can help to get good levels of *Striga* infestations. Low fertility and good drainage in deep vertisols promote good *Striga* establishmen Hanumantha Rao and Rana (1982) described a 3:1 planting pattern of test variety and susceptible check respectively. Where sick plot area is limited, this meth is more economical and easier over other planting patterns.

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2. *Striga* variability:

There is need to understand the variability within and between species of *Striga* attacking sorghum in India both for pathogenicity and morphological traits. Some simply inherited characters may be useful to determine the differences at the sub-specific level, and to identify its biotypes and ecotypes. Since S. asiatica attacks sorghum, sugarcane, pearl millet, maize, rice, some minor millets and wild grasses, studies on cross-infectivity will help to distinguish between different strains.

3. Mechanisms of resistance:

Some information on resistance mechanisms such as low stimulant production and mechanical barriers in some resistant stocks is available. However, the basis of resistance of other improved tolerant varieties is still to be worked out. These varieties can be classified into three groups (eg., stimulant negative, mechanically resistant and those possessing both mechanisms) and should be documented. Some of the physiological parameters such as gibberellins, cytokinin, inhibitors, differential osmotic pressures in the roots of sorghum and *Striga* (preferably haustoria), exo-enzyme production due to cell-wall thickening, sugar and amino acid content of sorghum roots appear to be the additional selection parameters. Their utility is to be examined further.

4. Stability of resistance:

Some known resistant varieties differ in their host-parasite interaction under varied environments. This differential behaviour at other locations may not be necessarily due to different physiological races of parasite alone, but may depend upon different threshold level of the variety, intensity of *Striga* infestation, seasonal and adaphic factors. A variety which shows resistance in a deep and saturated vertisol due to *Striga* dormancy induced by higher moisture will show susceptibility in well drained alfisols and deep vertisols since drainage in latter promotes the striga germination.

The shift in the level of resistance in BO-1 and N-13 under moisture stress condition at Hayatnagar farm and breakdown of Radar variety warrants studies of stability of resistance and to understand different agroclimatological situations promoting *Striga* germination. However, stability of individual resistance parameters over different locations will be useful.

5. Nature of resistance:

Low stimulant production in sorghum which confers resistance to *Striga* is inherited as a monogenic (Ramaiah, personal communication) as well as a quantitative character (Vasudeva Rao et al. 1983). Shinde and Kulkarni (1982) also treated *Striga* resistance as a quantitative character. However, our studies indicate different degrees of field resistance (Hanumantha Rao and Rana, 1982). It is difficult to say, "How complex is the resistance?". The individual components of resistance are expected to be simply inherited but the whole system should behave like a quantitative threshold character.

6. Sources of resistance:

The field resistance is presently available in poorly adapted genetic background. Some of the derivatives of IS 3687 x Aispuri cross such as 148, 168 and 555 from AICSIP with better genetic background woulf furnish the improved sources of resistance. Some of the high yielding varieties such as CSV-3, CSV-8R (SPV-86), SPV Nos. 103, 107, 109 and 221 possess moderate resistance (Hanumantha Rao and Rana, 1982). Specific sources of resistance to S. densiflora are still to be identified.

7. Breeding procedure:

There are two major objectives: (i) Gene pyramiding i.e., strengthening of resistance in order to achieve stable and race-nonspecific sources, (ii) Recombination breeding i.e., transferring resistance to high-yielding and agronomically desirable varieties.

The resistance can be strengthened by crossing varieties possessing different resistance mechanisms and alleles of different geographical diversity. Multilocation testing is essential to test the stability and multi-race resistance. Choice of parental material for the utilization of resistance genes in recombination breeding programme is important. The improved genetic background of resistant varieties, 168, 555 and IS 3924 may help to achieve higher frequencies of desirable segregates.

Continuous screening in a *Striga* sick-plot is essential for gene pyramiding. F_2 of resistant x high yielding crosses is evaluated in *Striga* free plot for yield and other agronomic traits but the subsequent generations are tested in a sick-plot.

7.1 Heterosis breeding:

Susceptibility in F_1 is due to partial to full dominance. The susceptibility of CSH-5 and CSH-6 hybrids can be attributed to their susceptible female parentage. Thus, both the parents of a hybrid should be resistant. In fact, none of the A lines are resistant except some marginal resistance in 296B. Priority should therefore be given to develop the resistant A lines. B line reaction of dwarf resistant derivatives should be ascertained.

7.2 Varietal improvement:

7.2.1 Pure line selection:

Pure line selection appears to be an effective breeding methodology to improve the level of resistance of land races. The red local selection from PJ 8K bulk, BO-1 and N-13 from local varieties are the products of pure line selection.

7.2.2 Pedigree breeding: The predominant additive genetic variance indicates that pedigree programme should be a success. The recovery of field resistance in 168 and stimulant negative type resistance in its sister line, 555 is an encouraging result from pedigree breeding programme. The progress in mechanical resistant x stimulant negative crosses is expected to be higher than resistant x susceptible (high yielding) crosses.

7.2.3 Backcross breeding: The evidence to transfer quantitative trait through backcross breeding and its efficiency over pedigree programme are available in the literature. In fact, backcrossing programme to transfer resistance in available B-lines may be more rewarding than adopting pedigree programme. The transfer of individual resistance parameter through backcrossing should be relatively easy job.

7.2.4 Population improvement: There is lot of optimism regarding population improvement in sorghum. The genetic male sterility of ms_7 should be transferred to some improved resistant sources before resorting to population improvement programme which requires more resources and advance knowledge of population genetics. Some of these factors imposes limitation for the use of pupulation breeding programme.

Conclusion

There is a need for pyramiding genes controlling different resistance mechanisms in a line to achieve the stability of resistance. Resistance can then be transferred in hihg-yielding agronomically superior varieties by making appropriate choice of parental material and pedigree or backcross breeding. However, the field screening technique should be standardized and made more reliable under conditions highly favourable to *Striga*.

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DISCUSSION 2. SOME CONSIDERATIONS FOR *STRIGA* MANAGEMENT IN SORGHUM

P.P. Tarhalkar[1]

Sorghum, a major cereal of drylands in India, is the principal host of *Striga*. Higher intensities of *Striga* infestation are seen in low fertility and droughty situations. The severity of this menace is reported to be increasing. The susceptibility of the released hybrids to *Striga* may become a potential problem in destabilizing production in many areas. Research efforts to incorporate resistance to *Striga* in agronomically superior genotypes were not much successful so far. Efficient biological control methods to reduce *Striga* intensity were also not reported. The prohibitive application cost of effective chemicals like ethylene gas or soil fumigants is a major constraint for recommending them to an average farmer in the SAT zone.

Two priority areas of future research work would be -

i) To reduce the infestation to such a level that sorghum hybrids produce an economically profitable yield,

ii) To develop control measures for its maximum eradication.

Based on the experience on the control measures by cultural methods (including crop rotation) and herbicides, some considerations for a comprehensive agronomic approach to *Striga* management is presented

A) Cultural Methods:

Cultural methods like deep tillage, frequent intercultivation etc., are not so far successful because of the small size and huge numbers of *Striga* seed, its dormancy. Pre-conditioning requirement for germination and dormancy which result in the unreliable occurrence and non-uniform distribution of *Striga* in the field present further problems in obtaining reliable field results. However, such treatments to keep a

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weedfree field are necessary, because more information is still needed on their role (i) in reducing the intensity of *Striga* infestation, (ii) as a supplement to chemical methods of control, and (iii) for the practicability of their direct recommendation to the marginal farmer.

B) Chemical Methods:

Among the various weedicides tried to control *Striga*, an effective control is offered by preplanting application of "Fenac" and post-emergence application of 2,4-D, when sorghum crop is about three weeks old and the *Striga* is subterranean. Post-emergence application of paraquat is also recommended before *Striga* comes to flowering. Though the cost of the chemical and its operation is a major consideration before recommending it to a farmer, the control is also assured making the difference between crop failure to its success. More information is still needed on i) combination of intercultural operation (upto 25 days of crop growth) with 2,4-D application later, ii) on pre-emergence application of Atrazine followed by2,4-D application at 25 days (and later possibly by paraquat), and iii) on comparison of their cost/benefit ratios, and effectiveness in reducing *Striga* infestation etc.,

C) Farming Systems:

Some information is available on the use of 'catch' and 'trap' crops like cotton, peanut, cowpea, pigeonpea etc., which could be used in rotation with sorghum for reducing the intensity of *Striga* infestation. Such system should also be compared with sorghum-based intercropping system, for which some of these crops have proved as efficient intercrops. Such intercropping systems could provide information on -

i) The system's yield advantage, i.e. even if sorghum yields suffer due to *Striga*, compensation is offered by intercrop yield; e.g.:sorghum+pigeonpea, sorghum+cowpea systems, etc.

ii) Reducing the intensity of *Striga* infestion in the following two ways -

a) Use of 'trap' crop as intercrop to induce the germination of *Striga* , followed by sacrificing the intercrop by post-emergence spray of 2,4-D on the same,

b) Use of suitable fodder legume (in the 'paired rows of sorghum) serving both as fodder intercrop and 'catch' crop. It is harvested after, say 35 days, and the inter paired-row spaces are sprayed with 2,4-D or paraquat.

It is to be noted that pairing of sorghum rows (90-45 cm or 90-30 cm) does not result in reducing sorghum yield, compared with a 'sole' crop in normal (45 cm) rows, with the same plant density/ha. The cost of intercrop seed should not become limiting, if it is to be sacrificed.

The following treatment combination is proposed for such a trial

1. T_1 = Control
2. T_2 = Cultural weed control (Weedfree check)

3* T_3 = Recommended cultural methods (like deep ploughing, interculture, hand pulling of *Striga* etc.)

4. T_4 = Preplanting application of Fenac @ 0.5 kg a.i./ha

5* T_5 = Cultural weed control (T_2) upto 25 days + post-emergence (at 25 days) application of 2,4-D @ 2.0 kg a.e./ha (before *Striga* emergence)

6*. T_6 = Atrazine application (pre-emergence to sorghum) @ 0.50 a.i./ha + post emergence application (to sorghum) of 2,4-D as in T_5.

7*. T_7 = As in T_6 + paraquat application @ 1 lit.a.i./ha at 50 days.

8. T_8 = Sorghum in paired rows (PR), alone + 2,4-D application as in T_5
9. T_9 = Sorghum in PR + Pigeonpea intercrop
10. T_{10}= Sorghum in PR + intercrop using suitable 'trap' crop (like desi cotton) + application of 2,4-D as in T_5 at 30 days
11. T_{11}= Sorghum in PR + intercrop using suitable 'catch' crop (like fodder cowpea) + application of 2,4-D as in T_{10}(intercrop harvested before for fodder purposes)
12. T_{12}= Sorghum as in T_2 in the first year - in rotation with suitable 'trap' crop (like cotton) in next year.

*NB: Calculation of cost/benefit ratio is compulsory.

For valid information, the experiment is to be conducted in '*Striga*-sick plots' and preferably on the same site year after year to study the cumulative effect of treatments and also that of rotation. For the 'on-farm' demonstration trial, on *Striga*-infested field, a small set of choice treatments may be selected and their effect on yield level of two genotypes (one susceptible hybrid along with '*Striga* resistant' check) may be compared.

DISCUSSION 3. GRAVITY OF *STRIGA* PROBLEM ON SORGHUM IN ANDHRA PRADESH

D. Narayana[1]

Sorghum is one of the important rainfed crops in Andhra Pradesh and is being cultivated over an area of 2.5 million hectares. *Striga*, a root parasite is one of the important serious problems on sorghum in Andhra Pradesh. The *Striga* incidence is severe in all the important districts for kharif sorghum, viz, Ananthapur, Mahaboobnagar, Warangal and Adilabad. Two important districts for early rabi, Khammam and Kurnool are also badly affected due to incidence of *Striga*. However, the *Striga* incidence is moderate in traditional rabi zones where the jowar crop is mainly grown with the receeding soil moisture, dew and cold weather conditions.

Normally *Striga* makes its appearance at 30 - 40 days age of the crop. It appears that all the *Striga* seed that is present in the soil, would not germinate at one time, eventhough the environmental conditions are favourable and a susceptible host is present in the field. The removal of first flush of *Striga* plants usually give way for the emergence of remaining *Striga* plants.

The damage due to *Striga* infestation usually depends on the stage of the crop at which *Striga* emerges and also the intensity of infestation. The heavy infestation at pre boot leaf stage of the crop results in the complete failure of crop. The crop under this situation, even fails to produce earheads and dries up. The heavy infestation at ear emergence or grain formation stage leads to reduction in yield, (up to 70%). The emergence of *Striga* at seed maturity stage may cause very little reduction in yield.

The experiences further suggest that *Striga* emergence is mainly dependent on the rainfall pattern of the region. During some seasons, there is no *Striga* emergence even in *Striga* sick plot. Accordingly the

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reaction of host plant (or variety) is also found to vary from season to season at the same location. The seasons in which heavy rains prevailed at crop growth stage without dry spells, the *Striga* incidence was found to be much less or some times practically nil, even on susceptible host. This may be due to extreme dilution and washing out of the sorghum root exudate that stimulates the germination of *Striga* seed. These are the practical field experiences which need to be investigated under systematic experimentation.

From among the released sorghum varieties/hybrids CSV-1, CSV-2, CSV-6, CSV-7R and CSH-1 are found to be highly susceptible to *Striga*. The varieties CSV-4 and CSV-5 are moderately tolerant to *Striga*. The hybrids CSH-5 and CSH-6 which have CSV-4 as one of the parents, have recorded low incidence of *Striga*. The hybrid CSH-5 which had low incidence of *Striga* during several seasons at *Striga* sick plot situated at early rabi region Nandyal, was found to be highly susceptible during kharif in Mahaboobnagar (in specific pockets). This suggests for the establishment of *Striga* sick plots at each agroclimatic region for screening and estimating the potency of material for *Striga* tolerance. The recently released maghi variety 'Mothi' is moderately tolerant to *Striga* during several seasons.

Since *Striga* appears to be a serious problem, the future line of work needs to be emphasized in understanding the real mechanisms involved for the *Striga* resistance. The presently known *Striga* resistant variety N-13 seems to possess mechanical strength of host roots which does not allow *Striga* haustoria to enter its roots . Similarly other varieties that are identified as resistant to *Striga* in the field need to be varified for these mechanisms before using them in future breeding programmes.

DISCUSSION 4: CONTROL OF *STRIGA* IN SORGHUM

V.S. Mani[1]

CULTURAL AND CROPPING METHODS

Deep ploughing effects burial of the witchweed seeds away from the roots of the host crop. Water saturation in the initial stages of crop growth is reported to be unfavourable for witchweed seed germination; the probable reasons for this might be leaching of the stimulant from the vicinity of witchweed seeds and lowered germination of the seed of the parasite due to reduced oxygen tension resulting from water saturation. Application of heavy doses of nitrogenous fertiliser reduces withchweed incidence. It is reported that nitrogenous fertilisation to the crop lowers the production of growth stimulants in the host; another reason may be an increase in the proportion of inhibitory substances. Crop rotations including catch and trap crops are effective in depleting the weed seed population in the soil. Both these crops stimulate germination of witchweed seeds, the difference being that the trap crops are not parasitised. It may be that the trap crops may present mechanical obstruction to haustoria attachment or the root exudate of the trap crops might lack the "haustorial initiation factor" necessary for haustorial development. There is still inadequate understanding of the behaviour of trap crops and response of *Striga*.

RESISTANT VARIETIES

Striga attacks the crop plants directly as insect pests and diseases. Resistance breeding to pests and diseases is an accomplished fact. Likewise it is within the realm of distinct possibility to breed for *Striga* resistance as the parasitic weed attacks the host directly in contrast to all other terrestrial weeds which offer competion to the crop indirectly for water,

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nutrients, light and space. Studies at ICRISAT have shown that breeding of varieties resistant or tolerant to *Striga* is a very practicable approach because of (i) a resistant variety is a non-monetary input and (ii) the direct subterranean damage is averted. *Striga* resistance breeding has the twin objectives of identifying sorghum source lines resistant to *Striga* and transfer the resistance to agronomically elite lines. The best available low susceptible source lines to *Striga* are N-13, 555, IS 4202, IS 7471 and IS 9985.

CHEMICAL METHODS

Herbicides are applied through post-emergence, pre-emergence and pre-planting techniques.

Post Emergence Treatment: 2,4-D and paraquat are the most effective chemicals against *Striga* in sorghum. 2,4-D being a selective translocated herbicide with some residual activity can be employed at 1-2 kg a.e./ha as early as 4 weeks after crop sowing but prior to *Striga* emergence whereas paraquat a non-selective contact-acting herbicide with no residual life in soil has to be directed against *Striga* plants. Spraying with either of the chemicals on the emerged *Striga* will prevent flowering and seeding thus eliminating or minimising further addition of *Striga* seeds to the soil. A suggestion is made by the author that a post-emergence spray of a combination of 2,4-D amine salt (0.5 kg@ha) and urea (3 percent) on a juvenile crop of sorghum (3-4 weeks old) may secure a good kill of *Striga*. The herbicide will be taken up in the food stream and will get translocated to the roots of the host plants thereby preventing the germination and establishment of *Striga* on the host. The function of urea in its combination with a low dose of 2,4-D would appear to facilitate greater mobility of the 2,4-D molecule and to allow the retention of the toxicity of the low dosage level of 2,4-D an effect that may result from resistance to 2,4-D breakdown inside the host tissue.

Pre Emergence Treatment: Surface application of triazines and urea - substituted herbicides has not proved effective. Sub-soil application of these chemicals is worthwhile in which case the deeper placement of the herbicide in proximity to witchweed seed may prove inimical to germination and establishment of the parasite. Sub-surface application of pendimethalin (Trade name:Stomp) is also worth trial. The advantage of these chemicals belonging to different groups of herbicides (triazines, ureas, dinitramines) lies in their established field use for selective weed control in graminaceous crops. Oxyfluorfen ('Goal') is a herbicide reported to give both contact kill and residual pre-emregence control.

Pre-Planting Treatment: Pre-planting soil incorporated treatment with fenac and trifluralin is effective. Fluchloralin (Basalin), readily available in our country, may prove effective against *Striga*. As this chemical is highly selective on legumes, its application is worth trial in mixed crops of sorghum and legumes.

New Approaches: The two recently employed strategies are (i) suicidal germination of witchweed seeds in soil through artificial induction of germination by growth stimulants or ethylene gas. In absence of the host crop, the germinated *Striga* seedlings die off (ii) pre-soaking hardening treatment of crop seeds with phenolic acids such as vanilic acid and caffeic acid (25 ppm) reduces the induction of seed germination in the parasite by the host-root-exudate; this effect is due to the increased level of phenolics in the root exudate. The first method provokes the germination of witchweed seeds in soil in absence of the host crop while the second method reduces or inhibits the germination and growth of the parasite in presence of the host crop.

SUGGESTION FOR FURTHER RESEARCH ON *STRIGA* CONTROL

Details of a few experiments that could be taken up are furnished below:

1. Post-Emergence Application with Combinations of 2,4-D and Urea:
   Treatments time and application: Spray to be made on sorghum plants
   3-4 weeks old.

Treatments: 1. Varieties: 2 (Resistant and susceptible)
2. Dosage levels :6

(1) Unsprayed control, (2) Urea spray alone, 3 percent, (3) 2,4-D amine alone (.05 kg/ha product), (4) Combination treatment (2+3) (5) 2,4-D amine alone, 0.75 kg/ha and (6) Combination treatment (2+5).

Total number of treatments: 2x6=12; Lay out: RBD with 4 replicates. Total number of plots 12x4 = 48. Divide the replications into 8 parts one way and 6 parts another way as to give 48 plots where the treatments can be fitted into 4 compact blocks each with 12 plots.

Observations: Counts of emerged *Striga* in the crop row and the grain yield.

2. Sub-Surface Application of Herbicides: Either irrigation or soil disturbance after surface application will move the herbicides to lower depth of the soil. This idea can be tested as under. Divide the field into 4 equal blocks one adjacent to the other (A,B,C, and D). Apply the herbicide pre- to A and B. After herbicide application do not disturb A but to B give a light digging with a spade or any other suitable implement so that the surface-applied herbicide is moved down. Give an irrigation to A,B and C after 2-3 weeks of crop emergence. When the field comes into condition, apply the herbicide on the soil to C and D. Immediately after surface application of the herbicide, give an irrigation to D.

Herbicides: 4 (atrazine, diuron, fluchloralin and pendimethalin)
Dosage levels: 2 (0.5 and 1.0 kg/ha) for each product.
Total number of treatments: 8+1 (untreated control)=9.
Replications: 4 in a RBD.
Total No. of plots: 36

Divide the field into six plots each way so as to give 36 plots where the replicates can be fitted into 4 compact blocks with 9 plots in each block.

Observations: Counts of emerged *Striga* in the plots and the grain yield.

3. Demonstration of the Effectiveness of Ethylene Gas: The experimental use of ethylene gas for eradication of witchweed seeds in soil can be demonstrated on a small scale. The demonstration should be laid out in a *Striga* -sick plot. A small portion of land can be divided into two parts A and B. Treat B with ethylene gas at 0.75 kg/ha. After about a fortnight sow a susceptible variety of sorghum in both parts. Record observations on the emergence of *Striga*, crop growth and final grain yield.

The practicability of using chemical growth regulants like GR7 and GR 4 to stimulate the germination of witchweed seeds in soil may also be tried. It may be possible to apply the synthetic analogues/or strigol in irrigation water. Simplification of the procedures involved in the application of ethylene gas as well as the use of synthetic analogues in irrigation water is required.

4. Pre-Soaking Hardening Treatment with Phenolics: Small-scale feeler trials can be laid out at a few centres to test the potency of seed-hardening treatment with phenolic acids under different agroclimatic conditions. Experiments can be taken up in pot culture to screen varieties for their response to different phenolic acids. Details of the treatments and techniques of studying the response of the germplasm can be had from Dr. Jayachandra and Bharathalakshmi, Department of Botany, Bangalore University, Bangalore.

5. Monitoring Studies on *Striga* Seed Population in Soil: These studies should be conducted on a long term basis (for atleast 5 years) with the same layout and treatment imposition. This experiment should be located at a few centres in *Striga*-sick fields. The following procedure is suggested:

A. Field Expt:

Varieties: 2 (one resistant, one susceptible).
Treatments: 6 (untreated control; 2,4-D pre-em.2 kg ae/ha
2,4-D postem; 1.0 kg a.e/ha; paraquat postem:750 ml/ha;
Manual pulling of *Striga* once; Repeated pulling of *Striga* as to secure complete freedom from emerged *Striga*.

No. of treatments: 2x6 Replications: Four.

Total No. of plots: 12x4=48

Arrangement of plots and replicates can be the same as indicated under Expt. 1.

Observations: *Striga* emergence counts at periodic intervals during the crop season and grain yield.

B. Pot Culture Experiment:

At the start of the season and at the end of the season, soil samples to a depth of one foot should be collected from different treatments in the field experiment. (A). Composite samples of the replicates of each treatment should be filled up in earthen pots (sufficiently replicated) which should be seeded to a suscptible variety of sorghum (one plant/pot) used in the field experiment. Observations should be recorded on *Striga* emergence and on crop growth, a measure of which can be obtained by removing the plants from the soil after they have grown for 8 weeks and recording the weight of roots and shoots separately.

RECOMMENDATIONS OF THE WORKING GROUP

The group noted with concern the high level of *Striga* incidence in hybrid sorghum plots at some places in the country leading to severe crop losses. The need to combat the menace on a war footing has been stressed so that the new production technology being recommended to the sorghum farmers do not receive a serious setback. To meet this challenge, it was felt necessary to intensify research on *Striga* control for which liberal financial support and other facilities should be provided by ICAR, Agricultural Universities and ICRISAT.

Broadly two lines of approach for *Striga* control are available agronomic and genetic. While the genetic control through breeding resistant varieties is economical, it is a long range program requiring several years. A suitable combination of agronomic methods, however, could bring down the *Striga* population to a manageable level quickly. The possibility of utilizing biological control methods and physio-chemical treatments needs to be explored.

Based on the discussion during the meeting, the following recommendations for *Striga* control and future lines of research work were decided.

A. Several studies on agronomic (cultural and herbicidal) control methods on *Striga* have been carried out in the past. From the available information on these studies, the following recommendations are made for adoption by the farmers growing hybrid sorghum as sole crop in *Striga* endemic areas.

(a) Application of 2,4-D as pre-emergence treatment 30 days after planting @ 2 kg a.i./ha is recommended to kill all the germinated *Striga* plants.

(b) Post-emergence application of 2,4-D or hand pulling of *Striga* plants before flowering is suggested as an alternate measure to prevent further addition of *Striga* seed to the soil.

(c) Application of higher dose of nitrogen (80 kg N/ha) reduce the striga damage significantly.

(d) Use of trap crops in rotation is recommended to minimise the *Striga* problem. The most ideal trap crops are cotton and groundnut. The suggested crop rotations for some of the regions are given below.

- Andhra Pradesh (Red Chalka soils)	- A four-year rotation of sorghum-castor-pearl millet-cowpea/pigeonpea.
- Maharashtra (Black soils)	- Two-year rotation of sorghum-cotton.
- Maharashtra (Red soils)	- Two-year rotation of sorghum-groundnut/ sunflower

2. The *Striga* situation under intercropping of sorghum with legumes and oilseed crops has to be critically evaluated. Since 2,4-D and other herbicides suggested for *Striga* control are harmful to dicot crops, studies to find alternate herbicides for use in intercropping systems needs to be taken up.

3. A suggestion has been made to study the use of systemic herbicides both as foliar and soil treatments. It is recommended that this work be taken up at Dharwar under the supervision of Dr. M.M. Hosmani, Associate Professor of Agronomy. It was agreed that arrangements for procuring the necessary chemicals will be made by the Project Coordinator (Sorghum).

4. Ethylene gas has been reported to be a very potential tool for eradicating *Striga*. While the prospects of using this method on a commercial scale

are not very bright owing to the high cost involved, it is felt that it could be put to use on research farms to eliminate *Striga* from experimental fields. The ICAR is requested to approve the import of the hand operated applicators for this purpose.

5. It is noted that no systematic studies on crop losses due to *Striga* have been made. Such studies would enable the assessment of relationship between *Striga* population and crop loss and also greatly assist in evolving suitable control strategy. It is suggested that the studies be taken up at ICRISAT and all centers of the sorghum project. This study may be taken up on research farms using CSH-5. Wherever such facilities are not available on research farms, it may be taken up on farmer's fields with due precautions.

6. Sorghum scientists at all centers are urged to undertake a survey for the occurrence of *Striga* to identify endemic areas. Any variation in respect of species or plant type and also other wild and crop hosts should be noted and reported. A key for identification of *Striga* species from India and instructions for conducting the survey will be provided.

7. It is suggested that entomologists and pathologists located at various centers of the sorghum project record the occurrence of pests and diseases on *Striga* and the extent of damage. The Senior Entomologist and Senior Pathologist of the Sorghum Project, Hyderabad, will coordinate the work on this program.

8. It is recommended that sutides on the possible utilization of some of the known pathogens of *Striga* as biological control agents be initiated at the Coordinated Center of the Sorghum Project in collaboration with the Dryland Agriculture Project, Hyderabad.

9. There is some indication for the existence of physiological races in Striga asiatica. The studies already initiated by ICRISAT in this regard should be continued. Similarly, the cross infectivity studies on S. asiatica strains from sorghum and pearl millet may also be pursued.

10. It is suggested that in endemic areas where sorghum hybrids are subjected to heavy *Striga* infestation, some of the high yielding varieties like CSV-5, SPV-103, SPV-221 etc., known to possess reasonably good levels of tolerance may be evaluated in adaptive trials by the concerned Agricultural Universities, Dryland Agriculture Project and ICRISAT.

11. It is recommended that the reaction of the coordinated yield trial entries for resistance to *Striga* be evaluated to identify promising genotypes for recommending to striga endemic areas.

12. Striga densiflora is known to occur in parts of Maharashtra and Karnataka. It is suggested that the known resistant sources and breeding lines developed in the resistance program be evaluated against this species also.

13. The need for intensifying the work on breeding for resistance to *Striga* is well recognized. It is proposed that the lead function in this regard be taken up by ICRISAT and the centers at Parbhani, Rahuri, Akola and Dharwar of the Sorghum Project. In order to avoid duplication of efforts each of the centers will be assigned specific responsibility to effect a set of crosses. The segregating material will be distributed among these centers as well as others for screening and selection of promising lines. The details of this program will be decided soon and communicated to all concerned.

14. The studies on inheritance of *Striga* resistance indicate that the genes and gene action vary in different varieties. It is suggested that the Parbhani and Rahuri Centers where these studies are in progress continue the work to gain a better understanding of the genetic basis for resistance. The genetic studies on resistance to S. densiflora may also be included in the program.

15. The available genetic information on resistance to *Striga* indicate that it is determined by few genes. It is, therefore, suggested that pedigree and backcross methods could be followed to transfer resistant genes to elite agronomic types.

16. At present, the laboratory screening facilities to determine stimulant production are available only at ICRISAT. In order to enable screening of the large number of breeding lines for this character, it is necessary to augment this facility. It is suggested that the Parbhani and Dharwar centers of the Sorghum Project take steps to establish such a laboratory screening facility. ICRISAT is requested to provide necessary technical help for this purpose.

17. Resistance to *Striga* based on mechanical barriers has been recognized as an important mechanism. It is suggested that anatomical and histochemical studies be taken up at ICRISAT, Dharwar and University of Bangalore.

18. The physiology of host-parasite relationship are not well understood. Basic studies on this aspect may be undertaken at Parbhani and Dharwar centers of the Sorghum Project and also at University of Bangalore.

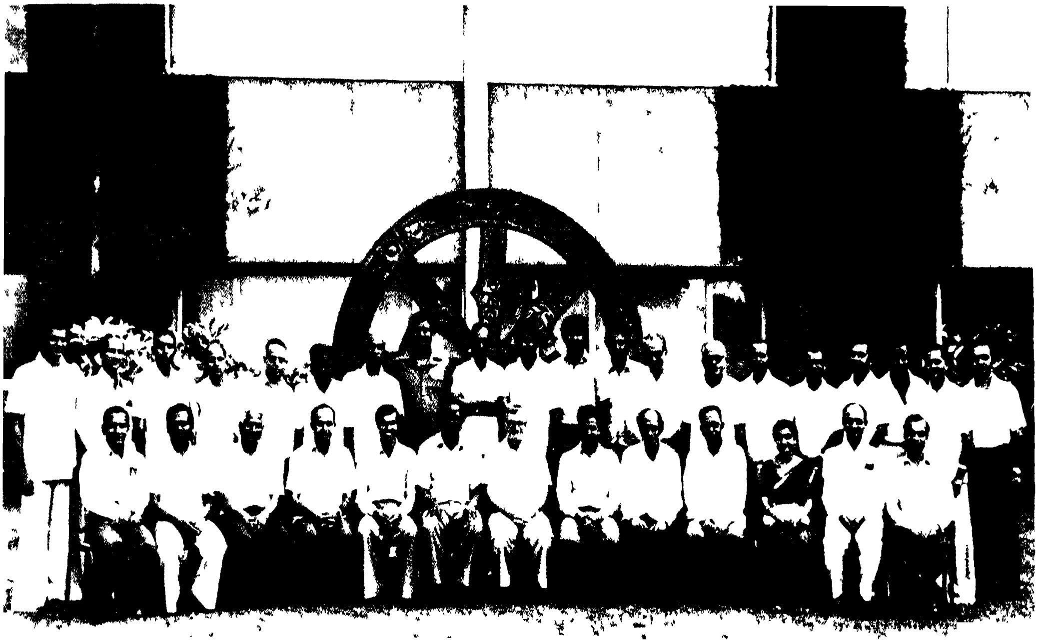
19. The need for evolving more efficient and rapid screening technique to identify *Striga* resistance is keenly felt. It is suggested to intensify the studies on various lab and field screening techniques being pursued at ICRISAT.

20. The group noted with interest the studies being carried out at University of Bangalore on seed hardening technique using various phenolic compounds for control of *Striga*. It is proposed to organize field trials to verify the efficacy of this technique in controlling *Striga*. It is also suggested that further work on this line using other compounds be continued at the University of Bangalore.

APPENDIX

PARTICIPANTS

THE PARTICIPANTS



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